**Reader Please Note: This is a very long document, a single chapter from one of the authors books. However, it has been subdivided into five sections consisting of The Past, The Present, Why Grow Food,
Food Trends In America and The Future. These links should help you relocate the individual sections, for your reading pleasure.**

# HISTORY OF HYDROPONICS

## THE PAST

Hydroponics, the growing of plants without soil, has developed from the findings of experiments carried out to determine what substances make plants grow and the composition of plants. Such work on plant constituents dates back as early as the 1600s. However, plants were being grown in a soilless culture far earlier than this. Hydroponics is at least as ancient as the pyramids. A primitive form has been carried on in Kashmir for centuries.

The process of hydroponics growing in our oceans goes back to about the time the earth was created. Hydroponic growing preceded soil growing. But as a farming tool, many believe it started in the ancient city of Babylon with it's famous hanging gardens, which are listed as one of the Seven Wonders of the Ancient World, and was probably one of the first successful attempts to grow plants hydroponically.

The floating gardens of the Aztecs of Central America, a nomadic tribe, they were driven onto the marshy shore of Lake Tenochtitlan, located in the great central valley of what is now Mexico. Roughly treated by their more powerful neighbors, denied any arable land, the Aztecs survived by exercising remarkable powers of invention. Since they had no land on which to grow crops, they determined to manufacture it from the materials at hand.

In what must have been a long process of trial and error, they learned how to build rafts of rushes and reeds, lashing the stalks together with tough roots. Then they dredged up soil from the shallow bottom of the lake, piling it on the rafts. Because the soil came from the lake bottom, it was rich in a variety of organic debris, decomposing material that released large amounts of nutrients. These rafts, called Chinampas, had abundant crops of vegetables, flowers, and even trees planted on them. The roots of these plants, pushing down towards a source of water, would grow though the floor of the raft and down into the water.

These rafts, which never sank, were sometimes joined together to form floating islands as much as two hundred feet long. Some Chinampas even had a hut for a resident gardener. On market days, the gardener might pole his raft close to a market place, picking and handing over vegetables or flowers as shoppers purchased them.

By force of arms, the Aztecs defeated and conquered the peoples who had once oppressed them. Despite their great size their empire finally assumed, they never abondoned the site on the lake. Their once crude village became a huge, magnificent city and the rafts, invented in a gamble to stave off perverty, proliferated to keep pace with the demands of the capital city of Central Mexico.

Upon arriving to the New World in search of gold, the sight of these islands astonished the conquering Spainards. Indeed, the spectacle of an entire grove of trees seemingly suspended on the water must have been perplexing, even frightening in those 16th century days of the Spanish conquest.

William Prescott, the historian who chronicled the destruction of the Aztec empire by the Spaniards, described the Chinampas as "Wondering Islands of Verdure, teeming with flowers and vegetables and moving like rafts over the water". Chinampas continued in use on the lake well into the nineteenth century, though in greatly diminished numbers. So, as you can see, hydroponics is not a new concept.

Many gardening writers have suggested that the Hanging Gardens of Babylon were in fact an elaborate hydroponic system, into which fresh water rich in oxygen and nutrients was regularly pumped.

The world's rice crops have been grown in this way from time immemorial. And also the floating gardens of the Chinese, as described by Marco Polo in his famous journal, are examples of "hydroponic culture".

Ancient Egyptian hieroglyphic records dating back to several hundred years B.C. describe the growing of plants in watre along the nile without soil.

Before the time of Aristotle, Theophrastus (327-287 B.C.) undertook various experiments in crop nutrition. Botanical studies by Dioscorides date back to the first century A.D.

The earliest recorded scientific approach to discover plant constituents was in 1600 when Belgian Jan van Helmont showed in his classical experiment that plants obtain substances from water. He planted a 5-pound willow shoot in a tube containing 200 pounds of dried soil that was covered to keep out dust. After 5 years of regular watering with rainwater he found the willow shoot increased in weight by 160 pounds, while the soil lost less than 2 ounces. His conclusion that plants obtain substances for growth from water was correct. However, he failed to realize that they also require carbon dioxide and oxygen from the air.

In 1699, John Woodward, a fellow of the Royal Society of England, grew plants in water containing various types of soil, the first man-made hydroponic nutrient solution, and found that the greatest growth occurred in water which contained the most soil. Since they knew little of chemistry in those days, he was not able to identify specific growing elements. He thereby concluded that plant growth was a result of certain substances and minerals in the water, derived from enriiched soil, rather than simply from water itself.

In the decades that followed Woodwards research. European plant physiologists established many things. They proved that water is absorbed by plant roots, that it passes through the plants stem system, and that it escapes into the air through pores in the leaves. They showed that plant roots take up minerals from eithr soil or water, and that leaves draw carbon dioxide from the air. They demonstrated that plants roots also take up oxygen.

Further progress in identifying these substances was slow until more sophisticated research techniques were developed and advances were made.

The modern theory of chemistry, made great advances during the seventeenth and eighteenth centuries, subsequently revolutionized scientific research. Plants when analyzed, consisted only of elements derived from water, soil and air.

The experiments of Sir Humphrey Davy, inventor of the Safety-Lamp, had evolved a method of effecting chemical decomposition by means of an electric current. Several of the elements which go to make up matter were brought to light, and it was now possible for chemists to split-up a compound into it's constituent parts.

In 1792 the brilliant English scientist Joseph Priestley discovered that plants placed in a chamber having a high level of "Fixed Air" (Carbon Dioxide) will gradually absorb the carbon dioxide and give off oxygen. Jean Ingen-Housz, some two years later, carried Priestley's work one step further, demonstrating that plants set in a chamber filled with carbon dioxide could replace the gas with oxygen within several hours if the chamber was placed in sunlight. Because sunlight alone had no effect on a container of carbon dioxide, it was certain that the plant was responsible for this remarkable transformation. Ingen-Housz went on to establish that this process worked more quickly in conditions of bright light, and that only the green parts of a plant were involved.

In 1804, Nicolas De Saussure proposed and published, results of his investigations that plants are composed of mineral and chemical elements obtained from water, soil and air. By 1842 a list of nine elements believed to be essential to plant growth had been made out. These propositions were later verified by Jean Baptiste Boussingault (1851), a French scientist who began as a mineralogist employed by a mining company, turned to agricultural chemistry in the early 1850s.

In his experiments with inert growing media. By feeding plants with water soulutions of various combinations of soil elements growing in pure sand, quartz and charcoal (an inert medium not soil), to which were added solutions of known chemical composition. He concluded that water was essential for plant growth in providing hydrogen and that plant dry matter consisted of hydrogen plus carbon and oxygen which came from the air. He also stated that plants contain nitrogen and other mineral elements, and derive all of their nutrient requirements from the soil elements he used, he was then able to identify the mineral elements and what proportions were necessary to optimize plant growth, which was a major breakthrough.

In 1856 Salm-Horsmar developed techniques using sand and other inert media, various research workers had demonstrated by that time that plants could be grown in an inert medium moistened with a water solution containing minerals required by the plants. The next step was to eliminate the medium entirely and grow the plants in a water solution containing these minerals.

From discoveries and developments in the years 1859-1865 this technique was accomplished by two German scientists, Julius von Sachs (1860), professor of Botany at the University of Wurzburg (1832-1897), and W. Knop (1861), an agricultural chemist. Knop has been called "The Father of Water Culture".

In that same year (1860), Professor Julius von Sachs published the first standard formula for a nutrient solution that could be dissolved in water and in which plants could be successfully grown. This marked the end of the long search for the source of the nutrients vital to all plants.

This was the origin of "Nutriculture" and similar techniques are still used today in laboratory studies of plant physiology and plant nutrition. These early investigations in plant nutrition demonstrated that normal plant growth can be achieved by immersing the roots of a plant in a water solution containing salts of nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca), and magnesium (Mg), which are now defined as the macroelements or macronutrients (elements required in relatively large amounts).

With further refinements in laboratory techniques and chemistry, scientists discovered seven elements required by plants in relatively small quantities - the microelements or trace elements. These include iron (Fe), chlorine (Cl), manganese (Mn), boron (B), zinc (Zn), copper (Cu), and molybdenum (Mo).

The addition of chemicals to water was found to produce a nutrient solution which would support plant life, so that by 1920 the laboratory preparation of water cultures had been standardized and the methods for their use were well established.

In following years, researchers developed many diverse basic formulas for the study of plant nutrition. Some of these workers were Tollens (1882), Tottingham (1914), Shive (1915), Hoagland (1919), Deutschmann (1932), Trelease (1933), Arnon (1938) and Robbins (1946). Many of their formulas are still used in laboratory research on plant nutrition and physiology today.

Interest in practical application of this "Nutriculture" did not develop until about 1925 when the greehouse industry expressed interest in its use. Greenhouse soils had to be replaced frequently to overcome problems of soil structure, fertility and pests. As a result, research workers became aware of the potential use of nutriculture to replace conventional soil cultural methods.

Prior to 1930, most of the work done with soilless growing was oriented to the laboratory for various plants experiments. Nutriculture, chemiculture, and aquiculture were other terms, used during the 1920s and 1930s to describe soilless culture. Between 1925 and 1935, extensive development took place in modifying the laboratory techniques of nutriculture to large-scale crop production.

In the late 1920s and early 1930s, Dr. William F. Gericke of the University of California extended his laboratory experiments and work on plant nutrition to practical crops growing outside for large scale commercial applications. In doing so he termed these nutriculture systems "hydroponics". The word was derived from two Greek words, hydro, meaning water and ponos meaning labor - literally "water-working". His work is considered the basis for all forms of hydroponic growing, even though it was primarily limited to the water culture without the use of any rooting medium.

Hydroponics is now defined as the science of growing plants without the use of soil, but by use of an inert medium, such as gravel, sand, peat, vermiculite, pubice or sawdust, to which is added a nutrient solution containing all the essential elements needed by the plant for its normal growth and development. Since many hydroponic methods employ some type of medium that contains organic material like peat or sawdust, it is often termed "soilless culture", while water culture alone would be true hydroponics.

Today, hydroponics is the term used to describe the several ways in which plants can be raised without soil. These methods, also known generally as soilless gardening, include raising plants in containers filled with water and any one of a number of non-soil mediums - including gravel, sand, vermiculite and other more exotic mediums, such as crushed rocks or bricks, shards of cinder blocks, and even styrofoam.

There are several excellent reasons for replacing soil with a sterile medium. Soil-borne pests and diseases are immediately eliminated, as are weeds. And the labor involved in tending your plants is markedly reduced.

More important, raising plants in a non-soil medium will allow you to grow more plants in a limited amount of space. Food crops will mature more rapidly and produce greater yields. Water and fertilizer are conserved, since they can be reused. In addition, hydroponics allows you to exert greater control over your plants, to unsure more uniform results.

All of this is made possible by the relationship of a plant with its growing medium. It isn't soil that plants need - it's the reserves of nutrients and moisture contained in the soil, as well as the support the soil renders the plant. Any growing medium will give adequate support. And by raising plants in a sterile grwoing medium in which there are no reserves of nutrients, you can be sure that every plant gets the precise amount of water and nutrients it needs. Soil often tends to leach water and nutrients away from plants, making the application of correct amounts of fertilizer very difficult. In hydroponics, the necessary nutrients are dissolved in water, and this rululting solution is applied to the plants in exact doses at prescribed intervals.

Until 1936, raising plants in a water and nutrient solution was a practice restricted to laboratories, where it was used to facilitate the study of plant growth and root development.

Dr. Gericke grew vegetables hydroponically, including root crops, such as beets, radishes, carrots, potatoes, and cereal crops, fruits, ornamentals and flowers. Using water culture in large tanks in his laboratory at the University of California, he succeeded in growing tomatoes to heights of 25 feet.

Photographs of the professor standing on a step ladder to gather in his crop appeared in newspapers throughout the country. Allthough spectacular, his system was a little premature for commercial applications. It was far too sensitive and required constant technical monitoring.

Many would-be hydroponic growers encountered problems with the Gericke system because it required a great deal of technical knowledge and ingenuity to build. Gericke's system consisted of a series of troughs or basins over which he stretched a fine wire mesh. This in turn was covered by a mulch of straw or other material. The plants were placed on this mesh, with the roots extending downward into a water/nutrient solution in the basin.

One of the main difficulties with this method was keeping a sufficient supply of oxygen in the nutrient solution. The plants would exhaust the oxygen rapidly, taking it up through the roots, and for this reason it was imperative that a continuous supply of fresh oxygen be introduced into the solution through some method of aeration. Another problem was supporting the plants so that the growing tips of the roots were held in the solution properly.

The American Press made their usual, and many irrational claims, hailing it the discovery of the century, in the most outlandish manner. Aftr an unsettled period in which unscrupulous promoters tried to cash in on the idea by peddling useless equipment and materials, more practical research was done and hydroponics soon became established on a sound scientific basis in horticulture. With recognition of its two principal advantages, high crop yields and it's special utility in non-arable regions of the world.

In 1936, W. F. Gericke and J. R. Travernetti of the University of California published an account of the successful cultivation of tomatoes in a water and nutrient solution. Since then a number of commercial growers started experimenting with the techniques, and researchers and agronomists at a number of agricultural colleges began working to simplify and perfect the procedures. Numerous hydroponic units, some on a very large scale, have been built in Mexico, Puerto Rico, Hawaii, Israel, Japan, India, and Europe. In the United States, without much public awareness, hydroponics has become big business, more than 500 hydroponic greenhouses have been started.

Dr. Gericke's application of hydroponics soon proved itself by providing food for troops stationed on non-arable islands in the Pacific in the early 1940s.

The first triumph came when Pan American Airways decided to establish a hydroponicum on the distant and barren Wake Island in the middle of the Pacific Ocean in order to provide the passengers and crews of the airlines with regular supplies of fresh vegetables. Then the British Ministry of Agriculture began to take an active interest in hydroponics, especially since its potential importance in the Grow-More-Food Campaign during the 1939-1945 war was fully realized.

During the late 1940s, Robert B. and Alice P. Withrow, working at Purdue University, developed a more practical hydroponic method. They used inert gravel as a rooting medium. By alternately flooding and draining the gravel in a container, plants were given maximum amounts of both nutrient solution and air to the roots. This method later became known as the gravel method of hydroponics, sometimes also termed nutriculture.

In wartime the shipping of fresh vegetables to overseas outposts was not practical, and a coral island is not a place to grow them, hydroponics solved the problem. During World War II, hydroponics, using the gravel method, was given its first real test as a viable source for fresh vegetables by the U. S. Armed Forces.

In 1945 the U. S. Air Force solved it's problem of providing it's personnel with fresh vegetables by practicing hydroponics on a large scale giving new impetus to the culture.

One of the first of several large hydroponics farms was built on Ascension Island in the South Atlantic. Ascention was used as a rest and fuel stop by the United States Air Force, and the island was completely barren. Since it was necessary to keep a large force there to service planes, all food had to be flown or shipped in. There was a critical need for fresh vegetables, and for this reason the first of many such hydroponic installations established by our armed forces was built there. The plants were grown in a gravel medium with the solution pumped into the gravel on a preset cycle. The techniques developed on Ascension were used in later installations on various islands in the Pacific such as Iwo Jima and Okinawa.

On Wake Island, an atoll in the Pacific Ocean west of Hawaii, normally incapable of producing crops, the rocy nature of the terrain ruled out conventional farming. The U. S. Air Force constructed small hydroponic growing beds there that provided only 120 square feet of growing area. However, once the operation become productive, it's weekly yield consisted of 30 pounds of tomatoes, 20 pounds of string beans, 40 pounds of sweet corn and 20 heads of lettuce.

The U. S. Army also established hydroponic growing beds on the island of Iwo Jima that employed crushed volcanic rock as the growing medium, with comperable yields.

During this same period (1945), the Air Ministry in London took steps to commence soilless culture at the desert base of Habbaniya in Iraq, and at the arid island of Bahrein in the Persian Gulf, where important oil fields are situated. In the case of the Habbaniya, a vital link in Allied communications, all vegetables had had to be brought by air from Palestine to feed the troops stationed there, and expensive business.

Both the American Army and the Royal Air Force opened hydroponic units at military bases. Many millions of tons of vegetables produced without soil were eaten by Allied Soldiers and Airmen during the war years. After World War II the military command continued to use hydroponics. For example, The United States Army has a special hydroponics branch, which grew over 8,000,000 lbs. of fresh produce during 1952, a peak year for military demand.

They also established on of the worlds largest hydroponic installations, a 22 hectare project at Chofu, Japan. It became necessary to use hydroponics in Japan because of the method of fertilization of the soil by the Japanese.

It had been their practice for many years to use "Night Soil", containing human excreta as a fertilizer. The soil was highly contaminated with various types of bacteria and amoeba, and although the Japanese were immune to these organisms, the occupying troops were not.

Covering 55 acres, it was designed to produce both seedlings and mature vegetables for American occupation forces. It remained in operation for over 15 years. The largest hydroponic installations up to that time were built in Japan using the gravel culture method. Some of the most successful installations have beeen those at isolated bases, noteably in Guyana, Iwo Jima and Ascention Island.

After World War II, a number of commercial installations were built in the United States. The majority of these were located in Florida. Most were out of doors and subject to the rigors of the weather. Poor construction techniques and operating practices caused many of them to be unsuccessful and production inconsistent. However, the commercial use of hydroponics, grew and expanded throughout the world in the 1950s to such countries as Italy, Spain, France, England, Germany, Sweden, the USSR and Israel.

One of the many problems encountered by the early hydroponics pioneers was caused by the concrete used for the growing beds. Lime and other elements leached into the nutrient solution. In addition, most metal was also affected by the various elements in the solution. In many of these early gardens, galvanized and iron pipe were used. Not only did they corrode very quickly, but elements harmful or toxic to the plants were released into the nutrient solution.

Nevertheless, interest in hydroponic culture continued for several reasons. First, no soil was needed, and large plant population could be grown in a very small area. Second, when fed properly, optimum production could be attained. With most vegetables, growth was accelerated and, as a rule, the quality was better than that of soil grown vegetables. Produce grown hydroponically had much longer shelf life or keeping qualities.

Many of the oil and mining companies built large gardens at some of their installations in different parts of the world where conventional farming methods were not feasible. Some were in desert areas with little or no rainfall or subsurface waters, and others were on islands, such as those in the Caribbean, with little or no soil suitable for vegetable production.

Big commercial American headquarters in the Far East have over 80 acres devoted to vegetable units, to feed landless city dwellers, while various oil companies in the West Indies, the Middle East, the sandy wastes of the Arabian Peninsula and the Sahara Desert, operating in barren areas, especially off the Venezuelan Coast at Aruba and Curacao, and in Kuwait have found soilless methods invaluable for ensuring that their employees get a regular ration of clean, health-giving greenstuff.

In the United States, extensive commercial hydroponics exist, producing great quantities of food daily, especially in Illinois, Ohio, California, Arizona, Indiana, Missouri and Florida, and there has been a noteworthy development of soilless culture in Mexico and neighboring areas of Central America.

In addition to the large commercial systems built between 1945 and the 1960s, much work was done on small units for apartments, homes, and back yards, for growing both flowers and vegetables. Many of these were not a complete success because of a number of factors: Poor rooting media, the use of unsuitable materials, particularly in constructing the troughs used as growing beds, and crude environmental control.

Even with the lack of success in many of these ventures, however, hydroponic growers the world over were convinced that their problems could be solved. There was also a growing conviction in the nimds of many that the perfection of this method of growing food was absolutely essential in light of declining food production and the worldwide population explosion.

Recent surveys have indicated that there are over 1,000,000 household soilless culture units operating in the United States for the production of food alone. Russia, France, Canada, South Africa, Holland, Japan, Australia and Germany are among other countries where hydroponics is receiving the attention it deserves.

In addition to the work being done to develop hydroponic systems for the production of vegetables, however, between 1930 and 1960 similar work was being conducted to develop a system to produce livestock and poultry feed. Researchers had found that cereal grains could be grown very rapidly in this manner. Using grains such as barley, they proved that 5 pounds of seed could be converted into 35 pounds of lush green feed in 7 days. When used as a supplement to normal rations, this green feed was extreemely beneficial for all types of animals and birds. In lactating animals, milk flow was increased. In the feed lots, better conversion rates and gains were achieved at less cost per pound of grain. In breeding stock the potency of males and conception in females increased dramatically. Poultry also benefitted in many ways. Egg production increased while cannibalism, a constant problem for poultrymen, ceased.

Here again, however, in developing a system that would produce consistently, a number of problems arose. The early systems had little or no environmental control, and with no control of temperature or humidity, there was a constant fluctuation in the growth rate. Mold and fungi in the grasses were an ever-present problem. The use of thoroughly clean seed grain with a high germination ratio was found to be absolutley essential if a good growth rate was to be achieved.

Nevertheless, in the face of these and other obstacles, a few dedicated researchers continued to work to perfect a system that could produce this nutritious feed continuously. With the development of new techniques, equipment, and materials, units became available that were virtually trouble free. Many of these are in use today on ranches, farms, and in zoos all over the world.

Hydroponics did not reach India until 1946. In the summer of that year the first research studies were commenced at the Government of Bengal's Experimental Farm at Kalimpong in the Darjeeling District. At the very beginning a number of problems peculiar to this sub-continent had to be faced. Even a cursory study of the various methods which were being practised in Britain and in America revealed how unsuited they were for general adoption by the public of India. Various physiological and practical reasons, in particular the elaborate expensive apparatus required, were sufficient to prohibit them.

A novel system, of which practicability and simplicity must be the keynotes would have to be introduced if hydroponics was to succeed in Bengal, or in fact ever to prove of widespread value to the people of this part of Asia. Careful appraisal of salient problems during 1946-1947 resulted in the development of the Bengal System of hydroponics, which represented an effort to meet Indian requirements.

One object guided all the experiments carried out; to strip hydroponics of it's complicated devices and to present it to the peiple of India and the world as a cheap, easy way of growing vegetables without soil. Now in India, thousands of householders raise essential vegetables in simple hydroponic units on rooftops or in backyards, the Bengal System has far more than proved itself, as being usefull in the most adverse conditions.

Numerous letters of appreciation from as far afield as the United Kingdom, France, the United States, Holland, Israel, Japan, Germany, Algeria, the Pacific, South and East Africa, Australia, New Zealand, Pakistan, South America, Burma, the Seychelles, Formosa, and those of the West Indies, have testified to what a large extent this object has been appreciated by the public, throughout the world.

Why use hydroponics when we have plenty of land if we would only develop, and by means of better cultural practices, including manuring, improve it? And then the cry: But hydroponic yields are after all no better than those which could be obtained under ideal soil conditions!

Both of these commetns call to mind a remark attributed to Charles II (King Charles II, British monarch (1660-1685)). Emphasizing the difference between himself and his brother, the Duke of York (afterwards James II), Charles is reported to have said: "Jamie would if he could, but I could if I would". Critics of soilless culture fall into these categories. They generally overlook the fact that to improve the soil of India, or of any other country, so as to make it perfect, will take 50 to 100 years. Where, after all, can ideal soil conditions be obtained?

Greenhouse culture, using earth beds, is at the best a warisome and expensive affair, involving periodic sterilization and it is only under such conditions, employing glass, that anything approaching an ideal soil can be produced, even after a long period of time. And after the first crop begins to mature, alas the balance is again upset.

An article in Forbes magazine, entitled, "Food Supply - Will Help from Science Come in Time?" calls hydroponics the "most spectacular current breakthrough" yet, for solving the world's food problems. An article in the Los Angeles Times, entitled, "Hydroponics: A New Chapter in Food Technology," states "...for the past several years, hydroponics has been refined to the point where it is now a commercially viable way to grow food."

Reading the unresearched accounts in the media, leads on to believe that hydroponics is a recent development in scientific technology which will save the world from starvation. Yes, it may very well help save the world from a food shortage, but it is hardly a new scientific development. In fact, the first plants on the earth were grown hydroponically. More than half of all plant life today is growing with hydroponics. And the healthiest, most nutritious plants in existance are hydroponic plants. I speak of the plants growing in the body of water, which covers over 70% of the earth's surface - our oceans. There is no soil in the ocean. Plants draw all their required nutrients directly from the most complete hydroponic nutrient solution available - sea water.

Among the well-known institutions which have contributed so much to the establishment of the soilless cultivation of plants as a practical proposition are, the Universities of Illinois, Ohio, Purdue and California in the United States; The University of Reading, in Great Britain, famous for it's pioneering work in new cropping techniques. Canada's Central Experimental Farm at Ottawa, as well as the internationally famous and important firm of Imperial Chemical Industries, Ltd., which undertook the adaption of hydroponics to British conditions.

Other pioneers of hydroponics were the Boyce Thompson Institute for Plant Research, New York; the New Jersey Agriculture Experiment Station; the Alabama Polytechnic Institute; and the Horticultural Experiment Station, Naaldwijk, Netherlands.

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# THE PRESENT

With the development of plastics, hydroponics took another large step forward. If there is one single factor that could be credited with making the hydroponics industry the success it is today, that factor is plastics.

As mentioned earlier, one of the most pressing problems encountered everywhere was the constant leaching of detrimental elements into the solution from concrete, rooting media, and other materials. With the advent of fiberglass and such plastics as the different types of vinyl, polyethelene film, and the many kinds of plastic pipe, this problem was virtually eliminated. In the better producing systems being built in the world today plastics are used throughout, and other than a few isolated bronze valves, there is absolutely no metal. Even the pumps are epoxy coated.

Using these types of materials, along with an inert material as a rooting medium, the grower is well on his way to success.

Plastics freed growers from the costly construction associated with the concrete beds and tanks previously used. Beds are scraped out of the underlying medium and simply lined with a heavy vinyl (20mil), then filled with the growing medium. With the development of suitable pumps, time clocks, plastic plumbing, solenoid valves and other equipment, the entire hydroponic system can now be automated, or even computerized, reducing both capital and operational costs.

A basic premise to keep in mind about hydroponics is its simplicity. After the wheel was invented, I am sure many were confused and thought it complicated. That was because they could not get their minds off all the work the wheel replaced. This is the way it is with hydroponics. Once you conquer the idea there must be more to it than this, and forget about the work it eliminates, you too will agree: It is simple!

Another important breakthrough in hydroponics was the development of a completely balanced plant food. Work in this area is still continuing, but there are many ready made formulas available. Most of them are good, but very few, if any, will work consistently without the use of various addatives at different stages of the crop. There are also many formulas available that can be mixed by anyone, but the average grower is far better off using one fo the many commercial formulas.

In addition to the progress rate through the use of plastics and the steady increase in production because of improved nutrient mixes, another factor of tremendous importance to the future of the industry was the development of better hardware for control of the environment in greenhouses.

Initially, nearly all fo the early greenhouses were steam heated, and the cost of this equipment virtually barred the small grower from entering this field. With the development of forced-draft heaters that used oil or gas, however, it became possible to build much smaller units, and the advent of LP gas, such as butane and propane, made possible the location of greenhouses in almost any area.

Constant improvements in these heating systems, particularly the introduction of high-velocity fans and the convection tube method of circulating warm air throughout a building, gave the grower better temperature control in the greenhouse. For commercial operations in larger greenhouses, however, a boiler system using steam or hot water remained the most economical. It gave the grower wide latitude in the choice of fuels. There has also been continuous improvements in techniques and equipment for cooling any size greenhouse.

In addition to better environmental control, the use of new materials such as polyethelene, poly-vinyl films, and translucent fiberglass panels introduced completely new methods of low cost greenhouse contruction. They give the builder a wide choice of material for covering any size unit and also made possible many new shapes, sizes, and configurations.

Some of these materials will last only one season; others are guaranteed for 20 years, against clouding, that causes light loss and against shattering from hail; despite damage to the cover, there was little or no damage to the crop. Had a light film or glass been used, however, both the crop and cover would have been completely lost. The films are good for temporary or semi-temporary cover. Many of these materials also gave light diffusion that is beneficial to most plants.

The combination of environmental control and improved hydroponic systems has largely been responsible for the growth of the industry over the past twenty years, and there can be no question that hydroponics will play a big part in feeding the world in the future.

As an example of the need for hydroponics, in 1950 there was a total of 3.7 million acres of land under cultivation in the United States. At that time the population in the United States was 150,718,000. In 1970 the total acreage in cultivation had dropped to 3.2 million and the population had grown to 204,000,000. In the next 20 years, it is estimated that the population of the United States will grow to 278,570,000, an increase of 79,000,000 people. It is hard to project how many more acres will be lost to production during this time. Above paragraph from United States Department of Agriculture and United States Department of Commerce.

Hydroponics has become a reality for greenhouse growers in vertually all climate areas. Large hydroponic installations exist throughout the world for the growing of both flowers and vegetables. For example, large hydroponic greenhouse complexes are now in operation in Tucson, Arizona (11 acres); Phoenix, Arizona (about 15 acres); and Abu Dhabi (over 25 acres), this installation uses desalted water from the Persian Gulf. Tomatoes and cucumbers have proven to be the most successful crops. Cabbages, radishes, and snap beans have also done very well.

The Salt River Valley, which surrounds Phoenix, Arizona, illustrates what happens when the population explodes in an area. The growth pattern of the Salt River Valley is characteristic of many areas not only in the United States, but the world over. The first settlers who came into this area were looking for good land and water, both of which existed in the Salt River Valley. After World War II, the excellent climate caused a massive population boom.

In 1950, within the boundaries of the Salt River Project, there were 239,802 acres, of which 225,152 acres were assessed as agricultural lands. Between 1950 and 1960, these agricultural lands decreased by 37,795 acres. There was a further decrease of 35,411 acres between 1960 and 1970. Between 1971 and 1973, there was an additional loss of 19,172 acres. In 23 years a total of 92,378 acres have been taken out of crop production forever.

The pace at which this fine land is disappearing from production is constantly accelerating. At the current rate, by 1990 there will be little, if any, cultivated land left within the present boundaries of the Salt River Project. Above information supplied by Mr. Reid W. Teeples, Associate General Manager of Water Resources at the Salt River Project, Phoenix, Arizona.

Traveling over the United States, one can see the same pattern being followed elsewhere. Another classic example is Southern California, particularly the Los Angeles area with its tremendous urban sprawl.

With hydroponics, there is no need for soil, and only about one twenty-fifth as much water is needed as in conventional farming. The hydroponic growers of the future will be using the roof tops of warehouses and other large buildings on which to install cmmercial systems. One such system has been designed by Deutschmann's Hydroponic Centers of St. Louis, and will be in operation sometime in 1986. The companies principle crop will be tropical foliage plants, raised in hydroculture. However, the rooftop greenhouses will be used solely for vegetable production. The author, who designed this installation, will be their Chief Olericulturist, and plans to hire all handicapped or underpriveledged employees.

Editors Note: The project became a reality in the fall of 1986. By the end of the summer of 1988, a total of 7 rooftop greehouses were in full production in the St. Louis area. The companies hydrocultural sales of tropical foliage plants had far surpassed their expectations with 433 ten inch hydroculture foliage plants being sold daily through 1994. The vegetable production department, utilizing the rooftop greenhouses, was thriving equally as well when an unfortunate event, unrelated to the business, forced the company to temporarily suspend operations. The patented hydrocultural planting system developed by the author is still available today through various companies and dealers who have maintained stock and new production facilites are operated by EcoTek Hydrocultural Plant Systems, Inc. of St. Louis.

There is ample space on almost any flat rooftop. All that is needed in addition to this space is electricity, fuel and water. Systems built in this manner will have the added advantage of being at, or near, the marketplace, eliminating the need for long-distance transportation of produce, such as we have today. Because the environment within the hydroponic installations can be controlled, these systems can produce vegetables year round in almost any climate.

The system designed and built in St. Louis proves there is no question that we already have the technology to build such systems, inexpensively. There will, however, be other systems, built by or for the homeowner that will take up very little space. Some of these will be small enough to be installed in the kitchen or other parts of the home. They will produce an abundant supply of many types of food, particularly lettuce, strawberries, and similar crops. There are already workable units of this type available now.

Today, hydroponics is an established branch of agronomical science, it helps feed millions of people; these units may be found flourishing in the deserts of Israel, Lebanon and Kuwait, on the islands of Ceylon, the Phillipines, on the rooftops of Calcutta and in the parched villages of West Bengal.

In the Canary Islands, hundreds of acres of land are covered with polyethylene supported by posts to form a single continuous structure housing tomatoes grown hydroponically. The structure has open walls so that the prevailing wind blows through to cool tha plants. The structure helps to reduce transpirational loss of water from the plants and to protect them from sudden rainstorms. Such structures can also be used in such areas as the Caribbean and Hawaii.

Almost every state in the United States has a substantial hydroponic greenhouse industry. Canada also uses hydroponics extensively in the growing of greenhouse vegetable crops. About 90% of the greenhouse industry in British Columbia, Canada, uses sawdust culture to overcome soil structures and soil pest problems.

One-half of Vancouver Island's tomato crop and one-fifth of Moscow's are hydroponically produced. There are full-fleged hydroponic systems in American Nuclear Submarines, Russian Space Stations and on off-shore drilling rigs. Large zoos keep their animals healthy with hydroponic green food, and race horses stay sleek and powerful on grass grown hydroponically year round.

There are large and small systems used by companies and individuals as far north as Baffin Island and Eskimo Point in Canada's Arctic. Commercial growers are using this marvelous technique to produce food on a large scale from Israel to India, and from Armenia to the Sahara.

In arid regions of the world, such as Mexico and the Middle East, where the supply of fresh water is limited, hydroponic complexes combined with desalination units are being developed to use sea water as a source of fresh water. The complexes are located near the ocean and the plants are grown in the existing beach sand. In other areas of the world, such as the Middle East, there is little land suitable for farming. Because of the development of the oil industry and the subsequent flow of wealth, the building of large hydroponic farms to feed the exploding populations in these nations is inevitable. If there is any one industry in the world today who's time has come, it is hydroponics.

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# WHY GROW FOOD?

Food is something most Americans take for granted. Yet, according to a recent poll "Gardens for All," by the Gallup Organization, 34 million households in America (that's over 43%) grow food, and the number is increasing rapidly. Not since the old Victory Garden era has there been more interest in gardening for food.

Years ago, most people were interested in gardening as a hobby. Few were concerned with taste or nutrition, and fewer still were interested in grocery costs or self-sufficiency. As long as good quality vegetables could be purchased at reasonable prices, there was little concern.

In the past several years, interests have changed. Fewer gardeners are hobbyists. Many are interested in food costs, and more still are concerned about taste and the nutritional values of the vegetables they feed their families, the effects of chemicals, both to the environment and health-wise. Also, there are growing numbers of people in the United States who have a strong desire to become more self-sustaining.

Countries like the Canary Islands balance their economies by exporting vast amounts of soilless-produced tomatoes, cucumbers and salad greens to industrial states like Britain every year. From the Caribbean area, too, Puerto Rican and Mexican growers ship immense quantities of luscious hydroponic fruits and greenstuff to the insatiable United States and Canadian markets. In England, Germany, France, the Netherlands and Switzerland, flower firms often prefer to employ the soilless method for commercial purposes, especially for the production of carnations and other quality blooms. Roses and chrysanthemums are grown extensively in Colorado and neighboring states for export. In 1971 nurseries in those areas made gross profits of over 25 million dollars from hydroponically raised flowers alone.

In the year 1975 alone, four different commercial Hawaiian growers were producing tomatoes hydroponically and more installations were planned. Stateside, more than five hundred commercial hydroponic greenhouses were in operation in the United States.

For one reason or another, most American greenhouse growers will not admit that they are using hydroponics to raise most, if not all of their flowers and plants. I believe one reason for this is because they usa a method that so closely resembles the Bengal System, and do all of their fertilizing and watering by hand, that they are to embarrased to refer to what they do as a form of hydroponics. Editors Note: In the United States the proven Bengel System is referred to as the modified slop method of hydroponics!

The authorities in the U.S.S.R. have encouraged the extension of hydroponics in their country. Large hothouses, soilless farms and gardens exist at Moscow and Kiev, while in Armenia an Institute of Hydroponics has been established at Erevan in the Caucasus region.

Officially, soilless cultivation of plants is looked upon in Russia as a biological industry coming between horticulture and manufacturing. Other countries, not already mentioned, where hydroponics is in current use include Australia, New Zealand, Spain, South Africa, Israel, particularly in the Negev Desert and along the Dead Sea, Italy, the Scandinavian lands, the Bahama Islands, Central Africa, East Africa, Kuwait, Brazil, Poland, the Seychells, Singapore, Malaysia and Iran. This list is not, of course, by any means exhaustive, but it does give some idea of how widely spread soilless gardening is today.

According to Funk & Wagnall's New Comprehensive International Dictionary:
"hy-dro-pon-ics...n. pl. (construed as singular) Soilless agriculture; the raising of plants in nutrient/mineral solutions without earth around the roots;..."

That's easy enough - growing without soil. I remember when I first learned about vegetable gardening; it seemed as though everything related to the soil - most of the work and most of the knowledge of farming. The soil had to have the proper texture, structure, and porosity. It had to include all the nutrients required for growing. Even after the garden was planted, the soil had to be worked and reworked.

If I could have eliminated the soil, what a pleasure it would have been to grow my own food. Without soil, more time could have been devoted to more productive efforts, such as maximizing my yields by proper pruning, pollination, intercroping, and proper harvesting. But now I use no soil. I grow with hydroponics.

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# FOOD TRENDS IN AMERICA

Everyday in America, there are 5,000 more people to feed from the production of farmland which is shrinking by over 15,000 acres a day. That is aloss of almost 6 million acres each year, 3 million to erosion and just poor land management, and 3 million to progress in the form of more homes, factories, and roads.

If we continue at this rate, I feel the demand for food may some day pass our ability to supply it as abundantly as we have in the past. In all probability, we will have to watch or diets a little more carefully and learn how to stop wasting food, as we had to learn how to stop wasting energy.

I do not mean to alarm anyone. Barring a catastrophe, I am convinced there will always be adequate supplies of food. No one will starve in America. But what will happen to our once high standards for taste and nutrition? And how much will food cost, when compared to our monthly incomes?

Not many years ago, most of our fresh food and much of our processed food was produced within a 100 mile radius of our homes. There were hundreds of local farmers and food processors, each competing for our business. With an abundance of food available, we could afford to be choosy. If we did not like what we were offered, we could voice a complaint or just buy from another source.

In those days "fresh" meant fresh. Local farmers were not as skilled in the techniques of disguising poor quality. Since good fresh produce was available at reasonable prices, we would not think of eating a meal without several servings of fresh vegetables, not frozen or canned, but fresh.

We see a much different picture today. Local farmers are almost extinct. We now have larger and more centralized farms, larger food processors and larger chemical companies supplying or farmers and food processors. It is estimated, by the year 2000, one percent of our farms will control over half our food supplies. Also, over 60 percent of farm profits wil go to as few as 50 major companies.

We cannot ignore the worldwide food shortage any longer. We need more food from fewer acres. But in order to get more from less, sacrifices will ahve to be made. Among these sacrifices will be "fresh" food which is not really fresh, less control over food quality, higher food prices, and a much higher ration of processed food over fresh food.

With the demise of our local farmers, I believe we have already lost out on fresh food and local control. Now in order to keep food costs from getting out of control, it only stands to reason more food will have to come to us processed.

It is estimated that 20 percent of all food produced in America (about 137 million tons, worth $31 billon) is wasted. Of that, about 60 million tons, worth $5 billion is simply left in fields and orchards for lack of commercial value. Add to that the increasingly high costs of packaging, storing, preserving, handling, and transportation after it leaves the field, and the result is clear. We as a nation must convert more of our crop yields from fresh produce to processed foods.

True hydroponic culture is generally a means of growing plants in a nutrient solution using no soil or other rooting medium, although today almost all of the many different methods of growing plants without soil employ various types of inert material for a rooting medium, such as gravel, haydite, perlite, vermiculite, pumice, sand and others.

What is known as the Herbagere method hydroponic cultivation, invented by a Belgian Botanist named Gaston Perin, is beginning to find widespread use in the United States. this growing technique utilizes a number of shallow rectangular trays containing grerminating seeds. The trays are stacked one above the other in a sealed growing chamber. Each of the tray bottoms contains narrow slits. This feature permits nutrient solution introduced at the top tray to drip down through each tray in the stack. This technique is sometimes referred to as vertical farming. It has been applied to the growing of highly nutritious grass for feeding of livestock and zoo animals.

The San Diego Zoo is one of a number of zoos that operate a hydroponic growing chamber of this type. It's the size of a large house trailer. Within the chamber a total of 252 white plastic trays are arranged in several neat tiers.

Each day, 36 trays, one seventh of the total, are seeded with presoaked barley. Nutrient solution is sprayed over the trays several times each day to keep the seeds moist. The temperature in the chamber is kept at from 64 to 68 degrees and the trays are bathed in flourescent light continously, which serve to stimulate seed growth.

Since the growing cycle is seven days long, each day mature barley is harvested from another set of thirty-six trays. The barley daily harvest yields from five hundred to six hundred pounds of grass and roots. Zoos in New York City (the Bronx Zoo), Chicago, Phoenix and St. Louis operate the same kind of growing chambers. At the Bronx Zoo, the grass is fed to most of the hoofed stock; the zebras, antelope, deer and Mongolian wild horses.

Editors Note: The St. Louis Zoo directors decided to reutilized their Herbagere climate controlled building for the rearing of rare baby birds, due to lack of funds to procure proper facilities for these animals. Their feed costs increased and animal health went down proportionately. The rearing of the rare baby birds was unsuccessful and all secumbed!

Lettuce is another crop that lends itself to vertical farming. Lettuce seedlings in small planting boxes are placed in trays which are stacked one above the other in a metal rack. After their diet of liquid nutrients for one month the plants reach maturity.

In the case of tomatoes, the dirt farmer raises about 3,500 plants per acre. In hydroponics, the plants can be placed much closer together, it's possible to cultivate as many as 10,000 plants on an acre of land.

In normal farming, crops have to be rotated, that is, grown in a fixed order of succession. Otherwise, the nutrient level of the soil falls below established minimums. Plainly speaking, the soil "Wears Out." With soilless culture, there's never any need to rotate crops. The farmer checks the solution and adds whatever nutrients may be needed. Thus the nutrient level can be just as high at harvest time as it was the day the crop was planted, and the same type of crop can be grown in endless succession. If however, the grower decides he wants to change to a different crop after the harvest, it's a simple matter to do so. Another plus is growing does not have to be done on a seasonal basis. Crops can be started so that a continuous supply of most any vegetable or fruit can be obtained at any time of the year.

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# THE FUTURE

Hydroponics is a very young science. It has been used on a commercial basis for only 40 years. However, even in this relatively short period of time, it has been adapted to many situations, from outdoor field culture and indoor greenhouse culture to highly specialized culture in atomic submarines to grow fresh vegetable for crews. It is a space age science, but at the same time can be used in developing countries of the Third World to provide intensive food production in a limited area. It's only restraints are sources of fresh water and nutrients. In areas where fresh water is not available, hydroponics can use seawater through desalination. Therefore, it has potential application in providing food in areas having vast regions of non-arable land, such as deserts. Hydroponic complexes can be located along coastal regions in combination with petroleium-fueled or atomic desalination units, using the beach sand as the medium for growing the plants.

Another area in which hydroponics promises to play an important role in the future is growing seedlings for reforestation, orchards, and ornamental shrubbery. In a report published in 1966, researchers at the University of Wisconsin stated that seedlings of white cedar, blue and white spruce, red pine, and others were grown in a controlled environment. Using a hydroponic system with controlled feedings of a nutrient solution, the results of growth in one year were three to four times as great as in year old nursery grown seedlings. The extension of the growing season in this northern area, through the use of hydroponics and more concentrated use of space, made it possible to grow five to ten times a many plants in a given area. Some plantigs of pine were 18 yeras old at the time this report was published and were said to be growing vigorously. Report - American Nursery Man, 1966.

Hydroponics is a valuable means of growing fresh vegetables not only in countries having little arable land and in those which are very small in area yet have a large population. It could be particularly useful in some smaller countries whose chief industry is tourism. In such countries, tourist facilities, such as hotels, have often taken over most arable areas of the country, forcing local agriculture out of existence. Hydroponics could be used on the remaining non-arable land to provide sufficient fresh vegetables for the indigenous population as well as the tourists. Typical examples of such regions are the West Indies and Hawaii, which have a large tourist industry and very little farm land in vegetable production.

To illustrate the potential use of hydroponics, tomatoes grown in this way could yield 150 tons per acre annually. A 10-acre site could produce 3 million pounds annually. In Canada, the average per capita consumption of tomatoes is 20 pounds. Thus, with a population of 20 million, the total annual consumption of tomatoes is 400 million poiunds (200,000 tons). These tomatoes could be produced hydroponically on 1,300 acres of land!

But there continues to be problems that hamper the growth and development of hydroponics as a whole. One problem is the negative attitude of the directors and people of position in many of our colleges, universities and government agencies, which has ranged from complete disinterest, to open hostility. This attitude partly results from their own failure to achieve crop yields matching those of many hydroponic growers.

Fortunately, in some of our schools, there are people who not only have open minds, but who have also given generously of their time and talents to help growers establish very successful hydroponic farms.

Another problem that has developed in the past few years is the ever-increasing cost of energy for heating. In many areas the high cost of fuel has caused a number of installations that were operating at a profit to suddenly plunge deeply into the red, and some operators have been forced to shut down entirely in the colder months. Since this is the time of year when vegetables are at or near peak prices, these increased fuel costs have had a disasterous effect on the industry as a whole, including soil-based greenhousemen.

One bright spot in this picture is the development of solar heating systems. Much research has and is being done in this field, and there are many ready-built systems available on the market today. Also available are a number of publications with detailed plans on hwo to build one's own solar energy system. There will of course, be many new developments in this field over the next few years, and solar energy may eventually solve the delemma for all growers.

Currently, plans are being drawn for using the techniques of soilless culture on space flights and even on the moon, or beyond. For hydroponics, the future seems very bright.

The biggest danger to the growth and development of hydroponics has been the influx of "instant experts" over the past 10 years. The success of many growers using properly designed equipment has attracted these self-styled authorities in ever-growing numbers. Making extravagant claims, they have sold many shabby, poorly made copies of workable units with the assurance that this was the easy road to riches. Many of these fly-by-night promotions have been short lived, but, sadly, others continue to flourish.

The cost to the would-be commercial grower for a properly designed hydroponic system, housed in a manner that provides good environmental control, can run into thousands of dollars. For this reason, he should check very closely the qualifications of the seller. He should require proof of claims regarding production and profit capability, back-up service after the sale, research facilities and past records of the manufacturing company.

If a person is willing to work and apply himself, plants can be grown hydroponically by a complete novice with no past experience at growing crops. The owner of a small 10x12 foot hydroponic greenhouse will be able to produce all the fresh vegetables needed by a family of four or five, provided he operates the unit on a year round basis.

Hydroponics can also be profitable on a commercial scale if the grower devotes the time and attention required for any successful business. The average yield of tomatoes per acre is eighteen times greater than in conventional soil methods. Rarely do pesticides have to be used.

Hydroponics is a fascinating method of growing plants and can give the hobbyist or serious grower many hours of pleasure.



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