

CHAPTER 1

CONTROLLED ENVIRONMENT AGRICULTURE AND HYDROPONICS: PAST, PRESENT AND FUTURE

CONTROLLED ENVIRONMENT AGRICULTURE =

Also “Protected Agriculture”.

Control of both the root zone and aerial environmental factors (temperature, humidity, gas composition including carbon dioxide around the leaves for photosynthesis and oxygen around roots and shoots for respiration, light, water, growing medium, and mineral nutrition) usually in a greenhouse or totally enclosed structure.

HYDROPONICS = A technology for growing plants (without soil) using a complete nutrient solution (water + mineral nutrients) with or without the use of an aggregate medium (e.g., sand, gravel, perlite, rockwool, etc.) to provide mechanical support for the roots.

THE PAST:

- *Several hundred years B.C. – The Babylonians had hanging water culture gardens considered one of the seven wonders of the ancient world.
- *Several hundred years B.C. – Egyptian hieroglyphs tell of the people growing plants in water culture.
- *Theophrastus (372-287 B.C.) – A Greek philosopher, performed experiments in crop nutrition.
- *During the 1st century A.D. – cucumbers were grown off-season for the Roman Emperor Tiberius using a “transparent rock” (presumably mica) covered structure (first known use of Controlled Environment Agriculture (CEA)).
- *1200’s and 1300’s (as described by the Venetian traveler, Marco Polo) - Floating gardens of the Chinese.
- *1400’s – The Aztecs, who settled near Lake Tenochtitlan (near the site of present day Mexico City), created gardens on floating rafts called “chinampas”.

NOTE: During the past 400 years plant culture techniques were developed to study the mineral nutrition requirements of plants. These techniques, known as “water culture”, were the beginnings of what later became “hydroponics”.

- *1600 – A Belgian, Jan Van Helmont, performed the earliest known experiments to determine the constituents of plants: A 5 lb willow shoot planted in 200 lbs of soil was covered to keep dust out and watered with rain water for 5 years. The willow increased its weight to 160 lbs., but the soil lost only 2 oz.
His conclusion: plants obtain substances from the water needed for growth.

- *1699 – An Englishman, John Woodward, used various types of soil to grow plants. He found that the greatest growth occurred in water which contained the most soil.
His conclusion: plant growth results from substances in the water derived from the soil, rather than from the water itself.

- *1804 – N.T. de Saussure made the first quantitative measurements of photosynthesis and proposed that plants are composed of chemical elements obtained from soil, water, and air.

- *1851 – The French chemist, Jean Boussingault, verified de Saussure’s proposal when he grew plants in insoluble artificial media such as sand, quartz and sugar charcoal plus solutions of known chemical composition.
His conclusions: plants require water and obtain hydrogen from it; plant dry matter contains hydrogen plus carbon and oxygen which comes from the air; plants contain nitrogen and other mineral nutrients.

- *1860 & 1861 – Two German scientists, Julius von Sachs and another by the name of Knop, used “nutriculture”. Today this is called water culture, a type of hydroponics. The roots were immersed in water that contained “salts” of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), sulfur (S) and calcium (Ca). It was shown that these minerals were needed in large amounts by the plant, hence the term “macronutrients”. Both scientists devised nutrient solution recipes.

NOTE:

*From the 1860’s to the 1940’s several other scientists studied plant mineral nutrition using water culture and identified other minerals needed by plants in much smaller amounts. These are called “micronutrients” and include iron (Fe), chlorine (Cl), manganese (Mn), boron (B), zinc (Zn), copper (Cu) and molybdenum (Mo).

*During this time several plant nutrition scientists also developed nutrient recipes for optimum plant growth, including Hoagland (U.C. Berkley, 1919), Hoagland and Arnon (U.C. Berkley, 1938 – “The water-culture method for growing plants without soil”) and Robbins (Rutgers U. 1946). D.R. Hoagland became so well known for his work in plant nutrient formulas that today it is common to refer to a nutrient solution recipe as a

“MODIFIED HOAGLAND’S SOLUTION”

1925 - 1935 – The greenhouse industry expressed an interest in using “nutriculture” instead of conventional soil culture because, over time, greenhouse soils would have problems with soil structure, fertility and pests. Small-scale laboratory techniques were modified to accommodate large-scale commercial crop production.

1930’s – W.F. Gericke (U.C. Berkley) experimented with nutriculture on a large scale and coined the term “hydroponics”, which is derived from two Greek words: “hydro” meaning “water” and “ponos” meaning “work”. Literally = “water working”.

1940’s (WWII) – The United States military used hydroponics to supply the troops stationed on isolated, non-arable islands in the Pacific. After the war the U.S. Army built a 22 hectare hydroponic operation at Chofu, Japan.

1950’s – Commercial hydroponic operations appeared throughout the world in Italy, Spain, France, England, Germany, Sweden, the USSR and Israel. However, hydroponics was not widely accepted since the techniques used incorporated concrete growing beds which were expensive to construct.

1970’s – With the advent of plastics an interest in hydroponics was renewed. Plastics began to be used as greenhouse covers, growing bed liners and in irrigation systems. However, two new problems arose: Escalating oil prices in 1973 substantially increased heating and cooling costs AND there were few chemicals registered for pest control in greenhouses. Increases in root pathogens (which when inadvertently introduced into a recirculating hydroponic system could spread to all the plants in the greenhouse), and an increase in aerial pests (which found a perfect environment to multiply in the climate controlled greenhouses) caused many operations to fail.

1990 – There is a renewed interest in hydroponics.

THE PRESENT:

Hydroponics is now used by researchers, commercial growers, teachers, hobbyists and horticultural therapists to name just a few.

Researchers – Certain experiments require specific root zone environments:

Mineral nutrition: can vary one nutrient at a time and note the symptoms.

Salt stress: can study the reactions to varying amounts of salt.

Heavy metal contamination: can study responses and also screen for tolerant species for revegetation of old mining sites.

Variations in root temperature: Ex – if the roots of lettuce (a cold weather crop) are chilled, the heads do not “bolt” (go to flower) when grown in warm temperatures.

Commercial Growers – Large-scale production of vegetable and flower crops, house plants and medicinals for sale.

In Arizona and surrounding “high light” states vegetable growers include:

- Bonita Nurseries, Willcox, AZ – 120 acres/tomatoes
- Suntastic, Snowflake, AZ – 20 acres/tomatoes
- Sunco, Ltd., North Las Vegas, NV – 12 acres/tomatoes
- Willcox Greenhouse, Willcox, AZ – 8 acres/tomatoes
- Sunizona, Willcox, AZ – 2 acres/cucumbers

Commercial facilities are also prominent in

- “lower winter light” countries such as Holland, Belgium, England and Canada (total about 500 ha – NOTE 2.5 acres/hectare)
- “higher winter light” countries such as Spain, Southern France, Israel and Mexico (total about 600 ha)

Commercial facilities have also been constructed in desert areas and/or near oceans where sea water is used for cooling and is desalinated and used for irrigation (Examples: Mexico and the Middle East).

Teachers – for use in schools as a teaching tool. Systems can include small desk-top units, outdoor units, or scaled-down commercial style units in greenhouses.

Subjects that can be covered during a study of hydroponics include

- *plant production, care, nutrition, seeding and transplanting
- *chemistry and math and the calculation of nutrient recipes
- *engineering (greenhouse and system construction and structures)
- *computers (sensors, heating and cooling systems, irrigation controllers)
- *marketing, business skills and economics
- *writing and oral communication skills

Hobbyists – for use by home gardeners to provide healthy, tasty produce for personal consumption. A variety of unit styles (home-made and commercially produced) are available to suit any location or crop.

Horticultural Therapy – for use in nursing homes or other situations where patients may not be able to work in a “traditional” garden but where gardening is suggested to exercise mental and physical faculties. For example, the elderly who may no longer be able to easily work in a soil garden or patients in wheel chairs can easily access their gardens of lettuce, herbs, or tomatoes which can be placed on tables or on a concrete floor.

Hydroponics at the South Pole: One unusual adaptation of this is the use of systems made of leftover PVC pipe for the growing of tomatoes, lettuce, strawberries and other fruits and vegetables at the scientific research station in McMurdo, Antarctica. A well lit “growth chamber” was constructed that provided more than fresh fruits and vegetable. It also provided a place for researchers to go to experience humidity, green and the smells of growing things: a needed mental break in the most bleak and driest desert on Earth. (A hammock was even hung amongst the plants!)

THE FUTURE:

Besides the groups and uses listed above, hydroponics has the potential for uses in:

- *The military – Highly specialized culture in atomic submarines can provide vegetables for the crew.
- *NASA/space program – NASA has been working with hydroponics for years for use on long duration space missions and on non-terrestrial bases.
- *Low-tech hydroponic systems can be used in developing countries to provide intensive food production using limited acreage.
- *Hydroponic systems and facilities could be used in small countries where the main industry is tourism. Hydroponic facilities can be located on non-arable land to feed both the indigenous population and the tourists.

LEADING GREENHOUSE TOMATO STATES IN THE U.S.A. (hectares):

Arizona	59.2	Tennessee	8.0
Texas	43.2	New Mexico	8.0
Colorado	37.6	Mississippi	6.8
California	20.0	New Jersey	6.0
Virginia	17.2	Florida	4.8
Pennsylvania	16.0	Nevada	4.8
New York	14.0	North Carolina	4.0
Ohio	8.0		

Total = 257.6 hectares

(NOTE: 2.5 acres = 1 hectare)

REFERENCES

1. **Hydroponic Food Production.** 2001. H.M. Resh. Woodbridge Press Publishing Company, P.O. Box 209, Santa Barbara, CA, 93160. ISBN 0-88007-222-9
2. **Hydroponic Gardening.** 1991. L. Dalton and R. Smith. Cobb/Horwood Publications, Auckland, New Zealand.
3. **Hydroponic Home Food Gardens.** 1992. H.M. Resh. Woodbridge Press Publishing Company, Santa Barbara, CA, 93160. ISBN 0-88007-178-8
4. **Hydroponics For The Home Gardener.** 1992. S. Kenyon. Key Porter Books Limited, Toronto, Ontario, Canada, M5E 1R2. ISBN 1-55013-375-6
5. **Protected Agriculture: A Global Review. Part 1: Background.** 1995. M.H. Jensen and A.J. Malter. The International Bank for Reconstruction and Development/The World Bank. 1818 H Street, N.W., Washington, D.C. 20433. World Bank Technical Paper ISSN 0253-7494. ISBN 0-8213-2930-8
6. **Web Pages:**
<http://ag.arizona.edu/hydroponictomatoes>