CHAPTER 5

BASIC PRINCIPLES OF HYDROPONICS

ADVANTAGES OF USING HYDROPONICS OVER SOIL CULTURE

1. **Crops can be produced on non-arable land (not fit for farming). Ex. Land with poor soils, and contamination (i.e., high heavy metal and salinity levels).**
   *The grower doesn't have to have good soil since the systems, bags, etc. are placed on top of the ground.

2. **Isolation from diseases or insect pests usually found in the soil**.
   *The plant roots are contained in systems, bags, etc. and do not grow through soil that might contain diseases or other pests such as insects and nematodes.
   *Additionally, white fabric ground covers can be placed on the greenhouse floor to further isolate the systems and plants from soil-borne pests.
   NOTE: The white fabric also reflects light back up into the canopy enhancing photosynthesis, allows for ease of cleaning and helps control humidity and weeds.

3. **Direct and immediate control over the rhizosphere**.
   *Since the roots are either growing in water or growing through an inert medium, whatever is in the nutrient solution is bathing the roots. Therefore, nutrient concentrations and pH can be adjusted quickly.

4. **High planting densities are possible which minimizes use of land area**.
   *For field tomatoes a typical planting density is 4000 to 5000 plants per acre. Greenhouse hydroponic tomatoes can be 10,000 to 11,000 plants per acre!
   *Plants can be grown closer together because of the use of indeterminate ("vining") varieties that take up less area than do bush varieties usually used for field cropping. Also they need less root room – the plants are "spoon fed" the nutrient and water they need and do not have to grow a large root system to find these, as field tomatoes do in the soil.

5. **Higher yields are possible.**
   *Because of higher planting densities, higher yields are possible. Also, indeterminate varieties (bred for greenhouse) can produce up to 12 months. Since most commercial hydroponic production takes place in greenhouses interplanting has also been used to achieve uninterrupted production. However, most growers now avoid interplanting to reduce pest transmission to new crops.
   *Yields are also greater due to better control over water, nutrition, EC, pH, the aerial environment and certain diseases (see above).
   *For field grown tomatoes yields are 10-40 tons per acre compared with 300 tons per acre or more for tomatoes grown using greenhouse hydroponics (equates to 75 kg/m^2; recently, has gone as high as 90-104 kg/m^2).

6. **Efficient use of water and nutrients.**
   *In soil culture water may be lost in wetting the soil beyond the reach of the plant roots or from the surface through evaporation.
   *In hydroponic culture, since the nutrient solution is enclosed in a bag, tube, etc., there is no loss of water to soil/air AND little or no water stress in the plant. NOTE: When comparing monetary return for water use – for every gallon of water used to irrigate cotton the grower gets 1/10th of a cent. For every gallon of water used to irrigate hydroponic tomatoes, the grower gets over 30 cents!
   *Nutrients (which equate to $money$) are also not lost to the soil but retained in the root zone and, in closed systems, are replenished and recycled.

7. **Ease of cleaning the systems.**
   *The aggregate growing media can be steam sterilized, or simply replaced.
   *Whole systems, including the drip irrigation system, can be quickly sterilized using 10% bleach and cleaned of salt build-ups using a mild acid (rinse well).

8. **No weeding or cultivation is needed**.

9. **Transplanting of seedlings is easy – No transplant shock.**
   * In soil culture the root mass can be easily disturbed during transplanting causing root breakage, plant stress and stunted growth for up to a week.
   *In hydroponic culture seeds are started in Rockwool cubes or plugs, then transplanted into larger cubes with holes made for that purpose (see Chapter 9 Transplant Production). There is no disturbance of the root mass, little or no root breakage and therefore minimal plant stress and transplant shock.

10. **Fruit of hydroponically grown plants can have more flavor.**
   *Hydroponically grown tomatoes, for example, are picked after they have begun to ripen, which includes the typical red color formation of the fruit (lycopene), the formation of gel within the locules and the characteristic taste. The grower can also raise the EC (electrical conductivity measuring salt levels – see Chapter 8 Fertigation Systems and Nutrient Solutions) in the root zone that tends to stress the plant and enhance fruit flavor.
   *Tomatoes from field grown plants (in many areas) are picked "green", then "gassed" with ethylene which induces lycopene formation but does not enhance the flavor. Therefore, you get nicely colored fruit with little or no taste.

ADVANTAGES OF GREENHOUSE CULTURE OVER FIELD CULTURE

1. **Virtual indifference to the seasons.**
   *Crops can be grown year around anywhere: desert southwest (and other high light areas) even in winter when field crops are not; South Pole; the Moon; etc.

2. **More efficient use of space.**
   *Due to the vertical nature of the greenhouse and the use of vining crops.

3. **Control over the aerial (upper) portions of the plant to achieve higher yields.**
   *The air temperature and, to some extent, the relative humidity can be regulated to suit the crop under cultivation in the greenhouse environment.
   *Higher than normal (390-400 ppm as of May 2013!) levels of carbon dioxide (up to 800 to 1000 ppm) can be reached using a carbon dioxide generator (burning natural gas) in order to enhance photosynthesis (but this costs money$$!).
   *Light levels and quality (wavelengths) can be controlled by using artificial lights or by choosing an appropriate shade cloth or glazing. Shade cloth can be used during summer to protect fruit from sunscald. Certain glazings can block UV radiation which can harm plants or allow UV to promote production of anthocyanin (i.e., strawberry fruit, red lettuces, etc.).

4. **The greenhouse can be cleaned more easily than the field (ease of cleaning).**

5. **The greenhouse environment is suitable for mechanization.**
   *Includes personnel carts for plant maintenance and picking as well as future designs for automated harvesting “robots” (may require changes in plant structure).

6. **The greenhouse can be a physical barrier to insects and diseases.**
   ***Specific sanitation practices (washing hands, foot baths, etc.) and the use of insect screening, sticky traps and other IPM methods can keep most insects and diseases out of the greenhouse. The use of beneficials can eradicate or maintain pests at a manageable level (see Chapter 4 Plant Protection).

DISADVANTAGES OF GREENHOUSE HYDROPONICS

1. **Requires a large capital ($money$) input, energy input & labor input.**
   *Any size commercial operation (including irrigation systems, computer controls, etc.) will cost about $600,000 to $1,000,000 per acre with the land itself costing $1000 - $2000 per acre or more (depending on location).
   *Energy costs can be high and include those for heating (usually burn natural gas), cooling (usually use evaporative cooling) and electricity to run equipment (injectors, computers, motors, sorting/packing/storage equipment, etc.).
   *Labor is daily & intensive → wages for year-around workers with benefits.

2. **The grower needs a high degree of competence in plant science, engineering, computer control systems and marketing.**
   *Or experts in these fields need to be hired. This is an intensive form of agriculture where a small problem can escalate to a major disaster very quickly.

3. **The technology is limited to crops of high economic value.**
   *Since the initial cost of a large commercial facility is so high it would not be profitable to grow anything but crops of high economic value including tomatoes, colored bell peppers, cucumbers, herbs, medicinals and even lettuce which, in a hydroponic greenhouse, can yield multiple crops per year.

4. **Plant diseases and insect pests may be more difficult to control.**
   *Root pathogens that produce water-borne spores (e.g., zoospores of *Pythium*) can be devastating to plants growing in a recirculating system since infected solution could circulate to all plants. NOTE: For treatments see Chapter 4.
   *The greenhouse, with its controlled environment, is a perfect habitat for many types of insects, good (beneficials) and bad (white flies, aphids, thrips, spider mites, shore flies and fungus gnats). Although IPM and biological control are available, the plants will require constant vigilance and swift action.

5. **Back-up generator:** will be needed in case of power failures.

REVIEW OF PLANT NEEDS (critical for building hydroponic systems)

1. **Water** – Critical for metabolic processes, for transport of substances throughout the plant body (phloem and xylem) and for transpirational cooling.
2. **Light** – Critical for photosynthesis. (Where you put your system is important.)
3. **Inorganic mineral nutrients** – at the correct concentrations (EC) and pH levels.
4. **Carbon dioxide** – Critical for photosynthesis (needed at the leaf surface).
5. **Oxygen** – Critical for respiration (needed by all parts of the plant including the roots, therefore aeration of the nutrient solution may be required).
6. **The proper temperature and relative humidity** (specific to type of plant).
7. **Support systems** for the roots and shoots. For plants where the roots hang directly into the nutrient solution and do not provide any support for the plant, mechanical support may be needed. For an indeterminate tomato plant, support for the stem will be needed in the form of hooks, twine and vine clips.

TYPES OF HYDROPONIC SYSTEMS

Systems categorized by where the roots are located:

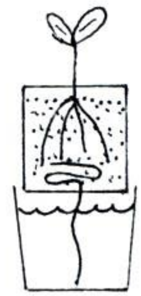
1. **Liquid Culture**: The roots are hanging into the nutrient solution which can be either in the form of a liquid or a mist.
2. **Aggregate Culture**: The roots grow into an inert medium such as sand, gravel, Rockwool, perlite, vermiculite, peat moss, foam, coconut coir, etc. and are then irrigated with a complete nutrient solution.

Systems categorized by what happens to the nutrient solution:

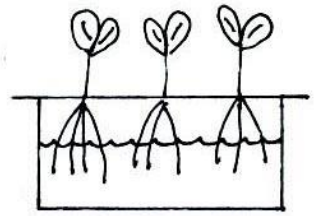
1. **Open:** The nutrient solution is distributed from a reservoir to the plants and is then "drained to waste" (i.e., not used again).
2. **Closed:** The nutrient solution is distributed from a reservoir to the plants. After passing through the root zone it is collected and reused. In large systems the solution should be analyzed, then modified by the additions of water, acid/base, and/or various inorganic elements to return the solution to the appropriate inorganic mineral composition (and EC) and pH. Solution sterilization (UV light, ozone treatment, etc.) is also important so that pathogens from one or a few plants, are not spread to all of the plants.

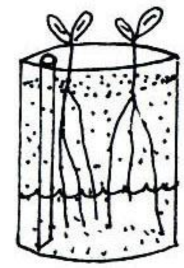
SYSTEM DESIGNS

1. **The basic wick:** The roots grow down through an aggregate medium. A wick (absorbent material) is laced through the medium and hangs down into a reservoir and draws the nutrient solution up into the root zone.
   Type of system = Aggregate/Closed
   Best for small crops.



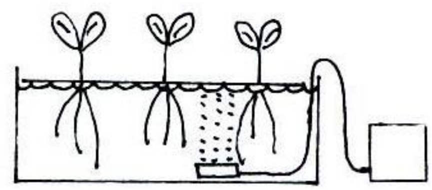
2. **The non-recirculating ("air-gap") system:** The roots hang into a nutrient solution reservoir, with the upper part of the root mass suspended in air (air roots to take up needed oxygen) and the lower part of the root mass in direct contact with the nutrient solution (water and nutrient roots).
   Type of system = Liquid/Closed
   Option: Aggregate/Closed
   Any crops can be grown.



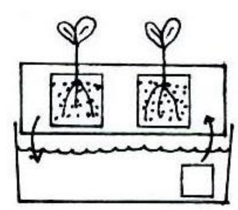


Aggregrate Option

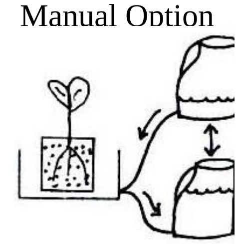
3. **The raft or floating system:** Plants are suspended through Styrofoam boards which float on the surface of the nutrient solution. Oxygen must be supplied to the roots using an aquarium pump and air stones or a "venturi" system. If large Styrofoam cups, filled with perlite or other media, are used, and positioned so that most of the cup is out of the solution, no pump is needed.
   Type of system = Liquid/Closed
   Best for lettuce, herbs, etc.



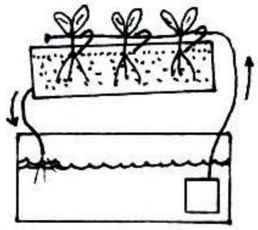
4. **The flood and drain (or ebb and flow) system:** The roots grow down through an aggregate. The nutrient solution is pumped into the aggregate medium, floods the root zone for a short time, and is then allowed to drain back into the reservoir.
   Type of system = Aggregate/Closed
   Best for lettuce, herbs, etc.

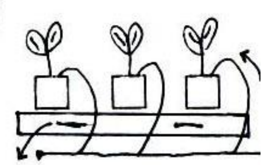


Manual Option

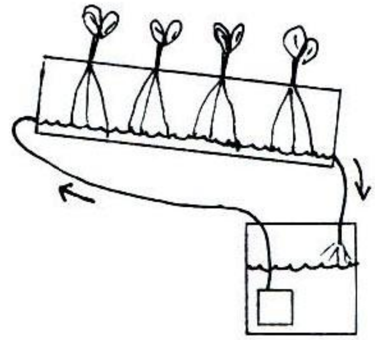


5. **The top feeder system:** The roots grow down through an aggregate. The nutrient solution is delivered to the top of the aggregate medium, percolates through and then either drains to waste or is recirculated into a reservoir.
   Type of system = Aggregate/Closed or Open
   Any crops can be grown; bag = tall crops.

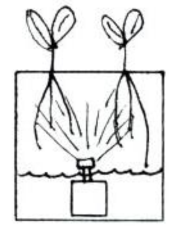




6. **Nutrient film (flow) technique (NFT):** The roots may be growing from Rockwool blocks or through cups filled with an aggregate for support but ultimately hang into a slightly slanted tube or trough. The nutrient solution is pumped to the higher end, flows past the hanging roots and then back to the reservoir.
   Type of system = Liquid-Aggregate/Closed
   Best for lettuce, herbs, etc.



7. **Aeroponics:** The roots are suspended in an enclosed space and, at regular intervals, sprayed with nutrient solution.
   Type of system = Liquid/Closed or Open
   Best for root crops (medicinals) but any crop could be grown.



NOTE: <u>Importance of a consistent power supply:</u> For any of the systems requiring electrical power (to run water or air pumps) a consistent power supply is critical. If the power goes out (for as little as 30 minutes!), especially to flood/drain, NFT or aeroponic systems, the roots will soon dry out and the plants will die for lack of water. In the case of top drip systems, there is some reservoir of moisture in the bags. However, the plants will begin to wilt quickly (1-2 hours), especially on a warm day (possible 30 minutes).

NOTE: <u>A word about aquaponics:</u> Aquaponics is typically a combination of 3 organisms that form a closed organic production system. Some type of fresh-water aquatic <u>animal</u> (usually Tilapia fish) eats food (usually organic) and produces waste (which contains ammonia). Two types of <u>bacteria</u> (housed in a bio-reactor or free in the solution) change the ammonia to nitrite then to nitrate. Finally, the nitrate and other nutrients are taken up by <u>plants</u> that clean the water which is then returned to the fish.

REFERENCE MATERIAL:

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5. **Planning a Profitable Hydroponic Greenhouse Business.** 1996. A.J. Savage. Sovereign University Publishing House, 30 Caro Mio 1, Sark, Channel Islands, United Kingdom GY9 0SE. ISBN 0-929440-00-5
7. **Web sites:** Search images/hydroponic systems for various system designs; Search info on hydroponics, Aquaponics, controlled environment agriculture.