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Michigan State University
Cooperative Extension Service
Vegetable Tips
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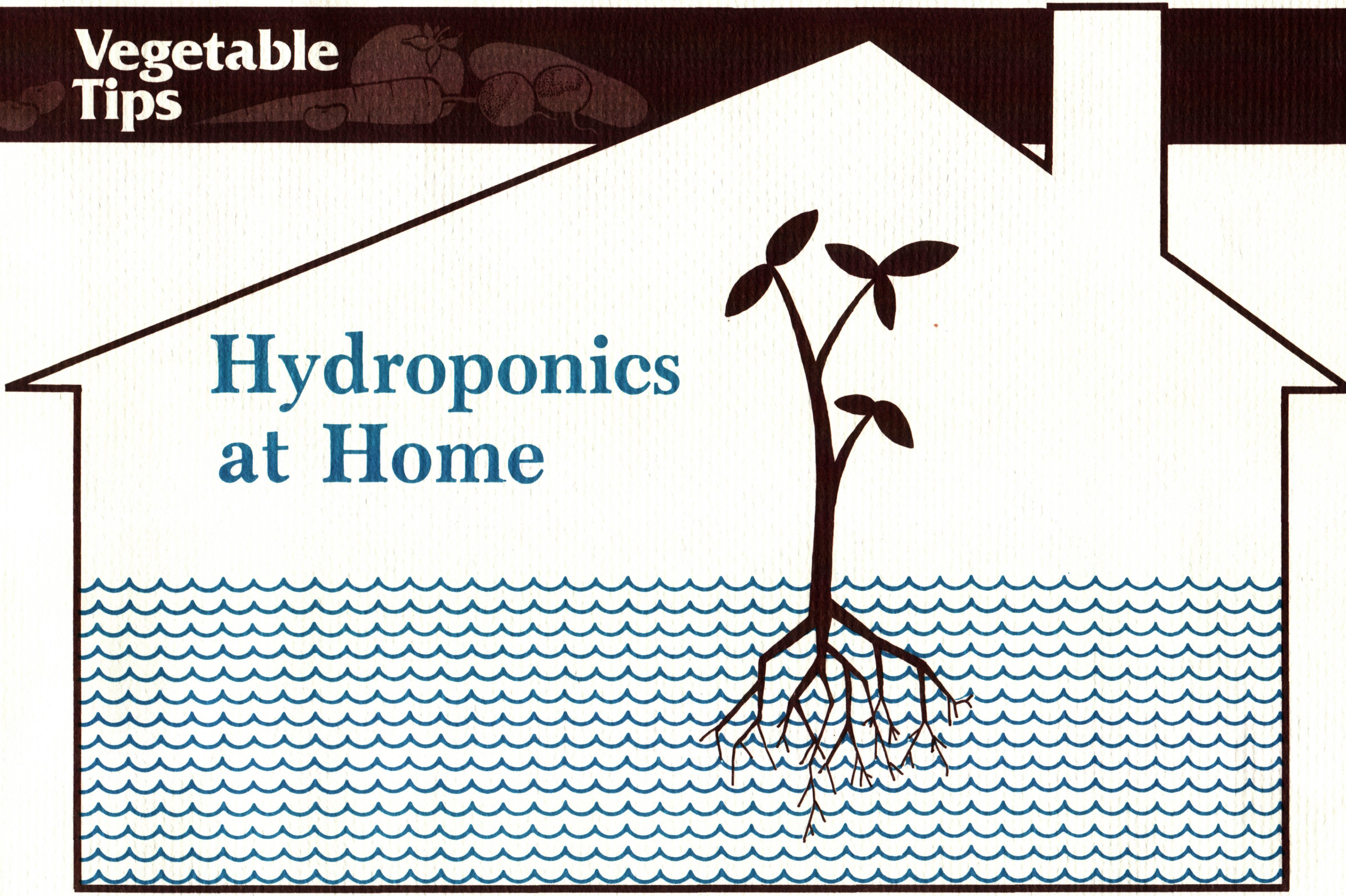

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Hydroponics at Home

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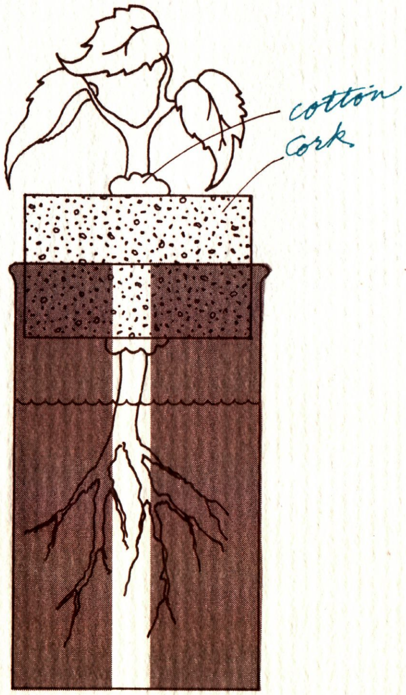


A small plant growing in a vial of nutrient solution.

This publication provides information on the hydroponic culture of plants for the home gardener, hobbyist or experimenter. It is not intended for commercial growers. Anyone interested in commercial hydroponics should study one or more of the books on hydroponics, such as those listed in the back of this publication, visit several commercial operations, and set up and operate a small system for two or three years before investing much capital in a commercial venture.

What Is Hydroponics?

Hydroponics — also called nutriculture, soilless culture, chemiculture, gravel culture, aggregate culture, water gardening, tank farming and tray agriculture—is a procedure for growing plants without soil. There are several ways to do this, but the basic principle of all hydroponic methods is growing plants with their roots in contact with a solution containing all of the essential plant nutrients in amounts needed for optimum plant growth (Fig. 1). Hydroponics is an intensive growing method that requires optimum light, temperature and humidity.

Almost any herbaceous plant can be grown using a hydroponic system. Growing plants hydroponically is more difficult and exacting than using traditional methods, however.

Advantages and Disadvantages

The major advantage of hydroponics is that plants can be grown where suitable soil is not available for cultivation. Another advantage is that weeds and soil pathogens are usually not a major problem in hydroponic systems.

Hydroponics also has a number of disadvantages. The setup, maintenance and operation of a hydroponic system are costly because of the specialized equipment required. The system must be monitored regularly by persons who are knowledgeable about the complex plant-nutrient solution interactions that occur. A growing plant can rapidly deplete a nutrient solution of water and mineral nutrients or modify its pH. Such changes can severely stress a plant and have deleterious effects on growth.

Even though a system may initially be free of pathogens, sanitation must be monitored carefully because introduced pathogens will spread very rapidly throughout the entire system. While a clean system has no pathogens, it also has no pathogenic antagonists. Therefore, once a pathogen gets into a system, its population will virtually explode because natural enemies are not present to check its spread.

Hydroponics does not necessarily result in larger yields or higher quality plants than soil culture. Plants must be spaced the same in both systems to allow light penetration. Soilless culture is justified only where arable soil is unavailable, where soil pathogens are uncontrollable, or for experimentation or hobby purposes. Some commercial growers produce plants by hydroponic methods, but the turnover of growers tends to be rather rapid.

Two Basic Hydroponic Systems

There are two basic hydroponic systems: water culture and aggregate culture.

The water culture system involves growing plants in closed containers with the roots immersed in a nutrient solution. This provides total root contact with nutrients. The plants must be attached to physical supports above the solution. To prevent algae growth, the container should not allow light inside. Aeration of the solution is essential and must be done mechanically.

An aquarium (painted over) or similar container can be used for a home hydroponics system. A sheet of Styrofoam with holes through which the plants are placed makes a good support. An aquarium aerator that continuously injects air into the nutrient solution would provide adequate aeration.

Individual plant containers can also be used. Jars or bottles with stoppers and painted sides are adequate for individual plants or for several plants at the seedling stage of development. Cut a hole in the jar stopper, place the plant through the hole so roots are suspended in the solution and gently pack cotton around the stem to keep it in position. Leave a narrow, unpainted strip down the side of the jar so you can determine the water level without removing the plant.

In **aggregate** culture, the aggregate provides plant support. Using the aggregate method is similar to growing plants in a peat-lite medium in which various fertilizers and mineral elements have been incorporated. Aggregates that can be successfully used include the following:

Sand. Fairly coarse sands are best, especially river or beach sands. A sieve size range of 14 to 100 mesh is good. Only half of the volume of sand should be able to pass through a 30-mesh screen. The other half should be made up of larger particles. Advice on sand sizes can usually be obtained from garden centers or suppliers who sell this material. Coarse white silica sand is available locally and is acceptable for sand culture.

Gravel. Gravels include pebbles, crushed rock, crushed limestone or corals, silica gravel and slate chippings. Particle sizes of gravels range from 1/16 to 1/2 inch in diameter. For home hydroponics, a mixture of 25 percent coarse gravel, 30 percent fine gravel, 40 percent coarse sand and 5 percent fine sand should give good results.

Vermiculite. Vermiculite should be standard garden grade. It can be used alone, but mixing it with an equal amount of coarse sand is better—it keeps the vermiculite from packing down and retaining too much water.

Perlite. Perlite should also be standard grade. Perlite is very lightweight and shouldn't be used with very large plants.

Broken bricks. Bricks can be broken up quite easily with a heavy hammer. The largest sized pieces should not be larger than 1/2 inch. All sizes of chips and dust should be mixed together and placed in the container. Use safety goggles while breaking up bricks.

Sand and other aggregates should be rinsed thoroughly with a dilute acid solution, such as half-strength muriatic acid, then rinsed with water to remove any potential contaminants.

It is also wise to rinse the aggregates once every one to two weeks with water to avoid toxic salt buildup, especially if the volume of solution put through the system is low.

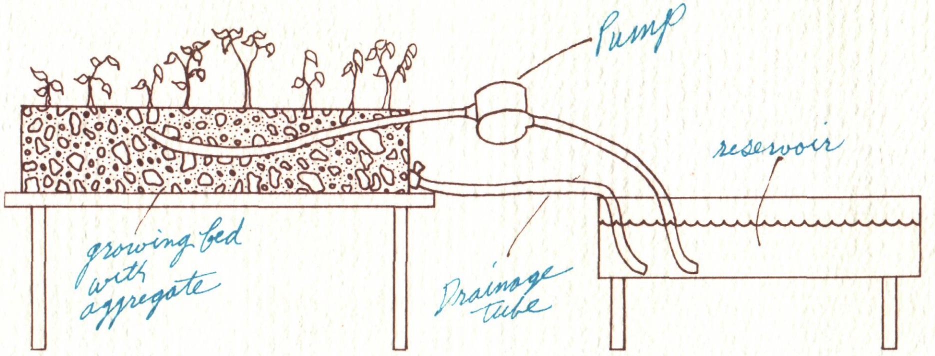
Aggregates differ in their water-holding capacity. Certain aggregates retain minimal amounts of water and consequently should be watered more frequently.

It should also be noted that the concentration of minerals in solution may be lower in an aggregate system than in a water system. In an aggregate system, new solution will be added frequently and excess solution is always leaching away. Frequently, 1/4 strength Hoagland solution is adequate for good growth and productivity in an aggregate system. In a water culture system using a Hoagland's solution (see page 4), the nutrient concentrations are adjusted quite high — several times higher than in a normal soil solution—to sustain growth for an extended period of time.

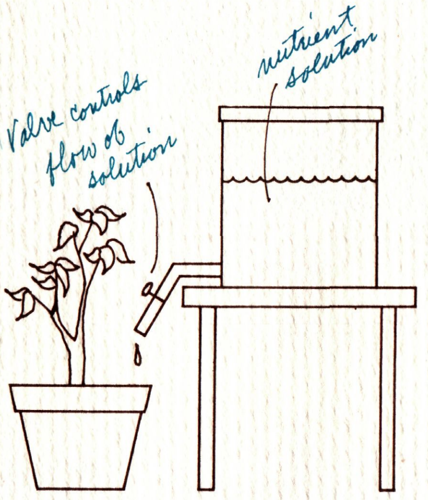
A general aggregate setup consists of a trough containing the aggregate with a drain at one end. Nutrient solution is poured or pumped into the trough at one end, and when the trough is flooded, the solution is drained out of the other end. With a pump and return hose, this can be made into a continuous system.

Aggregate culture can also be adapted to individual plant containers. The container should be at least 8 inches deep and have drainage holes with stoppers. Fill the container with aggregate and place the plant or seedlings in the aggregate. The container should stand in a tray to catch any seepage around the stoppers. Sprinkle nutrient solution evenly and thoroughly on top of the aggregate (an old-fashioned watering can with a sprinkle spout works very well), and then drain immediately.

The frequency with which the nutrient solution should be applied to plants growing in an aggregate depends on many factors, such as the size and type of plants, stage of development, temperature, light intensity and water-holding capacity of the aggregate. Large, fast-growing plants will probably require several applications daily when the temperature is warm and the light intensity is high. Small or slow-growing plants can get by with fewer applications, perhaps only once or twice a week. The aggregate should not be allowed to dry out so much that the leaves wilt. This injures plants and slows the growth rate.



A closed system - using a pump to move nutrient solution from the reservoir to the growing bed. Excess solution drains back into the reservoir by gravity. Such a system can be automated with a timer.



a gravity drip feed system: The nutrient solution drips into the pot just fast enough to keep the aggregate moist.

If you want to conserve nutrients, you may be able to occasionally flush the aggregate with water instead of always using the nutrient solution. How frequently this can be done is difficult to determine because many factors are involved. With experience, a grower may find that every other application may be water only for certain plants at certain times for certain aggregates.

Nutrient Solution

The nutrient solution must contain all of the elements essential for plant growth, it must have an optimum pH and it must be well aerated. The solution needs to be renewed (replaced) periodically—every one to four weeks, depending on the size of plants. If used longer, it will become depleted of essential mineral elements and plants will develop deficiency symptoms.

The nutrients essential to plant growth are nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, boron, zinc, copper, molybdenum and chlorine. Proper amounts and proportions are essential for optimum plant growth. The pH of the solution should be around 5.5 to 6.5.

The pH level can be tested quickly using nitrazine paper, available at pharmacies and drug stores. Test kits for swimming pools can also be used. For more accurate testing, use pH test kits for gardeners.

Premixed nutrient solutions are available through catalogs, garden supply stores and fertilizer suppliers. This would probably be the best way for beginners to obtain a nutrient mix with the proper balance of nutrients, which is so important for plants. The serious do-it-yourselfer, however, may want to mix a solution "from scratch." The ingredients are not easy to acquire and would have to be purchased through a chemical supply company or other supplier.

Water needs to be added to the nutrient solution system just as frequently as to the aggregate system. As water evaporates and/or is taken up by the plant and transpired, the volume of the solution is dramatically reduced. This can result in one of two effects on the plant: a specific salt toxicity because of the resulting high salt concentration, or a potential reduction in water uptake. A good way to monitor fluctuations in soluble salt concentration is by measuring the electrical conductivity of the nutrient solution using a conductivity meter obtainable from garden centers or electronic suppliers. The higher the salt concentration, the higher the conductivity reading on the meter. An initial reading should be taken when the solution is first mixed up and additional readings taken regularly to monitor the concentration.

Though a conductivity meter is helpful in determining the salt concentration in the nurient solution, it cannot indicate the concentrations of particular salts, so imbalances may still occur. Most growers just keep adding water to the solution to bring it back to the original volume, use the solution for a week to a month, and then discard the solution before serious imbalances occur.

Solutions will need to be changed weekly for large, fast-growing plants, whereas smaller plants may be able to grow satisfactorily for as long as a month. Some growers use a very dilute solution — perhaps 10 percent of normal nutrient solution — and run it through the system only once and discard it. This technique eliminates the possibility that imbalances will occur.

The Hoagland Solution

Various plant species require different relative amounts of mineral nutrients for optimum growth. What might be an ideal formulation for one plant species may not be for another. The classic Hoagland solution, developed by Dr. D. R. Hoagland of the University of California, was formulated for culturing tomatoes. It may not suit other types of plants.

Plants also differ in their sensitivity to salts, their total nutrient requirements and the rates at which they remove mineral nutrients and water from the system. A hydroponic system, therefore, should be designed for the crop to be grown.

Hoagland worked out the solutions in Tables 1 and 2. The nutrient solution (Table 1) is composed of four salts that are measured either by weight (ounces) or volume (tablespoons) and added to 25 gallons of water. These four compounds provide the major elements (macroelements) needed by plants.

The five salts listed in Table 2 are all made into separate concentrated or stock solutions (1 quart to 1½ gallons), and a small amount is added to the 25 gallons of nutrient solution prepared from the salts in Table 1. These five microelement stock solutions provide the microelements essential for growth.

Nutrient Deficiency/ Toxicity Symptoms

Plants grown hydroponically are extremely sensitive to imbalances in the nutrient mix, so it's important to recognize stress signs. Some common nutrient deficiency and toxicity symptoms are listed below.

Deficiency Symptoms:

Nitrogen:
Stunted growth and light or chlorotic foliage.

Phosphorus:
Stunted, very dark green foliage; lower leaves may become yellow between veins; monocots may have purple veins.

Potassium:
Lower leaves with interveinal chlorosis; browning leaf edges; brownish mottling.

Calcium:
Tip of shoot dies; interveinal chlorosis on upper leaves.

Magnesium:
Lower leaves with interveinal bleaching or chlorosis and dark green veins; leaf margins may curl; leaves eventually die.

Sulfur:
Light green upper leaves with veins lighter than surrounding tissue.

Iron:
Upper leaves develop interveinal chlorosis with green veins.

Manganese:
Also interveinal chlorosis of upper leaves but veins have wider green bands; upper leaves may also have necrotic spots.

Copper:
Veinal chlorosis starting in the middle leaves; a few leaves suddenly wilt and die and then a few more higher up, etc.

Zinc:
Malformation of leaves—leaves become asymmetric.

Boron:
Dieback of shoot resulting in witch's broom effect; flowers are deformed when open; stems and petioles become brittle.

Toxicity Symptoms:

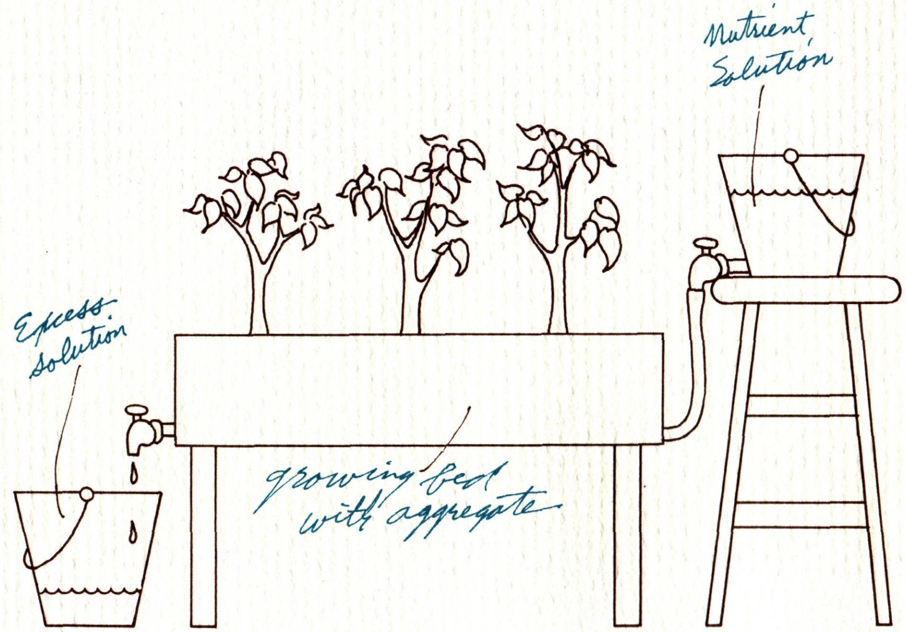
Nitrogen:
Long internodes; crispy stem.

Iron:
Dark leaf edges.

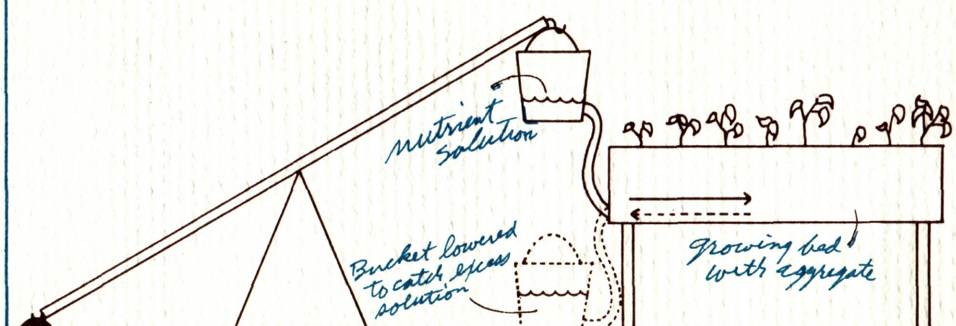
Manganese:
Dark brown leaf veins; also iron deficiency symptoms because too much manganese inhibits iron uptake.

Zinc:
Copper deficiency symptoms.

Boron:
Necrosis of leaf edges.



A simple gravity feed system— Nutrient solution flows into the growing medium in the growing bed. When the aggregate is flooded, excess solution is allowed to drain out into the lower container



A manual gravity feed system. The container, attached to the growing bed with a flexible hose, is raised to allow nutrient solution to flow into the aggregate and it is lowered to allow excess solution to drain out.

Sources of Hydroponic Supplies

Hydroponic supplies can be obtained from several places. Garden centers should carry some of the chemicals and perhaps even equipment. Fertilizer and chemical supply companies may carry the chemicals, but the minimum quantity that they may sell may be several pounds. Some suppliers advertise in garden magazines and related publications. Some of the books on hydroponics also list suppliers.

Table 1.

Macroelements

Salt	Grade	Nutrients	Amount for 25 gal of nutrient solution: Ounces	OR	Level Tablespoons
Potassium phosphate (monobasic)	Technical	Potassium Phosphorus	½		1
Potassium nitrate	Fertilizer	Potassium Nitrogen	2		4 (of powdered salt)
Calcium nitrate	Fertilizer	Calcium Nitrogen	3		7
Magnesium sulfate	Technical	Magnesium Sulfur	1½		4

Table 2.

Microelements

Salt (all chemical grade)	Nutrients	Stock solutions (1 gal of water)	Amount of stock solution to use, for 25 gal of nutrient solution
Boric acid, powdered (H_3BO_3)	Boron	2 tsp	1 cup
Manganese chloride ($MnCl_2$ $4H_20$)	Manganese Chlorine	1 tsp	¾ cup
Zinc sulfate ($ZnSO_4$ $7H_20$)	Zinc, Sulfur	2 tsp	½ tsp
Copper sulfate ($CuSO_4$ $5H_2O$)	Copper, Sulfur	1 tsp	¼ tsp
Iron chelate	Iron	4 tsp	½ cup

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