NON-CIRCULATING HYDROPONIC SYSTEMS FOR VEGETABLE PRODUCTION

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Abstract: Non-circulating hydroponic systems do not require electrical power, mechanical aeration or circulation of the nutrient solution and they are relatively inexpensive to set up and require little maintenance. A typical non-circulating hydroponic system consists of a tank with 0.1 to 0.4 m of nutrient solution located 0.1 to 0.2 m below an opaque tank cover. A net or layer of window screen is placed 10 to 20 mm above the nutrient solution surface; this encourages the development of fine roots and serves as an anchor point to better support the plant. The nutrient solution level may be allowed to recede or remain constant, but it should not be increased more than 10 mm. Tomatoes, cucumbers, melons and leafy crops have been successfully raised with non-circulating hydroponic systems.

INTRODUCTION

In modern hydroponic systems, the nutrient solution is typically aerated or circulated and the temperature, pH, electrical conductivity and nutrient contents are monitored and automically corrected to optimum levels (4). These tasks require specialized equipment and well-trained personnel to operate and maintain these systems. Interruptions of electrical supply and mechanical breakdowns of equipment are serious threats to plant survival and successful crop production. The high set-up and production costs of modern hydroponic systems, the risks of crop failure, the degree of skill required and the remoteness of many agricultural locations from electrical power have deterred many growers from attempting to raise vegetables by hydroponic culture.

Since it is well known that roots require aeration, horticulturists are frequently surprised to learn that Hoagland and Arnon grew tomatoes successfully in hydroponic culture without aeration (1). In their original system, the nutrient solution level was 5 cm below 'a suitably porous seedbed'. When the solution was aerated, yields increased by 34 per cent; henceforth, it has become a common practice to aerate or circulate the nutrient solution. Imai (2) improved upon the original non-circulating system of Arnon and Hoagland by increasing the air space between the tank cover and the nutrient solution, and also, by adding a layer of screen in this space. This system is simple to maintain and operate while permitting the possibility of high yields.

The objective of this paper is to provide insight into the non-circulating hydroponic concept and show that it is simpler, less expensive to set up and operate and is capable of high yields.

Methods and Materials

A typical non-circulating hydroponic system consists of a tank (Figure 1) containing 0.1 to 0.4 m of a complete nutrient solution consisting of (in ppm): N, 100 to 175 ; P 15 to 65; K, 120 to 210; Ca, 150 to 210; Mg, 40 to 50; Fe, 3; Mn, 0.5 to 1.0; Cu, 0.02 to 0.2; Zn, 0.05 to 0.4; B, 0.5 and Mo, 0.01 to 0.1. The level of nutrient solution is positioned 0.1 to 0.2 m below an opaque tank cover. A net or layer of window screen is placed 10 to 20 mm above the nutrient solution level. The screen encourages development of lateral and branching roots and also serves as an anchor point to enable roots to better support the plants. Seedling containers tested include tapered rock wool cubes, plastic seedling pots with a layer of nylon net in the bottom or a bag or basket made of netting and filled with smoked rice husks or peat and vermiculite. When small rockwool cubes were used, considerable care on water management was required during early seedling establishment.

Immediately after transplanting, care must be taken to insure that the seedlings have adequate moisture. They may either be hand watered with nutrient solution or the level of nutrient solution may be initially raised to help accommodate the moisture requirements of young seedlings; the solution will then be allowed to recede to a point 10 or 20 mm below the level of the screen through evaporation, transpiration, absorption or physical removal of the solution as the roots extend downward. As the nutrient solution recedes furthur, water or nutrient solution is added. However, the sudden addition of a large increment of water or nutrient solution adversely affects the roots and causes the plants to wilt. The nutrient solution level may be allowed to stay the same or decrease, but it should not be increased by more than 10 or 20 mm. Plants have grown well, in some cases, with an air space of 25 cm below the tank cover. Thus, if the nutrient solution level decreases much below the original level, it should be maintained at the new lower level rather than brought back to the original level. If concentrated nutrient solution is added, it should not directly contact any roots above the nutrient solution level; otherwise, symptoms of salinity injury will develop. Since there is no circulation in this system, the addition of water alone from a single point will cause a nutrient layering effect. For example, when water was added to the surface, K levels at 30, 100 and 170 mm below the nutrient solution surface reached 104, 248 and 376 ppm, respectively.

We shall briefly describe the operation and performance of three non-circulating systems.

Yields of 'Vendor' tomatoes growing in a non-circulating hydroponic system similar to Figure 1 were compared with those of tomatoes growing in a soil bed (Manu silt loam) and which were maintained in a good state of nutrition (3). The concentrations of nutrients in the hydroponic system were maintained by adding 5 increments of fertilizer throughout the growing season. The trial was conducted in a greenhouse at 1300 m elevation in Hawaii.

'Li-yan' cucumbers (*Cucumis sativus* L.) and 'Tien Xiang' melons (*Cucumis melo* L.) were raised in a hydroponic system consisting of a polyethylene-lined concrete tank, 2 m x 1.5 m x 0.6 m deep with a nylon netting 0.15 m below the cover and the nutrient solution level was maintained 20 mm below the netting (2). Seedlings were raised in net bags (3 x 2.5 mm mesh and 80 mm diameter x 150 mm depth) containing smoked rice husks or a vermiculite medium. Bags were placed in PVC sleeves and immersed in a 50 mm depth of nutrient solution. When the seedlings were 1 month old, 24 seedling bags were transplanted in the tank and cultured for 100 days.

An urban home garden non-circulating hydroponic system was devised (Figure 2). A polystyrene container (0.54 m x 0.34 m x 0.25 m deep) effectively excluded light from the roots and maintained relatively stable temperatures of the nutrient solution due to the insulating properties of polystyrene. Tapered plastic seedling pots, 65 mm diameter x 75 mm height were filled with smoked rice husks and 15 pots were inserted into 60 mm diameter holes in the container lid. The following leafy crops were tested: 'Green Tender' amaranth (*Amaranthus mangostanus* L.), 'Simpson's White' lettuce (*Lactuca sativa* L.), 'I-Tiao-Ken' pai-tsai (*Brassica campestris* L.), 'Five Claws' sweet potato tips (*Ipomoea batatas*) and 'Large Leaf' water convolvulus (*Ipomoea aquatica*). The entire unit was covered with a screen to protect against insect damage and by a plastic cover to protect the plants from rain and also to prevent rainwater from entering the polystyrene container.

Results and Discussion

Yields of salable tomatoes from the non-circulating hydroponic treatment (3.5 kg/plant ± 0.38 SE) and the soil bed treatment (3.1 kg/plant ± 0.23 SE) were similar during the harvest period Dec. 11, 1986 to Feb. 11, 1987.

The 24 cucumber plants growing in a 3 m^2 tank area produced 113 kg of fruit over a June 14 to Aug 20 harvest period. The average fruit weight was 117 grams. The 24 melon plants produced 38 fruits which weighed 56 kg over a July 2 to Aug 20 harvest period.

Yields of leafy vegetables from the home gardening containers were substantial (Table 1). For example, yields of amaranth, lettuce, pai-tsai, sweet potato tips and water convolvulus from the 0.18 m^2

polystryene containers ranged from 10 to 28 grams/day. This calculates to 56 to 155 grams/m^2 of container/day.

Imai (2) concluded that in a non-circulating hydroponic system the upper portion of the root system specializes in oxygen uptake and the lower area of the root system specializes in water and nutrient uptake. For a plant to grow well, the root system above the nutrient solution must grow rapidly and bountiful. The screen layer causes accelerated lateral root growth and branching in this zone, and thus, promotes plant growth.

The non-circulating hydroponic system requires a relatively large water volume. Advantages to this include the maintenance of relatively stable nutrient solution temperature, pH, electrical conductivity and nutrient levels. For a short term crop (7 weeks or less) such as leaf lettuce or pai-tsai, it is usually not necessary to add additional water or nutrients for the duration of the crop. Thus, once the original solution has been prepared, transplanting and harvesting are the only labor operations required to grow the crop. For longer term crops such as cucumbers and tomatoes which are very nutrient demanding, it may be necessary to add additional fertilizer at weekly to monthly intervals.

The non-circulating hydroponic system is relatively inexpensive to set up and easy to maintain compared with conventional hydroponic systems. Electrical power and specialized equipment and training are not required for producing high vegetable yields. Thus, it is likely that widespread use of this concept will develop, especially after furthur improvements and refinements are made.

Literature Cited

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Table 1. The growth duration and yield of leafy vegetables growing in an urban home garden polystyrene container (0.54 m x 0.34 m x 0.25 m deep) with the non-circulating hydroponic system.

Crop	Planting date	Growth duration (days)	Yield kg/container
Amaranth (leaf)	July	89	0.91 (7 harvests)
Lettuce	October	48	0.76
Lettuce	January	63	1.20
Pai-tsai	January	43	0.74
Sweet potato tips	July	96	2.73 (14 harvests)
Water convolvulus	July	96	2.11 (6 harvests)

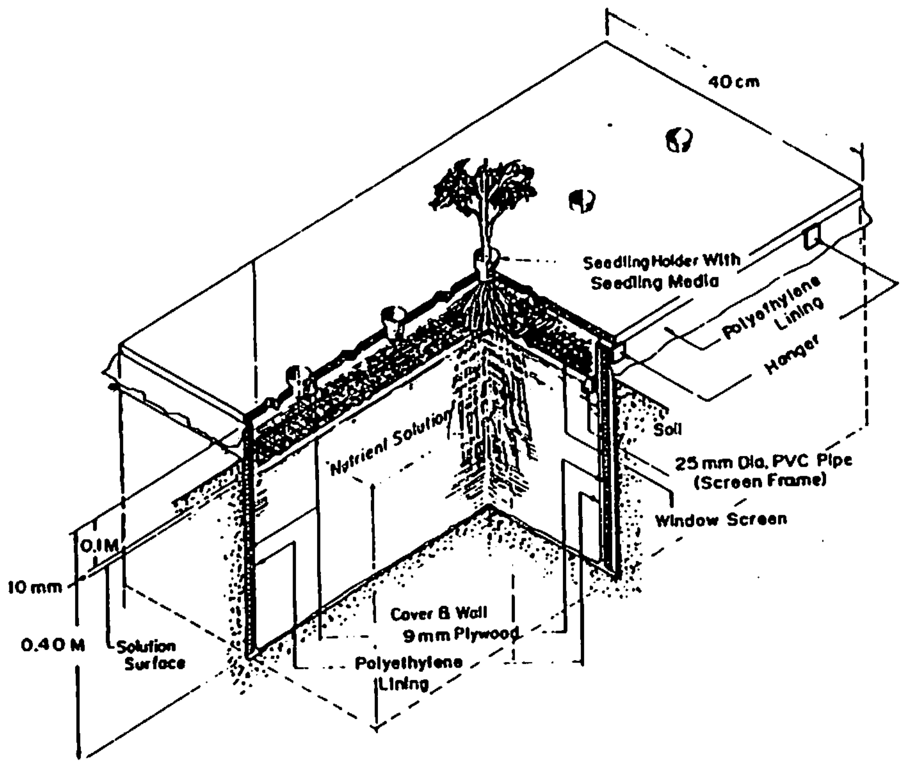

Figure 1. A typical non-circulating hydroponic system.

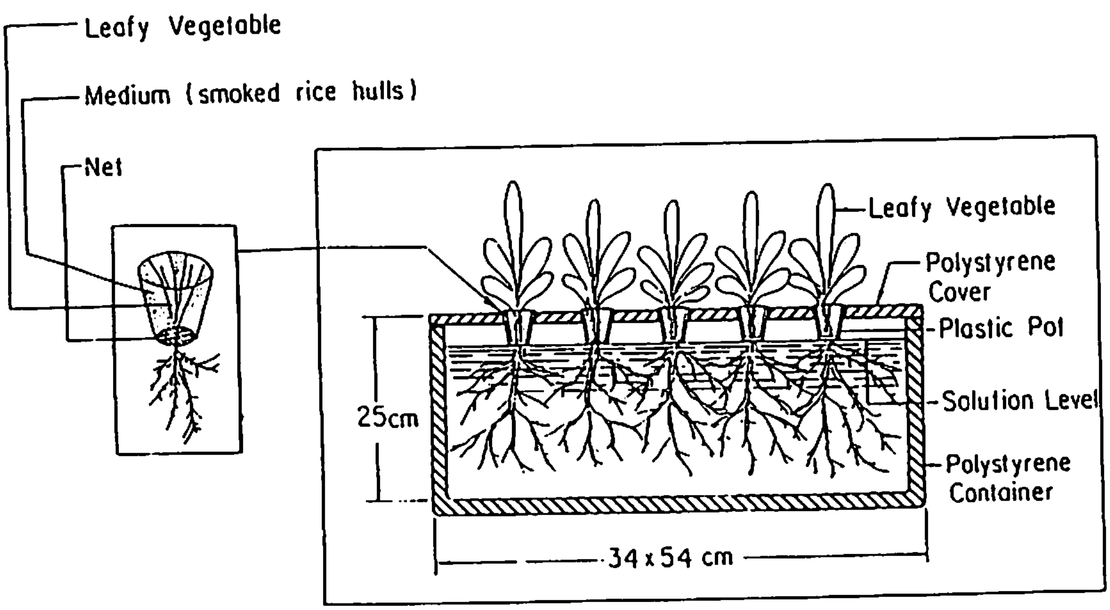

Figure 2. An urban home garden, non-circulating hydroponic system