A Capillary, Noncirculating Hydroponic Method for Leaf and Semi-head Lettuce

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Summary. **A simple, capillary, noncirculating hydroponic method is described. Lettuce seedlings are transplanted into 218-mm-long plastic tubes containing 160 ml of growing medium and the bottom 25 mm is submerged into a tank of nutrient solution. No additional fertilization, watering, or monitoring is required from transplanting until harvesting. Although the nutrient solution level may drop below the bottoms of the tubes, the roots continue to take up adequate water and nutrients to sustain growth. This method does not require pumps or electrical power. 'Green Ice' leaf lettuce produced 24% more salable yield growing with this method than comparable plants growing in conventional soil culture.**

Horticulturists routinely have recommended aeration or circulation of nutrient solution in hydroponic systems since 1940, when Arnon and Hoagland reported a 34% yield increase of tomatoes by aerating the nutrient solution (Arnon and Hoagland, 1940). The additional production costs and complexities associated with aeration and circulation of nutrient solution have retarded the adoption of hydroponic practices to their full potential in commercial agriculture. Thus, there is a need to develop simple, low-maintenance hydroponic systems that do not require power or complex equipment and are relatively low in cost.

Noncirculating hydroponic systems have been described in which a small pot or some other plant container rests on or above a layer of screen (Imai, 1987; Kratky et al., 1988, 1989). The screen encourages root development and provides an anchor for plant support. The lower part of the plant container must be submerged in nutrient solution immediately after transplanting. As the plants grow, the nutrient solution level must be lowered gradually to a point just below the screen. The correct management of the nutrient solution level is very important for the proper establishment of transplants, and this process involves diligent attention of the grower. This report describes a noncirculating capillary hydroponic method for growing leaf and semi-head lettuce (*Lactuca sativa* L.) in which no maintenance or monitoring is required from the time of transplanting until harvesting.

A shallow tank was built in a greenhouse located at 1300 m elevation by placing two layers of 0.15-mm-thick black polyethylene over a rectangular frame, 9.7 × 1.2 m (Fig. 1). The frame was constructed with 50 × 150-mm lumber at ground level and 50 mm of soil was excavated and removed from within the frame to provide for a deeper tank. Sheets of 13-mm-thick plywood coated with white latex paint and reinforced with 19 × 64-mm lumber (to prevent sagging) were placed over the frame. Holes 38 mm in diameter were drilled in the plywood at 200 × 230-mm spacings.

Nutrient solution with a pH of 6.5 and an electrical conductivity of 1.0 mS was added to the polyethylene tank. It consisted of a 75-mm depth of water containing the following (in mg•liter^{-1}): N, 93; P, 33; K, 108; Ca, 110; Mg, 18; S, 23; Fe, 2; Mn, 1; Zn, 0.3; Cu, 0.3; B, 1; and Mo, 0.05. Fertilizer salts included calcium nitrate, potassium nitrate, potassium phosphate, and sulfates of potassium, magnesium, manganese, zinc, and copper.

'Green Ice' leaf lettuce and 'Green Mignonette' semi-head lettuce were seeded in tapered plastic containers (Stuewe and Sons, Corvallis, Ore.), 40 mm in diameter and 218 mm deep, filled to the top with 160 ml of a 1 sand : 1.2 peat : 0.8 vermiculite medium and watered by overhead mist in a seedling greenhouse. Care was taken to pack the media uniformly, thus eliminating voids in the containers. The containers with 18-day-old seedlings were transplanted into the top cover of the tank such that 47 mm of the seedling container extended above the surface and 158 mm remained below the plywood cover. There were ten 4-mm-diameter holes in the portion of the tapered plastic containers located below the cover, four oval holes (12 × 4 mm) in the lower 20 mm of the container, and a 7-mm-diameter hole in the bottom of the container.

The bottom 25 mm of each container was immersed in nutrient solution and the resulting capillary action was sufficient to wet the medium throughout the containers, thus automatically watering the plants. No additional maintenance was required from this time until harvesting. Daily minimum temperatures ranged from 7 to 17C, and daily maximum temperatures ranged from 19 to 31C. No supplemental lighting was supplied.

After a 35-day growing period, 89% of the 'Green Ice' and 81% of the 'Green Mignonette' heads were of marketable quality, and the average weights were 198 and 176 g/head, respectively. In a succeeding trial with 19-day-old transplants and a 32-day growing period, all of the 'Green Ice'

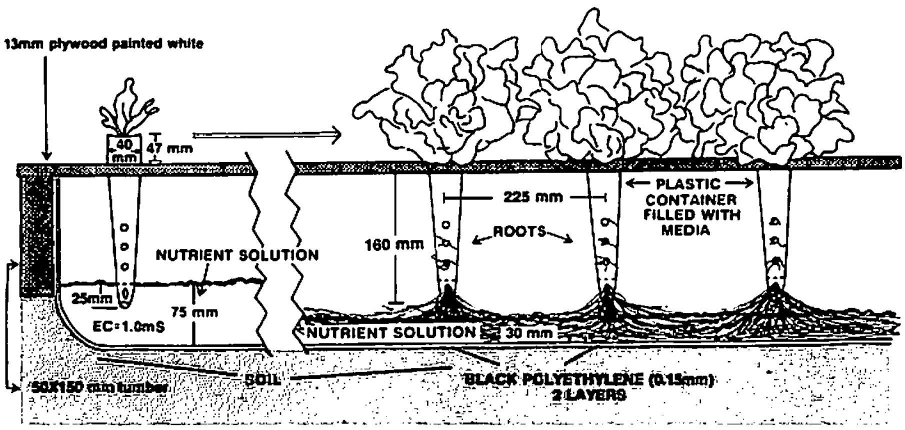

Fig. 1. *A capillary, noncirculating hydroponic method for leaf and semi-head lettuce.*

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and 97% of the 'Green Mignonette' were of marketable quality, and the average weights were 157 and 134 g/ head, respectively.

The water consumption rates for 'Green Ice' and 'Green Mignonette' were 14.4 and 12.6 liter•kg^{-1}, respectively, of harvest fresh weight of lettuce. Although the final nutrient solution levels were 6 to 20 mm below the bottom of the containers, the growing medium in the containers remained moist. However, when the nutrient solution level was 40 mm or more below the bottom of the containers, the medium in the containers was often dry, but the plant continued to grow well. No determination was made on the maximum distance between the container and the nutrient solution that would permit satisfactory growth of the plants.

Lettuce growth from the capillary, noncirculating hydroponic method was compared to lettuce growth from the noncirculating screen method and from conventional greenhouse soil (Manu silt loam) in an open-sided, plastic-covered greenhouse located at a 1300-m elevation. The noncirculating hydroponic methods used polyethylene-lined tanks (2.4 × 0.3 × 0.3 m) containing the same nutrient solution described earlier. Rockwool cubes (25 × 25 × 40 mm) served as the plant containers for the screen method, and the screen was located 75 mm below the top cover. The soil bed received a preplant, broadcast, and incorporated 200-g•m^{-2} rate of 16N–6P–13K. Plants were arranged in double rows spaced 150 × 240 mm apart. There were four replicates of each treatment, and the experiment was arranged as a randomized complete block. There were six trials with 'Green Ice' leaf lettuce, which were harvested in January, February, April, May, July, and August, with an average transplant age of 20 days and a transplant-to-harvest time of 41 days. Throughout this period, daily minimum temperatures ranged between 7 and 17C and daily maximum temperatures ranged between 19 and 31C. No supplemental lighting was supplied.

Salable yield of 'Green Ice' lettuce was 24% greater from the capillary, noncirculating hydroponic method than from the conventional soil method (Table 1). However, yields from both noncirculating methods were statistically similar. Therefore, because the screen noncirculating method required diligent attention during the transplant establishment period, the capillary noncirculating hydroponic methods enjoys the advantage of high yield potential with no maintenance from transplanting until harvesting. The nutrient solution pH values at the end of these trials ranged from 6.1 to 7.0.

Table 1. *Salable yields of 'Green Ice' lettuce grown by two noncirculating hydroponic methods and conventional soil culture.*

Growing method	Salable yield of 'Green Ice' lettuce[z] (g/plant)
Noncirculating capillary method	249.6
Noncirculating screen method	238.6
Manu silt loam soil bed	200.5
LSD, $P = 0.05$	35.5

[z]*Leaf lettuce. Mean yields of six trials with 15 heads per treatment and four replications. The average transplant age was 20 days and the average transplant-to-harvest time was 41 days.*

Minimal root growth was observed from the 4-mm holes in the containers located between the original nutrient solution surface and the plywood cover. However, there was substantial root growth from the bottom hole and the oval holes of the containers that were immersed in nutrient solution at the start of the growing period. A significant portion of this root mass emerged in a conical form and was suspended in the air above the nutrient solution. Remaining roots floated both on and below the nutrient solution. Roots from adjacent plants intermingled with each other. When the plywood top cover was lifted during the growing period, roots tore and many roots in the conical suspension sank below the nutrient solution level, causing the foliage to wilt or lose vigor. Thus, it is important not to disturb the plants while they are growing.

After lettuce was transplanted in the capillary, noncirculating hydroponic method, no additional watering, fertilization, or monitoring of pH or electrical conductivity was required. Thus, the only cultural operations required for this system are: preparation of the nutrient solution, transplanting, harvest, cleanup, and, perhaps, disease or insect control.

In the capillary, noncirculating hydroponic method, plant growth is not affected adversely when the nutrient solution level drops or remains constant. However, severe wilting or even death often occurs after a significant rise in the nutrient solution level. Once roots have become acclimated to a microclimate of moist air, they can no longer tolerate submerged conditions. Therefore, this method is not suitable for outdoor production because rainfall would cause the nutrient solution level to rise.

Longer-term crops such as tomatoes would present a challenge to this method because it would be necessary to add nutrient solution during the growing season. Application increments should be small to prevent root injury.

Other types of tanks have been used successfully with this growing method. These includes plastic buckets with lids, large planting containers lined with plastic trash bags, insulated coolers, and old refrigerators lined with polyethylene.

Additional studies are needed to adapt this method to crops with longer growing seasons. The capillary, noncirculating hydroponic method offers promising potential for production of intensive crops, for home gardens protected from rain, for educational purposes, and for growing plants used in research.

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