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THREE NON-CIRCULATING HYDROPONIC METHODS FOR GROWING LETTUCE

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Abstract

Three non-circulating hydroponic methods for growing lettuce are described which do not require electricity, pumps or wicks. All of the nutrient solution is added prior to planting or transplanting. In the simplest system, lettuce is seeded in a tapered plastic net pot filled with growing medium and placed in a darkened, 4-liter plastic bottle filled with nutrient solution with the lower 3-cm-portion of the pot immersed in nutrient solution. Plants are automatically watered, because the entire growing medium in the net pot becomes moistened by capillary action. Plant growth reduces the nutrient solution level, creating an enlarging moist air space. Meanwhile, the root system expands and continues to absorb water and nutrients. Leaf and semi-head lettuce cultivars are usually harvested at about 6 to 7 weeks after seeding. A typical expansion of this concept to a commercial scale employs a 14 cm high tank lined with polyethylene sheeting which is filled with nutrient solution and covered with an expanded or extruded polystyrene sheet resting on the tank frame. Lettuce is planted or transplanted into net pots filled with growing medium and placed in holes in the cover. Lettuce seedlings are initially watered by capillary action, and later, by direct root uptake. The crop is harvested before the nutrient solution becomes exhausted. Another modification of this method is a float-support system in long rectangular raceway tanks. Lettuce is planted or transplanted into net pots placed in a sheet of extruded polystyrene. The cover initially floats on the nutrient solution, and then, comes to rest on 2 parallel plastic pipes (10 cm diam) resting on the tank floor as the nutrient solution level recedes due to plant growth. The tank is filled with water immediately prior to harvesting and floating rafts may be easily moved to a harvesting station.

INTRODUCTION

The suspended net pot, non-circulating hydroponic growing method is a unique and powerful technique for growing leafy, semi-head and small romaine lettuce cultivars, because the entire crop can be grown with only an initial application of water and nutrients (Kratky, 1993, 1995, 1996, 2004, 2005). After planting or transplanting, no additional labor is required until harvesting. Electricity and pumps are not needed, so the additional production costs and complexities associated with aeration and circulation in many conventional hydroponic systems are totally avoided by this method. This system is extremely efficient with water use. Water use efficiencies of less than 20 liters per kg of lettuce are common, and an efficiency as low as 11 liters per kg of lettuce has been recorded (Kratky *et al*., 2008). Growers typically aim for 150 to 250 gram heads with this growing method, and the nutrient solution consumption range is typically in the range of 3 to 6 liters per plant.

DISCUSSION

Model growing system

A model growing system consists of a covered tank which is filled with 4 to 8 liters of nutrient solution per plant prior to planting (Fig. 1). Lettuce is either seeded or transplanted into containers (preferably, tapered plastic net pots with slits to allow root emergence) containing growing medium. The containers are supported by the tank cover such that their lower portion is initially immersed in nutrient solution.

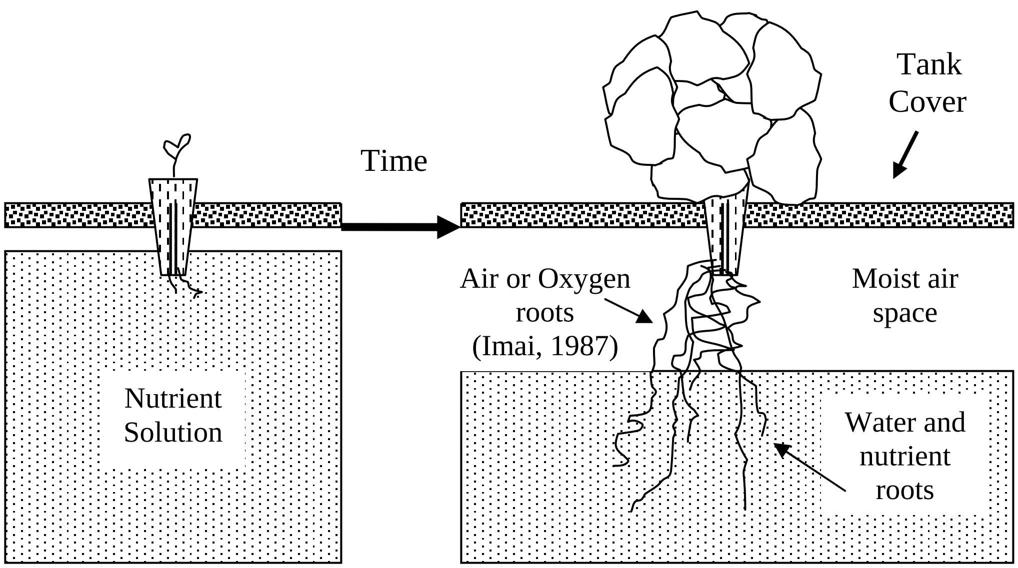

Fig. 1. A model suspended pot, non-circulating hydroponic system at seedling stage where the seedling container is partially immersed in nutrient solution and at harvestable stage where an expanded moist air space forms after the nutrient solution has dropped below the seedling container.

Plants are automatically watered, because the entire growing medium in the net pot becomes moistened by capillary action. Plant growth causes the nutrient solution level to decrease, thus creating an expanding moist air space which is maintained, because the tank cover prevents roots from drying. At some point, direct capillary wetting of the substrate is no longer possible, but the expanding root system is capable of absorbing nutrient solution from the tank. Roots occupying the moist air space above the solution have been described as *oxygen roots* whose main function is aeration; these roots experience vigorous lateral and branching growth (Imai, 1987). Roots extending into the nutrient solution are considered to be *water and nutrient roots* that have limited elongation capabilities, because the oxygen content of the nutrient solution becomes progressively lower with depth. The nutrient solution level may remain the same or be lowered, but it should not be raised because submerging the oxygen roots will cause the plant to 'drown'.

4-Liter bottle method

The 4-liter bottle method is suitable for lettuce and other short-term crops which require less than 4 liters of water for their lifespan (Fig. 2, Kratky, 2002). The simplest version of this method is a 4-liter plastic bottle filled to within 4 cm from the top with water to which 5 grams of a complete hydroponic granular fertilizer are added (Chem-Gro 10-8-22 plus other nutrients; Hydro-Gardens, Colorado). The bottle should either be covered or darkened to discourage algae growth. Lettuce is seeded or transplanted into a tapered net pot or forestry tube filled with growing medium which is supported by the neck of the bottle. The lower 3 cm of the net pot is immersed in the nutrient solution. This moistens the entire medium in the net pot by capillary action, thus automatically watering the young plant.

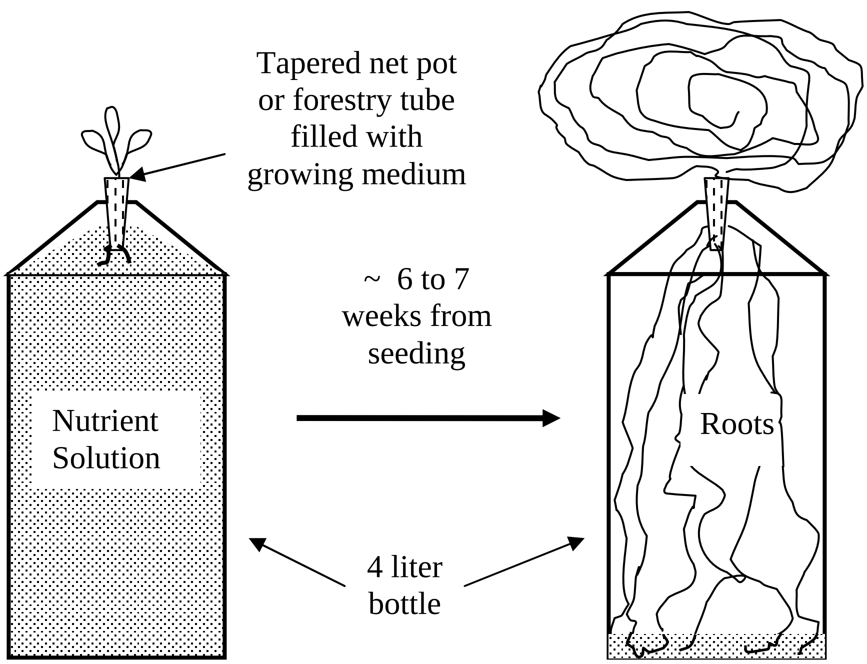

Fig. 2. Lettuce growing in a 4-liter plastic bottle.

The lettuce grows to maturity (usually in about 6 to 7 weeks from seeding) and the nutrient solution level typically drops 15-25 cm below the original level because no additional nutrient solution is added to the bottle. The increasing zone of moist air between the nutrient solution and the net pot does not hinder plant growth. In Hilo, Hawaii, a 200 gram lettuce plant typically only consumes about 3-4 liters of nutrient solution. Other embodiments of this method are to grow 3 or 4 lettuce plants in a 20-liter plastic bucket with a lid or grow 6 to 8 lettuce plants in a plastic storage container or an ice chest.

Educators can use this inexpensive method to teach students about plant growing concepts. The bottles can be prepared during one class period along with the presentation of instructional agenda, and there is no additional day-to-day effort required to maintain the lettuce plants. There is no need for weekend watering! Gardeners can use this method to grow lettuce on lanais, porches and under the overhangs of buildings. Researchers and farmers can use this method to conduct nutritional studies, test pesticides and produce seed.

Top cover supported by the tank frame

The bottle concept can be expanded to growing lettuce in commercial-sized tanks (Fig. 3). Lettuce is normally grown by this method in screened, plastic-covered rainshelters or greenhouses. A tank is constructed by fastening 3.8 x 14 cm dimension lumber to a 1.9 cm-thick plywood sheet (1.2 x 2.4 m) and lined with 2 layers of 0.15 mm-thick black polyethylene sheeting. Other tank embodiments include increasing the length up to 10 m and replacing the plywood bottom with recycled corrugated roof iron. The tank is supported on concrete blocks or a lumber support and leveled. Tanks may also be constructed immediately over level ground, thus eliminating the material for the bottom of the tank.

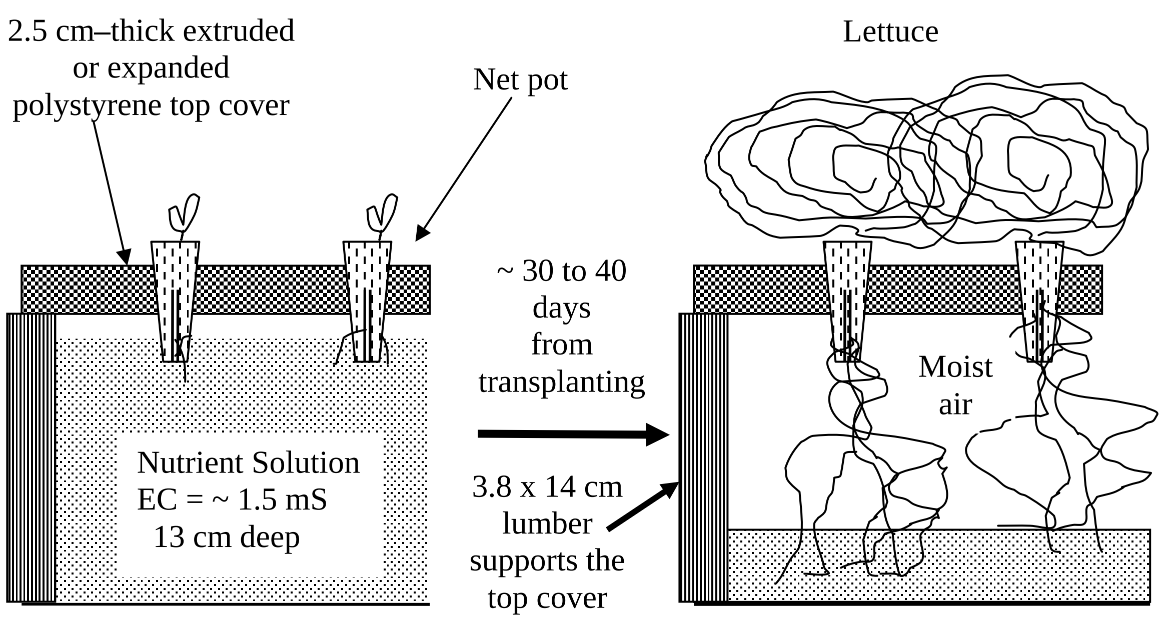

Fig. 3. Growing lettuce by a non-circulating hydroponic system where the top cover is supported by the tank frame.

Tanks are covered with 1.3 to 2.5 cm thick expanded or extruded polystyrene, but plywood sheets or supported plastic covers may also be used. The edges of the cover are supported by the sides of the tank. Soft plastic pots may be placed on the floor of the tank to provide additional support and prevent sagging of the top cover, if needed. Holes are cut at 20 x 30 cm spacings into the cover to accommodate 5 cm net pots which hold the lettuce plants; other spacings may also be used.

The tank is nearly filled with water prior to transplanting and nutrients from 2 stock solutions are added in equal volumes to prepare a nutrient solution with an EC of 1.5 mS. One stock solution consists of 120 g/liter of a commercial (Hydro-Gardens, Colorado) hydroponic fertilizer (8% N, 6.6% P, 29.9% K, 0.20% B, 0.05% Cu, 0.4% Fe, 0.2% Mn, 0.01% Mo and 0.05% Zn) plus 72 g/liter of magnesium sulfate; the second stock solution consists of 120 g/liter of soluble grade calcium nitrate. No additional watering and fertilization are needed for the crop. One to 2 week-old lettuce seedlings are transplanted into 5 cm net pots which are then supported by the tank cover. Typical growing substrates include peat/perlite/vermiculite mixtures and oasis blocks. The lower 1 to 2 cm of the net pots are immersed in the nutrient solution. At harvest, the nutrient solution level typically drops 6 to 12 cm and is replaced with a zone of moist air.

Leafy or semi-head lettuce is ready for harvest in about 5 weeks from transplanting depending upon the season and cultivar. Growers typically harvest and replant on the same day, thus maintaining full capacity of the tanks. Lettuce is harvested with a knife or scissors. The net pots are removed and cleaned. Some growers drain and refill the tanks after each crop; other just ‘top off’ the remaining solution with new nutrient solution. As a general rule, tanks should be drained and refilled after every 3 crops or sooner.

Float-support system in long, rectangular raceway tanks

Rectangular, raceway tanks, 14 cm deep, with an inside width of 1.25 m and an optional length are constructed on a level surface by draping 0.15 mm-thick polyethylene over a lumber frame, and they are filled with nutrient solution similar to the previous method (Kratky *et al*., 2008). Two parallel lengths of 10 cm diameter plastic pipes are placed 0.9 m apart and supported by the floor of the tank. Sealed zip-lock bags filled with pebbles may be placed in the pipes to prevent them from floating. Holes for 5-cm net pots are cut in 1.3-cm or 2.5-cm-thick extruded polystyrene boards (61 x 122 cm) with a staggered 20 x 30 cm spacing arrangement. Expanded polystyrene bead boards are not suitable for a float-support system, because they have occasional air pockets and may become waterlogged and covered with algae, but extruded polystyrene boards have a consistent structure without any large air pockets and do not become waterlogged (Jensen, 2002).

Lettuce seedlings (1 to 2 weeks old) are transplanted into 5-cm net pots filled with peat-perlite growing medium and placed into the openings of the extruded polystyrene boards. The extruded polystyrene boards initially float on the nutrient solution, because the nutrient solution is deeper than the height of the support pipes. As nutrient solution is lost by evaporation and transpiration, the extruded polystyrene boards come to rest on the pipes – thus, creating a moist air space between the extruded polystyrene cover and the nutrient solution. This gap typically becomes 3 to 9 cm at harvest. Then, the raceway is filled with water to float the boards. A pair of strings may be tied to brackets attached to the last board in the raceway, and the entire lettuce raft can easily be pulled towards the collection end where individual boards are manually elevated on a platform to facilitate lettuce harvesting. The net pots are removed and cleaned, the extruded polystyrene boards are washed and replanted, fertilizer stock solutions are added to the tanks and the newly replanted boards are floated back onto the raceway.

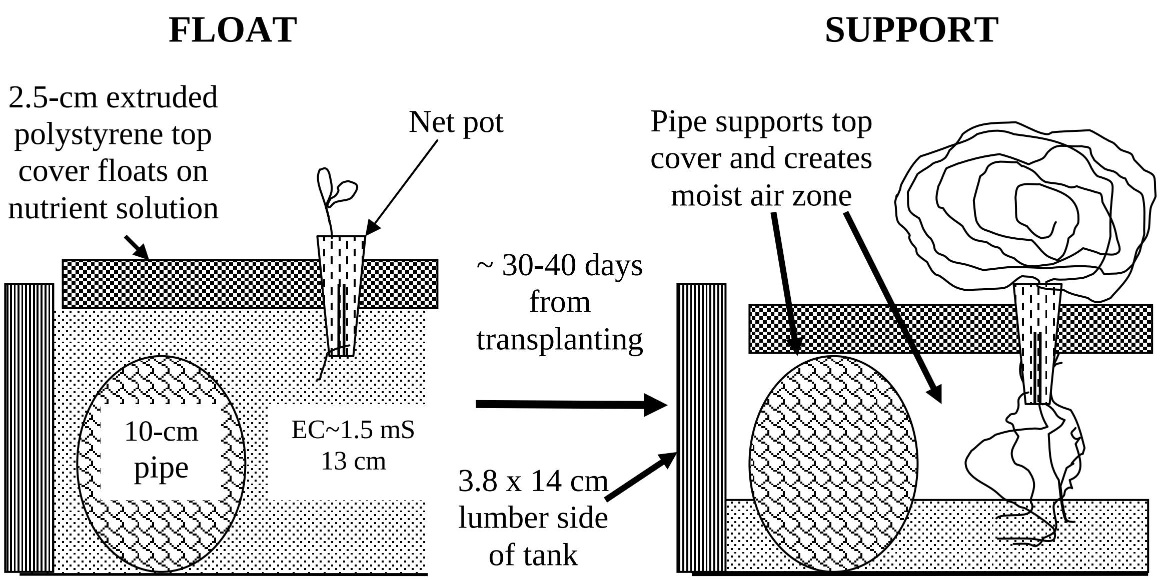

Fig. 4. Growing lettuce by a float-support, non-circulating hydroponic system.

Yields from the 14 cm deep tanks with 10 cm pipe supports were always as good as from the previous method where the top cover was continuously supported by the tank frame. However, this was not always true with 5 cm supports in an 8.9 cm deep tank (Kratky, 2005). No moist air space developed in experiments where the top cover was continuously floating without a support, and this resulted in yield decreases of up to 23 percent compared to a lettuce growing system where the top cover was supported by the tank frame.

Other considerations

Mosquitoes can breed and multiply in nutrient solution which is not circulated or aerated and become both a health menace as well as a nuisance to workers. Mosquitoes can be somewhat controlled by screens on the greenhouse sides. Also, the screen may be draped in a tank such that the initial solution level is higher than the screen, and then the solution drops below the screen as the crop grows, thus trapping the newly hatching mosquitoes under the screen. Other mosquito control methods include salt-tolerant fish in the tanks, *Bacillus thuringiensis subspecies israelensis* toxins (Furutani and Arita-Tsutsumi, 2001) or by pesticides in the air or nutrient solution. Cool air temperatures or dry, windy conditions discourage mosquito populations.

Good water quality is required for this method, because salts may concentrate as the nutrient solution is consumed. For example, water with an initial EC of 0.5 mS from salt contaminants may concentrate to 2.0 mS when 25 percent of the original nutrient solution remains, and this could lead to tipburn and other problems. The use of rainwater is recommended in locations with poor water quality. If this is not possible, then deeper tanks will cause less concentration of the salts, and the tanks must be emptied after each crop.

Cropping cycles for these methods are typically completed without altering pH while using commercially available hydroponic fertilizers with relatively good water quality in Hawaii trials. However, if pH becomes too acidic, dolomite may be placed in a nylon stocking or similar mesh material which is immersed in the tank until the pH normalizes; the stocking prevents a residue of undissolved dolomite in the tank. If the pH is too basic, add ammonium sulfate which will cause a release of hydrogen ions when taken up by the plant, thus acidifying the nutrient solution. One approach is to make a stock solution containing 12 g per liter of ammonium sulfate and apply this stock solution to the tank at a similar volumetric rate as the other 2 fertilizer stock solutions. The tank pH is checked after 4 days and adjustments are made as needed. More caustic acids and bases may also be used with caution to adjust nutrient solution pH.

CONCLUSIONS

A non-circulating hydroponic concept for growing lettuce is described where electricity and pumps are not needed and the entire crop can be grown with only an initial application of water and nutrients. At seeding or transplanting time, the growing containers are supported by the tank cover with their lower portion being immersed in nutrient solution. This moistens the growing medium in the containers by capillary action, thus automatically watering and fertilizing the plants. Plant growth causes the nutrient solution to lower and creates an expanding moist air space and an expanding root system. The main function of the roots in the moist air space above the nutrient solution is aeration whereas the roots extending into the nutrient solution absorb water and nutrients. Three methods for growing lettuce are described**.** Lettuce is planted or transplanted into a net pot which is supported by the neck of a 4-liter plastic bottle filled with nutrient solution. Lettuce may also be transplanted into 5-cm net pots which are placed in an expanded or extruded polystyrene cover that is supported by the frame of a 14 cm-high tank which is nearly filled with nutrient solution. In a float-support system, an extruded polystyrene cover with net pots floats at transplanting time, and then comes to rest on 10-cm pipe supports as the nutrient solution level recedes due to plant growth, and this provides a moist air space.

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Literature Cited

Furutani, S.C. and L. Arita-Tsutsumi, L. 2001. Use of *Bacillus thuringiensis* i*sraelensi*s and methoprene to control Asian tiger mosquito, *Aedes albopictus* (Skuse) (Diptera: Culicidae), in non-circulating hydroponic tanks. Proc. Hawaiian Entomol. Soc 35:113-119.

Imai, H. 1987. AVRDC non-circulating hydroponic system. pp. 109-122. *In*: C.C. Tu and T.F. Sheen (eds.) Proc. Symposium on horticultural production under structure. Taiwan Agr. Res. Inst. Taichung.

Jensen, M.H. 2002. Deep flow hydroponics – Past, present and future. Proc. Nat. Agr. Plastics Congress 30:40-46.

Kratky, B.A. 1993. A capillary, non-circulating hydroponic method for leaf and semi-head lettuce. Hort-Technology. 3(2):206-207.

Kratky, B.A. 1995. Non-circulating hydroponic plant growing system. U.S. Patent No. 5,385,589.

Kratky, B.A. 1996. Non-circulating hydroponic plant growing system. U.S. Patent No. 5,533,299.

Kratky, B.A. 2002. A simple hydroponic growing kit for short-term vegetables. U. of Hawaii CTAHR HG-42.

Kratky, B.A. 2004. A suspended pot, non-circulating hydroponic method. Proceedings of the South Pacific Soilless Culture Conference, Acta Hort. 648. p. 83-89.

Kratky, B.A. 2005. Growing lettuce in three non-aerated, non-circulated hydroponic systems. Journal of Vegetable Crop Production. 11(2):35-41.

Kratky, B.A., G.T. Maehira, E.J. Magno, M.D. Orzolek and W.J. Lamont. 2008. Growing Lettuce by a float-support non-circulating hydroponic method in Hawaii and Pennsylvania. Proc. of the 34 th National Agricultural Plastics Congress, 6 pages.