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NON-CIRCULATING HYDROPONIC METHODS FOR GROWING TOMATOES

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Abstract. 'Big Beef' tomatoes produced 2.68 kg/plant from a 72 day harvest period when they were grown in 0.35 liter aluminum beverage cans by a sub-irrigation hydroponic method. Tomatoes growing in net pots (70 ml) suspended by expanded polystyrene bead boards with a sub-irrigation method gave similar yields in one trial but lower yields in another trial than tomatoes growing in beverage cans. Tomatoes growing in 10 cm square plastic pots filled with perlite (700 ml) rested on 5 cm high upside-down nursery trays and yielded significantly higher than plants growing in aluminum beverage cans resting on the tank floor in 2 trials. Placing a 5 cm high nursery tray as a support for a 10 cm pot increases the root exposure to moist air (i.e. air between the nutrient solution surface and the tank cover) and provides a net-type surface which encourages root formation and anchorage. Hawaii's lower elevations are warm and very conducive to mosquito reproduction in these non-circulating hydroponic tanks. In an effort to control mosquitoes, window screen was supported on the nursery tray above the nutrient solution level, thus trapping newly hatched mosquitoes below the screen where they eventually died. Tomatoes were also grown in 7.6 liter pots which were sub-irrigated by microtubes. Each pot contained an upside-down 3.8 liter pot with slits, so only 3.8 liters of cinder growing medium was needed to fill the pot. In several cases, roots grew into the microtubes supplying the nutrient solution and this blocked nutrient flow to the pots, thus killing the plants. Tomatoes growing in both of these mosquito-proof systems yielded similarly when protected by a simple polyethylene rainshelter from 158 cm of rainfall during the growing period, but unprotected tomato plants yielded 55 per cent lower in the pot-screen-tank system and no salable yields were obtained from the unprotected sub-irrigated 7.6 liter pots.

Introduction

Non-circulating hydroponic methods avoid the additional production costs and complexities associated with mechanical aeration and circulation of the nutrient solution including the need for electrical power and pumps. The suspended pot, non-circulating hydroponic method allows an entire crop to be grown with only an initial application of water and nutrients (4). This system is very suitable for short-term crops like lettuce with a relatively low water requirement. However, a long term crop like tomatoes has a high water requirement and it would be costly to build large tanks to supply the entire crop with nutrient solution. Cucumbers were successfully grown in aluminum beverage cans resting in tanks of continuously maintained, shallow nutrient solution (7). Tomatoes were grown in 0.4 m deep tanks where nutrient solution level was maintained immediately below a screen placed 10 cm below a top cover (5). The screen encouraged the development of fine roots and served as an anchor point for the roots.

This paper will discuss several non-circulating hydroponic growing methods for tomatoes where the goals include achieving reasonable yields with no electrical requirements, a low growing medium requirement, and avoidance of developing a mosquito problem.

Methods and Materials

Nutrient solution was made by diluting 3 stock solutions of Hydro-Gardens Chem-Gro 4-18-38, calcium nitrate and magnesium sulfate (1:1:0.6 ratio, respectively) to an EC of 1.0 mS until fruit set and then was increased from 1.5 to 2.5 mS for the duration of the crop. Nutrient solution depth was 7.5 cm high at transplanting and was reduced to below 5 cm as roots emerged from the growing container and maintained at that level for the duration of the experiments.

Cultivar trial in aluminum beverage cans.

'Big Beef', '5000', 'Joker' and 'Vendor' tomatoes were planted in 0.35 liter recycled aluminum beverage cans containing a peat-perlite-vermiculite (1:1:1) potting medium and planted in tanks with double rows spaced 0.3 m between rows and plants. Tanks consisted of a 0.6 m wide lumber (3.8 x 14 cm) frame lined with 2 layers of 0.15-mm-thick polyethylene sheeting resting on leveled greenhouse soil. Aisles between tanks were 0.76 m wide. Tanks were covered with one layer of black polyethylene and openings were made for the beverage cans which rested on the bottom of the tank. Bottoms of the beverage cans were removed with a Swing-A-Way can opener and cans were inverted so the pop-tab faced downward and 3 vertical slits were made in the cans to allow roots to emerge from the sides of the cans. Tomatoes were seeded on May 5, 1999, transplanted into the tanks on June 18, 1999 and harvested from August 18 to October 29, 1999. Experiments were conducted in a rainshelter with screened sides at 1300 m and there were 3 replications with 12 plants per treatment.

Growing in beverage cans, net pots and 10 cm plastic pots resting on nursery trays.

'Healani' tomatoes were grown in the first trial and 'Big Beef' tomatoes were grown in the second trial. The location, rainshelter, tanks, row spacing and beverage can methodology were similar to that described above. Plant spacing for the first trial was also similar, but plants were spaced 30, 45 and 60 cm apart in the second trial. Tapered net pots (3.8 cm diameter x 7.5 cm length) with a 70 ml capacity were supported by 2.5 cm thick expanded polystyrene bead board which rested on the tank frame. Ten cm square plastic pots filled with perlite (700 ml) rested on 5 cm high upside-down nursery trays. The nursery tray surface was configured in a lattice-like arrangement with a plurality of square 0.6 cm apertures which allowed roots to pass through the tray into the nutrient solution. The first experiment was harvested from July 31 to October 23, 2001. There were 12 replications of 12 plants. The second experiment was harvested from February 20 to May 21, 2002 and there were 4 replications of 6, 8 and 12 plants per treatment for the 60, 45 and 30 cm plant spacings, respectively.

Growing in sub-irrigated 7.5 liter pots and 10 cm pots in a mosquito-proof tank.

'Healani' tomatoes were grown in single row plots with a 30 cm plant spacing at an elevation of 100 m. One treatment consisted of growing tomatoes in 3 m long, polyethylene-lined tanks which were constructed of 3.75 cm thick lumber such that the inside width and height were 24 cm and 10 cm, respectively (Figure 1). Plastic nursery trays (5 cm high) were cut to size and rested on the floor of the tank. Fiberglass window screen rested on the nursery trays and was stapled to the outside of the tank. Ten cm plastic pots were filled with perlite and rested on the screen. Extra slits were cut into the sides of the pots to allow root emergence. A black polyethylene top cover with openings for the pots was placed over the top of the pots and stapled to the outsides of the tank. A plastic sump with a float valve was installed in the tank and 2 microtubes (1 and 2 m long) were inserted into the sump container to transport nutrient solution to 2 different locations in the tank where the nutrient solution level was maintained at 4 cm. Another treatment consisted of growing tomatoes in a 7.6 liter pot (without drainage holes) wherein an upside-down 3.8 liter pot with slits in the sides was placed, so that only about 3.8 liters of volcanic cinder was needed to fill the 7.6 liter pot. The pots rested on a level wooden plank. Microtubes (0.5 cm diameter) originating from a sump controlled by a float valve were inserted into the lower 3 cm of individual 7.6 liter pots, thus transporting nutrient solution by gravity flow into the pots to the same height as in the sump assembly. Half of the plants from both treatments were grown under a simple 180 cm high polyethylene rainshelter with open sides and ends and the other half were unprotected from the weather. Nutrient solution stored in an 1100 liter elevated tank flowed to the sumps via 1.3 cm polyethylene tubes.

Results and Discussion

Relatively short cropping periods were utilized in these trials as a management tool to combat the high insect and disease pressures in Hawaii's environment.

The highest yielding tomato cultivar, 'Big Beef', produced 2.68 kg/plant of salable tomatoes from a 72 day harvest period when they were grown in aluminum beverage cans by a sub-irrigation hydroponic method (Table 1). Beverage cans are typically at least 12 cm tall. The lower 5 cm of the cans and root systems were immersed in nutrient solution and the upper 7 cm of the cans and root system were exposed to moist air. Imai described the roots above the nutrient solution as 'O' or oxygen roots whose main function is aeration and that plant performance is dependent upon the growth rate and quantity of 'O' roots (1). In previous experiments (3) tomatoes grown in sub-irrigated bags were allocated 14 liters of growing medium per plant. Beverage cans as plant containers required less than 3 per cent of that growing medium requirement in these experiments.

Net pots require even less growing medium than beverage cans (70 ml), but tomato yields were significantly similar (Table 2) or less than from beverage cans (Table 3). The expanded polystyrene bead boards were not secured to the tank and wind caused movement of the plant and tank cover, thus creating a potential for damage to the roots. Nevertheless, a reasonably comparable yield to the beverage can method provides hope that there is potential to develop a method based upon net pots.

Yields were significantly greater from plants growing in 10 cm pots resting on a nursery tray than from plants growing in aluminum beverage cans resting on the tank floor and from the net pot treatment (Tables 2 and 3). Placing a 5 cm high nursery tray as a support for a 10 cm pot increases the root exposure to moist air (i.e. air between the nutrient solution surface and the tank cover) and provides a net-type surface which encourages root formation and anchorage (6). In theory, this system is very similar to that reported in 1988 (5), but the current method is much simpler to construct and can easily be converted to large scale production.

Tanks of non-circulating nutrient solution become breeding grounds for mosquitoes. The cool temperatures at 1300 m elevation discourage mosquito reproduction and, thus the above methods have been satisfactory for this location. However, lower elevations are warmer and very conducive to mosquito reproduction in stagnant nutrient solution. Thus, it was imperative to develop a method which discouraged mosquito production.

The '10 cm pots resting on nursery tray' system has promise as a tomato growing method, but a mosquito problem remains. Placing window screen above the nutrient solution level (Figure 1) traps the newly hatched mosquitoes below the screen where they eventually die. However, the nutrient solution level must be higher than the screen at transplanting time to enable initial watering by capillary action of nutrient solution into the growing medium. As the plants grow and produce roots, the nutrient solution level may be lowered below the screen. Hopefully, there will be minimal mosquito problems during this interim period.

Tomatoes growing with this method yielded 1.75 kg salable fruits when the tanks were protected by a simple rainshelter from the 158 cm of rainfall that occurred during the term of this crop, but only a 0.78 kg yield was gathered from plants which were not protected and had more intense foliage diseases (Table 4). Apparently, the sloped top cover of the tanks repelled some rainfall, thus reducing the dilution of the nutrient solution. This system could be assembled over an uneven surface, because each tank has its own float valve and is independent of other tanks. The tank system may be expanded to a larger scale without great difficulty.

A container which is sub-irrigated with nutrient solution and filled with growing medium does not support mosquito reproduction. Paterson and Hall (8) maintained 1 cm of water in a container with 8 liters of perlite. We tweaked this concept by placing an upside-down, empty 3.8 liter pot in a 7.6 liter pot, thus saving half of the growing medium and were able to grow tomatoes with about 7 per cent of the growing medium required for our 1996 study. Our arrangement was similar to Jones (2) who supplied nutrient solution to 2 liter bottles of growing medium through an irrigation line originating from a sump with a float valve. This system resulted in yields similar to the previous system when the plants were protected by a rainshelter, but no salable yields were obtained from plants growing without the protection of rainshelters. Each pot collected approximately 57 liters of rainfall during the course of the crop and this diluted the nutrient solution and disrupted crop growth. The sub-irrigation pot system works fine when protected from rainfall, but it may be difficult to conduct on a large scale. Under certain conditions, roots grew into the microtubes and blocked nutrient flow to the pots, thus killing the plants. Since each pot requires its own microtube, this system requires considerable plumbing. Leakage in one pot or overturning of one pot can cause all of the nutrient solution to drain from the supply tank. Microtubes tend to curve upwards between the supply line and the containers, thus preventing nutrient solution flow, but this may be prevented by placing a weight (like a small board) on the microtubes to keep them below the water level.

In the future, we will be looking to improve upon the existing systems by utilizing an off-the-shelf plastic container as a growing tank which holds 2 to 6 plants and maintains the attributes of satisfactory tomato production, no electrical requirement, a low growing medium requirement, and avoidance of developing a mosquito problem.

Literature Cited

Kratky, B.A., G.T. Maehira, R.J. Cupples and C.C. Bernabe. 2005. Non-circulating hydroponic methods for growing tomatoes. Proc. National Agricultural Plastics Congress 32:31-36.

1. Imai, H. 1987. AVRDC non-circulating hydroponic system. pp. 109-122 *In:* C.C. Tu and T.F. Sheen (eds.) Proc. Symp. On Horticultural Production Under Structure. Taiwan Agr. Res. Inst. Taichung.
2. Jones, J.B. Jr. 1997. Advantages gained by controlling root growth in a newly-developed hydroponic growing system. Proc. 18th Annual Conference of the Hydroponic Society of America, Windsor, Canada. pp.125-136.
3. Kratky, B.A. 1996. Greenhouse tomato production in top and sub-irrigated vertical bag culture. Proc. Nat. Agr. Plastics Congress 26:54-59.
4. Kratky, B.A. 2004. A suspended pot, non-circulating hydroponic method. Proceedings of the ISHS South Pacific Soilless Culture Conference. Acta Horticulturae 648:83-89.
5. Kratky, B.A., J.E. Bowen and H. Imai. 1988. Observations on a non-circulating hydroponic system for tomato production. HortScience 23 (5): 906-907.
6. Kratky, B.A., H. Imai and J.S. Tsay. 1989. Non-circulating hydroponic systems for vegetable production. Proc. Of the National Agricultural Plastics Congress 21:22-27.
7. Kratky, B.A., L.A. Peterson, M.Yamasaki and A.R. Krueger. 1994. Growing cucumbers in beverage cans resting in shallow tanks of aerated and non-aerated nutrient solution. Proc. of the American Society for Plasticulture 25:101-107.
8. Paterson, J.A and D.A. Hall. 1981. A method for studying the influence of nutrition on tomato plant vigour in hydroponic culture. Hort Res. 21:103-6.

Nursery
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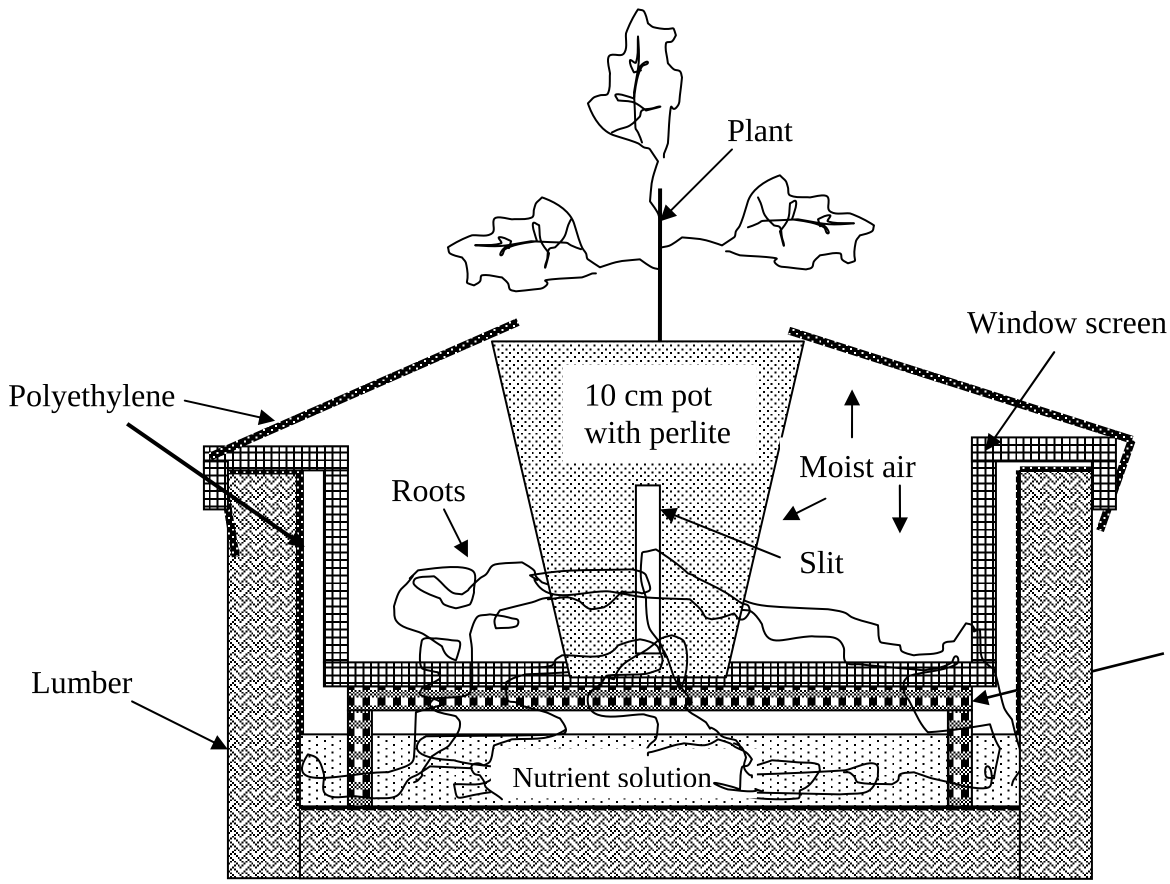

Figure 1. Cross-section of a polyethylene-lined tank with a tomato plant growing in a 10 cm pot filled with perlite where the pot rests on window screen supported by a 5 cm high nursery tray and nutrient solution level is maintained at 4 cm with a float valve.

Table 1. Yield from 4 tomato cultivars grown in beverage cans by a sub-irrigation non-circulating hydroponic method at a 1300 m elevation in a rainshelter.[zy]

Cultivar	Total salable	Grade 1	Grade 2	Offgrade	Cull
			Kg/plant		
Big Beef	2.68b[x]	1.52a	0.72b	0.44b	0.32a
5000	2.20ab	1.40a	0.32ab	0.48b	0.48b
Joker	1.99ab	1.32a	0.42ab	0.25a	0.42ab
Vendor	1.46a	0.87a	0.15a	0.44b	0.70c

[z]Harvested from August 18 to October 29, 1999.
[y]Plant spacing – Double rows in 0.6 m wide tanks spaced 0.3 m between plants and rows.
[x]Mean separation within columns by Duncan's Multiple Range Test, P=0.05.

Table 2. Yield of 'Healani' tomatoes grown by 3 non-circulating hydroponic methods at a 1300 m elevation in a rainshelter.[zy]

Treatment	Total salable	Grade 1	Grade 2	Offgrade	Cull

			Kg/plant		
Beverage can	2.49a[x]	1.17a	0.49a	0.82a	0.29a
Net Pot	2.43a	1.16a	0.43a	0.85a	0.38b
10-cm pot on tray	3.55b	1.90b	0.66b	0.99b	0.30a

[z]Harvested from July 31- October 23, 2001
[y]Plant spacing – Double rows in 0.6 m wide tanks spaced 0.3 m between plants and rows.
[x]Mean separation within columns by Duncan's Multiple Range Test, P=0.05.

Table 3. Yield of 'Big Beef' tomatoes grown by 3 non-circulating hydroponic methods at a 1300 m elevation in a rainshelter.[zy]

Treatment	Total salable	Grade 1	Grade 2	Offgrade	Cull
			Kg/plant		
Beverage can	1.36b[x]	0.72a	0.16a	0.48b	0.78b
Net Pot	1.19a	0.66a	0.16a	0.37a	0.63a
10 cm pot on tray	1.80c	1.11b	0.18a	0.51b	0.66ab

[z]Harvested from February 20 to May 21, 2002.
[y]Plant spacing – Double rows in 0.6 m wide tanks spaced 0.3 m between rows and 0.3, 0.45 and 0.6 m between plants. Yields were averaged over the 3 spacings.
[x]Mean separation within columns by Duncan's Multiple Range Test, P=0.05.

Table 4. Yield of 'Healani' tomatoes grown by 2 non-circulating hydroponic methods at a 100 m elevation under a rainshelter or unprotected.[zy]

Method	Rainshelter	Total salable	Grade 1	Grade 2	Offgrade	Cull
				Kg/plant		
7.6 liter pot	no	0a[x]	0a	0a	0a	0a
7.6 liter pot	yes	1.74b	0.69b	0.47bc	0.58b	0.41b
Tank	no	0.78a	0.35ab	0.26b	0.18a	0.28ab
Tank	yes	1.75b	0.70b	0.50c	0.55b	0.78c

[z]Harvested from December 22, 2003 to February 9, 2004.
[y]Plant spacing – single row of plants spaced 30 cm apart.
[x]Mean separation within columns by Duncan's Multiple Range Test, P=0.05.