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Portable Grow Beds with Roll-out Plastic Tanks

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Abstract: Portable grow beds with roll-out plastic tanks were designed for sub-irrigated, non-circulating hydroponic production of vegetables and edible ginger (*Zingiber officinale* Roscoe) in remote locations or temporary growing situations. A 1.1 m wide, 25-mil plastic film was rolled out and formed into an oval tank (58 cm wide and 12 cm high). *Fairy Tale* eggplant, *King Arthur* pepper and *Cherokee Purple* tomato transplants were grown in 4.2-cm cells of 25 x 50-cm flats resting on upside-down nursery trays (43 x 43 x 6 cm height) in the tank. Pepper transplants were also grown in 10-cm pots and aluminum beverage cans which rested on upside-down trays. Only 340 to 850 ml per plant of growing medium were used for the 3 growing methods. Yields from eggplants, peppers and tomatoes transplanted in a Pennsylvania high tunnel on July 13, 2007 were 0.3, 0.7 and 4.9 kg/plant, respectively. A 1.26 m wide, 20-mil plastic film was rolled out and formed into a channel (45 cm wide and 19 cm high) with the edges folded over and clipped to propagation flats (40 x 40 x 12.7 cm) containing edible ginger and which rested on upside-down nursery trays in a Hawaii high tunnel. Upside-down, plastic cell-paks (12 cells of 200 cc each) were placed in each flat to reduce the need for growing medium. Ginger rhizome yields were lower when the growing medium consisted of 2 perlite:3 sphagnum moss (1.33 kg/flat) than 2 perlite:3 Sunshine #4 (2.90 kg/flat) or 3 perlite:2 Sunshine #4 (2.89 kg/flat). Yields with the Sunshine #4:perlite mixes in the portable grow bed system were 34 per cent greater than the average yield (2004 to 2008) from field culture in Hawaii. Materials for the portable grow beds are compact and would decrease shipping costs and be especially beneficial for remote growing locations. The portable grow bed concept would be useful for growing vegetables in vacant city lots, because the system would be relatively rapid to build and dismantle, and pollutant exposure would be limited to only the crop growing period.

Introduction

Hydroponic production of vegetables in remote locations or temporary situations (such as a short or uncertain lease) would greatly benefit from the development of a system which uses less materials and/or materials which can be greatly compacted to facilitate movement to and from the growing site. Tanks constructed from wood, metal or concrete are bulky to transport and time-consuming to build and dismantle. Bag or slab culture materials are bulky to transport and messy to clean up. In addition, many systems require electrical power which may not be available at remote or temporary locations. Non-circulating, sub-irrigation methods for growing cucumbers (5), edible ginger (3) and tomatoes (4) have been described which utilize relatively little growing medium and do not require electrical power.

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The purpose of this paper is to develop a portable grow bed hydroponic system which does not require electrical power and only employs a small volume of materials and would be suitable for a temporary growing situation or remote location.

Methods and Materials

Experiments were conducted in high tunnels at the Rock Springs Horticultural Research Farm near State College, Pennsylvania in 2007 and at The Waiakea Experiment Station near Hilo, Hawaii in 2008. Equal volumes of 2 fertilizer stock solutions were applied through 2 drip irrigation tubes running the length of the tank by gravity flow from plastic containers. One stock solution consisted 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 consisted of 120 g/liter of soluble grade calcium nitrate.

Pennsylvania trial. A 1.1 m wide black /white co-extruded plastic film (25-mil) was rolled out on a level surface. Upside-down nursery trays (6 cm height) were placed on the bottom of the film to occupy 58 cm of the film's width (Figure 1). Eleven upright flats (25 x 50 cm) with 72 tapered cells (4.2 cm square x 6 cm height) rested on the upside-down trays. In another arrangement, 3 upright and 3 upside-down pot holding trays (50 cm long) also rested on the upside-down trays. Nine pots (10 x 10 x 9 cm) rested in these upright trays and 9 aluminum beverage cans with slit sides were held upright through perforated cells of the upside-down trays. The flats, pots and cans were filled with 850, 750 and 340 ml per plant, respectively, of peat-perlite growing medium. A 2-mil reflective aluminized plastic mulch (60 cm wide) was placed over the pots, cans and trays and perforated to allow transplanting. Then, the opposing sides of the 25-mil tank film were drawn to within 14 cm of each other and secured with segments (40 cm apart) of plastic drip irrigation tape placed through holes near opposing edges of the film. Thus, the flat 25-mil film became a 12-cm high oval tank with a white exterior. Seedlings of *Fairy Tale* eggplants (15), *Cherokee Purple* tomatoes (9) and *King Arthur* peppers (9) were transplanted into the 11 nursery trays with 3 plants per tray. In addition, 9 *King Arthur* pepper seedlings were transplanted into both the 10-cm pots and the aluminum beverage cans. The tank was originally filled with 8 cm of water. After the original liquid level receded by 3 cm, daily irrigation of 27 liters of water was applied and excess solution beyond the 7-cm height drained through a run-to-waste siphon device (Figure 2). There were 14 applications of stock nutrient solutions from July 13, 2007 to Oct. 22, 2007 supplying a total application of 10.4 liters each of the 2 stock solutions. The nutrient solution ranged from 0.8 to 1.7 mS during the growing season from July 13, 2008 to Nov. 19, 2008. Fruits were harvested and total weights were recorded. Statistical analysis was not conducted on these data.

Hawaii trial. Three, 20 mil, 1.26 m wide, black /white Permalon films (Reef Industries) were rolled out on a nearly level surface with a 1.27 m center-to-center spacing. The film was formed into a channel, 45 cm wide and 19 cm high, with the edges folded over (Figure 3). Upside-down nursery trays (43 x 43 x 6 cm height) were placed in the channel and shimmed, if needed, to make all trays level. Twenty deep propagation flats (40 x 40 x 12.7 cm) rested on the upside-down nursery trays in each channel. The Permalon film was secured by clipping to the propagation flats. Rows of intermittent concrete blocks were placed outside the channels to provide additional support. Upside-down, plastic cell-paks (12 cells of 200 cc each) with a total displacement of 2.4 liters were placed in each flat to reduce the need for growing medium. Flats in the 3 individual channels were filled with 3 perlite:2 Sunshine #4 growing medium, 2 perlite: 3 Sunshine #4 growing medium or 2 perlite:3 sphagnum moss. Seven flats were planted with 2 edible ginger (*Zingiber officinale* Roscoe) seed pieces (50 ± 10 g) and 13 flats were planted with 3 seed pieces. A drip irrigation line was placed on the top of the trays and daily watering was controlled by a timer. Initially, the solution level was 1 to 2 cm higher than the bottom tray and this level was dropped below the upper flat after roots had established. A visible float indicator (Figure 2) enabled the technician to change watering time as needed throughout the crop so that all of the nutrient solution was conserved for plant growth. Stock solutions were added weekly to maintain an EC range of 1.5 to 2.5 mS. Ginger rhizomes in each propagation flat were washed, trimmed and weighed at harvest. Rhizome weight data harvested from each flat were analyzed as a growing media x seed piece factorial with each flat treated as a replicate.

Results and Discussion

Yields of *Fairy Tale* eggplant, *King Arthur* pepper and *Cherokee Purple* tomato grown in a portable grow bed with a roll-out plastic tank in a Pennsylvania high tunnel were 0.3, 0.7 and 4.9 kg/plant, respectively (Table 1). When yields are calculated based upon a center-to-center row spacing of 1.5 m, eggplant yields were only about half of the U.S. average, whereas peppers produced about average yields and tomatoes produced higher than average yields (2). The late transplant date (July 13, 2007) negatively affected production. Perhaps, better growth would have occurred with a lower liquid level in the tank. Only 340 to 850 ml per plant of growing medium were used in this trial as compared to a minimum of 7 to 19 liters/plant typically required for top-irrigated vertical and lay-flat bags (2). Higher production of these crops might be expected with improvements in the growing containers, fertility levels and optimum liquid levels in the tank.

Edible ginger grew very well in the portable grow beds with roll-out tanks, although yields were reduced somewhat due a later than optimum planting date (Table 2). Ginger rhizome yields were lower when the growing medium consisted of 2 perlite:3 sphagnum moss (1.33 kg/flat) than 2 perlite:3 Sunshine #4 (2.90 kg/flat) or 3 perlite:2 Sunshine #4 (2.89 kg/flat), because the pH of the sphagnum moss medium became too acidic. Yields with the Sunshine #4:perlite mixes with the portable grow bed system were 34 per cent greater than the average yield (2004 to 2008) from field culture in Hawaii (7). Yields were similar when either 2 or 3 rhizome seed pieces were planted per propagation flat. There was a very large range between the lowest and highest yielding tray within each treatment. Some of this may have originated from the vegetative seed pieces. The tanks were not dead level and varied by 4 cm throughout the length of the tank causing a slightly variable nutrient solution depth; however all flats were shimmed up to the same level relative to the top of the nutrient solution.

Future trials could be enhanced by injection of stock solutions directly into the irrigation water to improve the precision of fertilizer application, save labor and eliminate the nutrient distribution lines so only one drip irrigation line would be needed per tank. In the Hawaii ginger trial, a float indicator guided the grower to adjust irrigation timing as needed so that all of the nutrient solution was utilized for plant growth. The Pennsylvania portable grow bed system (Figure 1) would be suitable for outdoor production, because a siphon tube maintained nutrient solution depth by expelling liquid above the 7 cm level, whereas the Hawaii portable grow beds (Figure 3) would accumulate rainfall if placed outdoors, and therefore, must be protected by a rainshelter or placed inside of a high tunnel. Liquid level may also be controlled with a float valve which releases liquid through a pipe fitting and then may be routed to a drip irrigation tube for uniform distribution. However, a float valve which only releases liquid at one point is not satisfactory for a long tank because a non-uniform nutrient solution mixture would occur.

Portable grow beds with roll-out plastic tanks promote high quality vegetable production. Fertilizer and water use efficiency are encouraged by employing micro-irrigation, plastic mulches, fertilizer injection, complete nutrient solutions and control of leachates. There are no crop losses due to poor soil fertility, soil diseases and nematodes. Foliage does not contact moist soil, thus reducing foliage and fruit diseases with the portable grow bed concept. *Cherokee Purple* tomatoes grown outdoors in soil plots experienced much more foliage and fruit disease than tomatoes grown in the portable grow bed.

Materials used for the portable grow bed with roll-out plastic tank concept are very compact. For example, 20-mil Permalon Ply X-210 weighs only 38 kg/100m^2 and can be transported in a roll 1.3 m x 25 cm diameter which occupies only 0.08 m^3. A stack of 100 soft plastic pots 10 x 10 x 8.9 cm (750 ml) conveniently nests in a 97 cm high stack occupying about 0.01 m^3. Likewise a 100-layer stack of 43 x 43 x 6.3 cm nursery trays nests into a 93 cm high stack occupying 0.17 m^3. These items can be conveniently carried in a pick-up truck or small cargo van. The compactness of the materials would decrease shipping costs and be especially beneficial for remote growing locations such as island communities. The ease of dismantling the system and small volume of materials would be advantageous for temporary growing situations such as a rented tunnel or a temporarily vacant urban lot.

An urban vegetable farm would reduce marketing transportation logistics and expenses. Most urban areas have vacant lots scattered throughout the city. For example, Philadelphia has over 570 ha (1400 acres) of vacant land. Urban lands would usually only be available on temporary leases, because they would eventually revert to commercial, industrial or housing uses, so it would not be feasible to invest in major improvements such as permanent tanks for an uncertain time period. However, the portable grow bed concept promotes mobility, because it would be relatively rapid to set up and take down the growing tanks.

Many urban lots may have only a close resemblance to soil and are generally not considered fit for plant production. Urban soils may have elevated concentrations of metals including Cd, Cu, Pb and Zn (6) plus numerous other contaminants originating from traffic emissions and industrial activities. Slag is often used for landfill and has an elevated content of heavy metals. When slag was added to soil, the tissue levels of As, Pb, Tl and Zn of beans, kohlrabi, mangold, lettuce carrots and celery increased as compared to control soil with lower levels of these metals (1). Growing vegetables in a portable grow bed system would limit pollutant exposure to only the crop growing period, whereas growing crops in the soil would additionally expose the plants to residual pollutants.

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Eggplant, peppers, tomatoes and edible ginger were successfully grown in portable grow beds with roll-out tanks. The portable grow bed concept is potentially useful for remote locations and temporary growing situations including vacant city lots. Portable grow beds promote high quality vegetable production because they can be used in conjunction with other advanced vegetable production practices.

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Table 1. Yields of *Fairy Tale* eggplant, *King Arthur* pepper and *Cherokee Purple* tomato transplanted in a portable grow bed on July 13, 2007 in a Pennsylvania high tunnel.

Crop	Growing container	Harvest Date	Fruit yield (kg/plant)
Eggplant	4.2 x 4.2 x 6 cm deep tapered cell	Aug 20 to Nov 19	0.34
Tomato	4.2 x 4.2 x 6 cm deep tapered cell	Sept 12 to Nov 19	4.91
Pepper	4.2 x 4.2 x 6 cm deep tapered cell	Sept 04 to Nov 19	0.73
	10 x 10 x 9 cm tapered pots		0.48
	340 ml aluminum beverage can		0.84

Table 2. Effects of 3 growing media and planting 2 or 3 seed pieces per propagation flat on yields of ginger rhizomes planted in 3 portable grow beds on May 30, 2008 and harvested on Jan. 27, 2009 in a Hawaii high tunnel.

	Kg/ Propagation Flat[z]	Range	Standard Error
Growing Medium		*kg/flat*	

3 perlite:2 Sunshine #4	2.89b[xy]	1.40 – 4.94	0.209
2 perlite:3 Sunshine #4	2.90b	0.95 – 4.89	0.275
2 perlite:3 sphagnum moss	1.33a	0.38 – 2.33	0.111
<u>Number of seed pieces/flat</u>			
2	2.43[v] ns	0.38 – 4.89	0.294
3	2.33 ns	0.52 – 4.94	0.177

[z] 40 x 40 x12.7 cm

[y] Means followed by the same lower case letter are not significantly different ($P \leq .05$) by Duncan's Multiple Range Test.

[x] Data averaged over 2 seed piece treatments.

[v] Data averaged over 3 growing medium treatments

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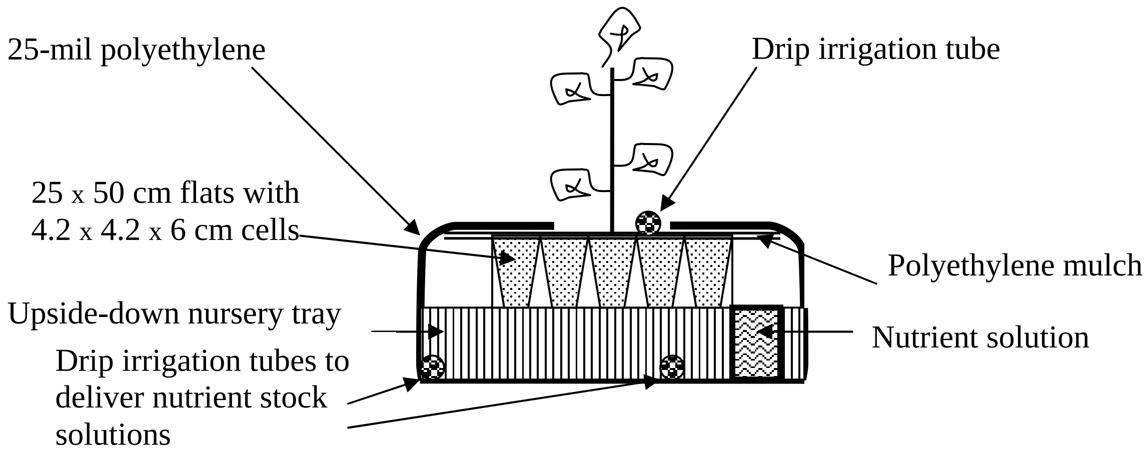

Figure 1. Cross-section of a portable grow bed to produce eggplants, peppers and tomatoes.

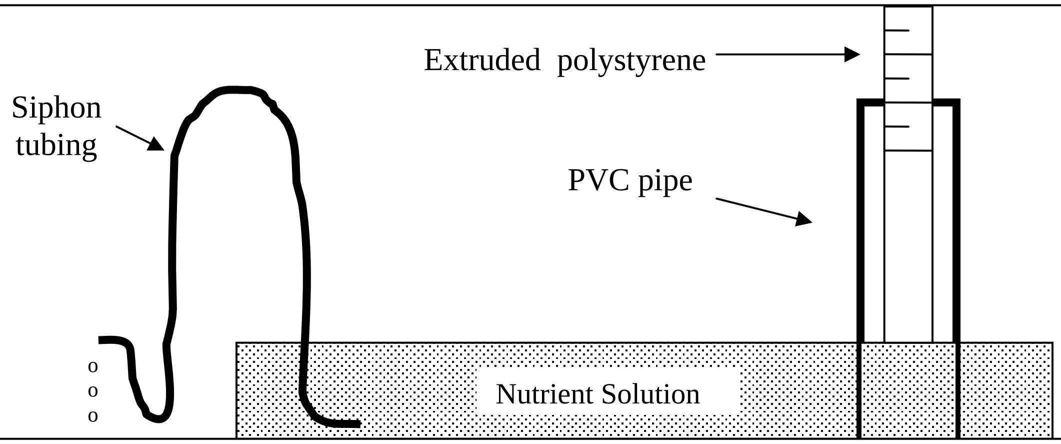

Figure 2. Schematic of a.) plastic or copper tubing siphon device which maintains tank fluid level and b.) float indicator consisting of 1 x 1 cm extruded polystyrene sheltered by a similar length of PVC pipe.

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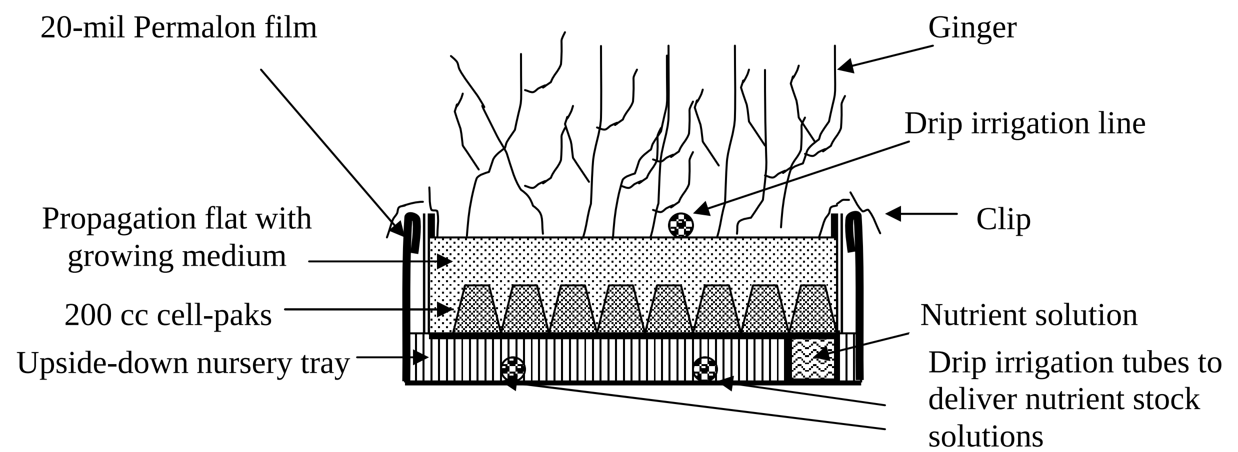

Figure 3. Cross-section of a portable grow bed to raise edible ginger.