COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY—COLLEGE OF AGRICULTURE

# Controlled Water Table Irrigation of Container Crops

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**Warning:** Use caution when working with electricity. When in doubt, consult an electrician.

# Introduction

The controlled water table irrigation system (CWT) can be used to automatically irrigate bedding plants, poinsettias, pot chrysanthemum, vegetable transplants, tomatoes in large containers and many other crops. It has several advantages over existing irrigation systems.

- Optimum moisture and air content are maintained in container growing media.
- Differences in greenhouse environmental conditions will not affect the moisture content in individual containers even though the transpiration and evaporation rate is higher in one area on the bench than another.
- Water stress is reduced and growth rate and quality of plants potentially increase compared to other container irrigation methods.
- No runoff occurs; the nutrient solution is held within the capillary mat under a constant tension; water is lost only through transpiration and evaporation.
- Because water and nutrients are always moving upward into the growing medium, very little, if any, solution moves from the growing medium in one container to the growing medium in another, thus reducing potential for disease transfer.
- No pumps or large water holding tanks are needed as with ebb-and-flow irrigation systems.

The CWT irrigation system is easily retrofitted to most existing benches and is adaptable to greenhouse vegetable and flower transplant production, as well as the production of crops in 10-cm, 15-cm, and larger containers (Figure 1).

**Figure 1.** The CWT is used to produce a wide variety of commercial greenhouse crops, including poinsettias and bedding plants.

# General Description

The CWT is a modification of traditional capillary mat irrigation. A capillary mat is placed on a smooth, level surface (Figure 2). One side (approximately 2 inches) of the capillary mat is suspended in a trough of water maintained at a constant level (water table) at or below the bench surface. The capillary mat draws water by capillarity, from the trough upward and then horizontally across the level bench. A root barrier on top of the capillary mat prevents roots from growing into the mat but allows water movement to the container growing medium. The growing medium, by capillarity, absorbs water from the mat.

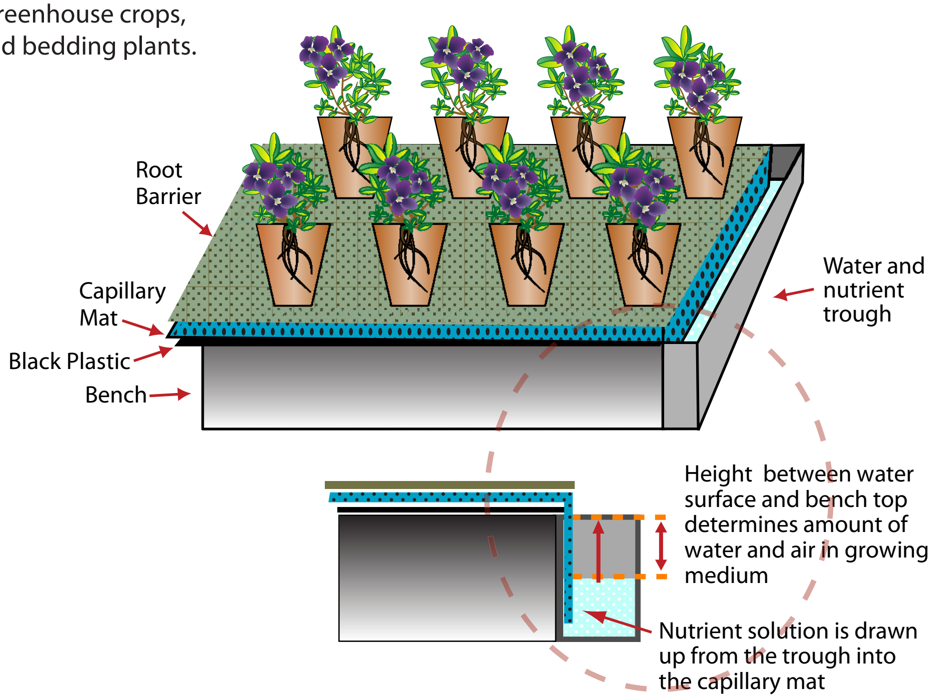



**Figure 2.** Basic principles of a controlled water table irrigation system.

## Principles

The amount of water drawn into and maintained in the growing medium depends upon how tightly the water is held by the capillary mat and the physical properties of the growing medium. The water and air content in the growing medium remain constant if the vertical distance between the container bottom and water table does not change. As the distance between the water table and the container bottom increases:

- Water in the capillary mat decreases.
- Water moves slower within the capillary mat.
- Water content in the growing medium decreases.
- Air content in the growing medium increases.
- Water is under more tension in the growing medium, decreasing the plant root's ability to remove water.

The opposite occurs if the distance between the water table and container bottom decreases.

Water, removed from the growing medium through root absorption and evaporation, is replaced by water from the capillary mat, which is replaced by water from the trough; the trough is then immediately automatically resupplied with water. Plants regulate the amount of water used. The capillary forces, on water in the mat and growing medium, maintain an unbroken chain of water from the trough to the roots. If the chain of water is not broken, water and air at optimum concentrations are continuously available to the roots.

For best plant growth, the optimum distance between the water table and the bench surface is directly related to the growing medium's physical characteristics, the stage of plant development, and the depth of the growing medium. The volume of the growing medium has no effect on placement of water table. For example, a fine-textured growing medium (compared to a coarse-textured growing medium) is capable of drawing water to a greater height above the water table and at equilibrium contains more water and less air in the pore space. Because of these characteristics, the optimum placement of the water table for a fine-textured medium would be farther below the container bottom than it would be for a coarse-textured medium.

## Bench and Trough Construction

CWT construction consists of several individual assemblies. On the following pages, each part of the construction is illustrated. Parts are generally available from hardware or electrical supply stores. For parts not readily available from these stores, suggestions are provided about where they may be purchased.

### *Bench*

Many existing greenhouse benches may be retrofitted with CWT. A commercially available aluminum bench (4 to 6 feet wide) (Ro-Flo from Rough Bros., Cincinnati) was modified (Figure 3 a-g). Support bars were spaced 1 foot apart and the original expanded metal top was replaced with a ¾-inch thick Styrofoam sheet to create a smooth surface for the capillary mat. The bench was leveled with a transit.

Theoretically, the bench could be 100 feet in length or longer, but because of the difficulty of leveling over this distance, shorter distances may be more practical.

### *Metal Trough*

The trough is constructed from a header terminator used in greenhouse construction (Rough Bros., Cincinnati) (Figure 3b). A vertical ¾-inch piece of the header terminator was removed (Figure 3c). The trough is ⅝ inch wide and 2¼ inches deep. The 2¼-inch-deep trough will usually provide the range in depth required for most container production. However, a deeper trough may be needed for some crops.

A metal pipe (1⅞ inches od) with a slot cut along the side (Figure 3e) is welded to the aluminum trough to install the liquid level controller. A 1½-inch PVC cap is screwed onto the bottom of the threaded pipe, and a 1½-inch PVC cap with ⅝-inch hole drilled in the center (Figure 3g) is placed over the top of the


**a.** Cross-bars 1 foot apart

**b.** Header terminal for greenhouse construction

**c.** Trough diagram showing piece cut off

**d.** Trough with sealed end attached to bench

**e.** Slot cut into pipe for water to move into

**f.** Aluminum pipe welded to trough

**g.** PVC cap with hole drilled in top

**h.** Capillary mat, root barrier, etc.

**Figure 3.** Bench and trough construction.

pipe. A rectangular aluminum piece (Figure 3d) is welded to the opposite end to seal the trough.

The metal trough can be installed along the side or in the middle of the bench. If the trough is placed in the middle of the bench, the water then moves only half the distance as from a trough on the side of the bench. The metal trough fits tightly to the side of the bench; the horizontal 1-inch flange fits over the edge of the bench (Figure 3d). The trough is attached to the bench with 3-inch bolts, 3 to 4 feet apart, that run through the flange into the side railing of the bench.

## *Capillary Mat*

A 6 millimeter polyethylene sheet is placed on top of the Styrofoam to prevent water leaks from the capillary mat into the Styrofoam and between Styrofoam sheets. The capillary mat is placed on the polyethylene sheet. A root barrier (WeedX or Hangloose) was then placed on top of the capillary mat (Figure 3h) to prevent roots from growing into the mat.

## Water Level Control Assembly

Figure 4 shows the water level control assembly. Figures 5–10 describe the construction of separate parts of the assembly:

- Water level controller (Figure 5)
- Solenoid modification (Figure 6)
- Electrical connections (Figure 7)
- Water supply to trough (Figures 8–9)

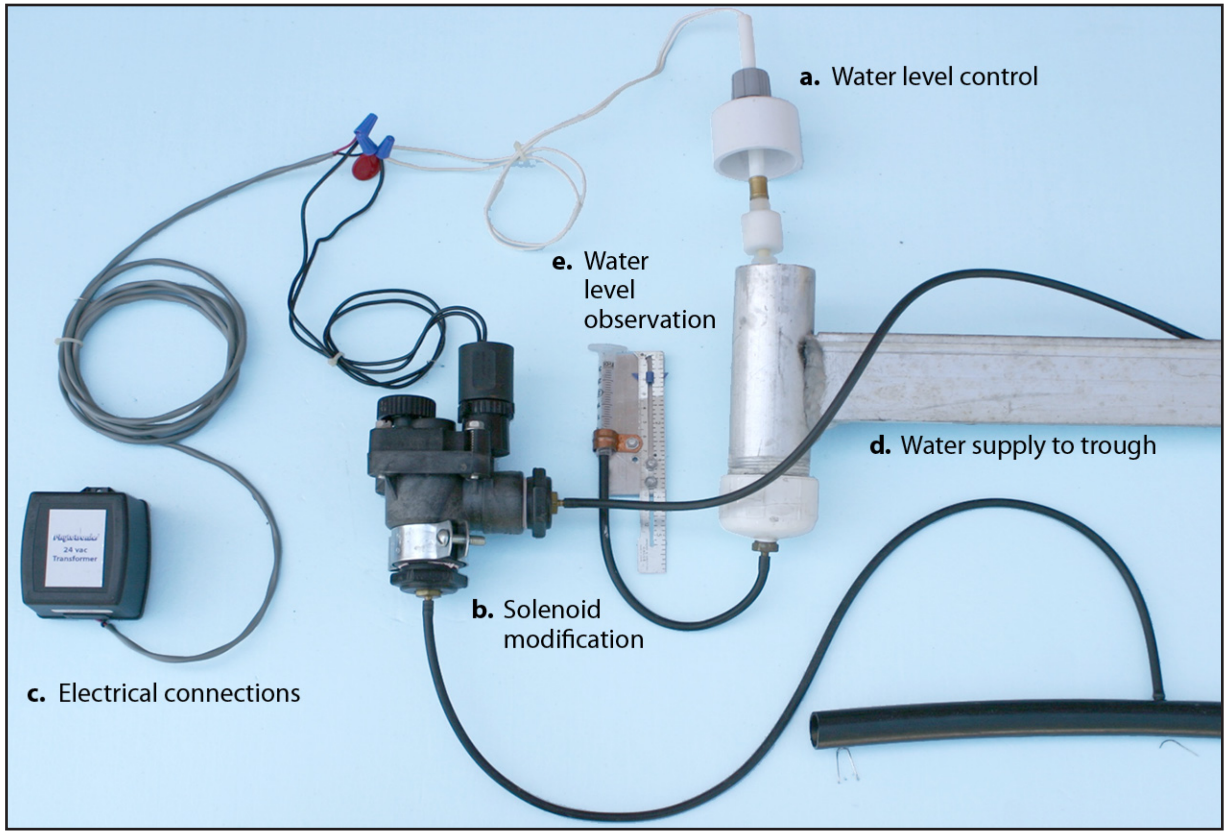



**Figure 4.** Individual assemblies of CWT construction.

## *Controller*

The water level control assembly (Figures 5a–b) maintains a constant water level in the trough by opening and closing the solenoid valve (Figure 6). A liquid level switch, with polypropylene float (30-watt, 24-volt, 0.28A, ⅛-inch NPT) (Figure 5c), attaches to the polypropylene tube (¼-inch inside diameter, ⅜-inch outside diameter, 8 inches long) (Figure 5d). One end of the tube is threaded and a ⅜-inch-long brass connector (Figure 5e) usually used for lamp repair connects the tube to the water level switch. The wires from the liquid level switch are pulled through the tube.

A connector (Figure 5f) is inserted through the hole drilled in the PVC cap (Figure 5g). The polypropylene tube is inserted through the connector. The top nut on the connector, when tightened, secures the float valve at a fixed level in the pipe.  The control is inserted vertically into the 1⅞-inch aluminum pipe so the float valve is suspended in water in the pipe. The liquid level control is moved up and down and the connector tightened to adjust the water in the trough.

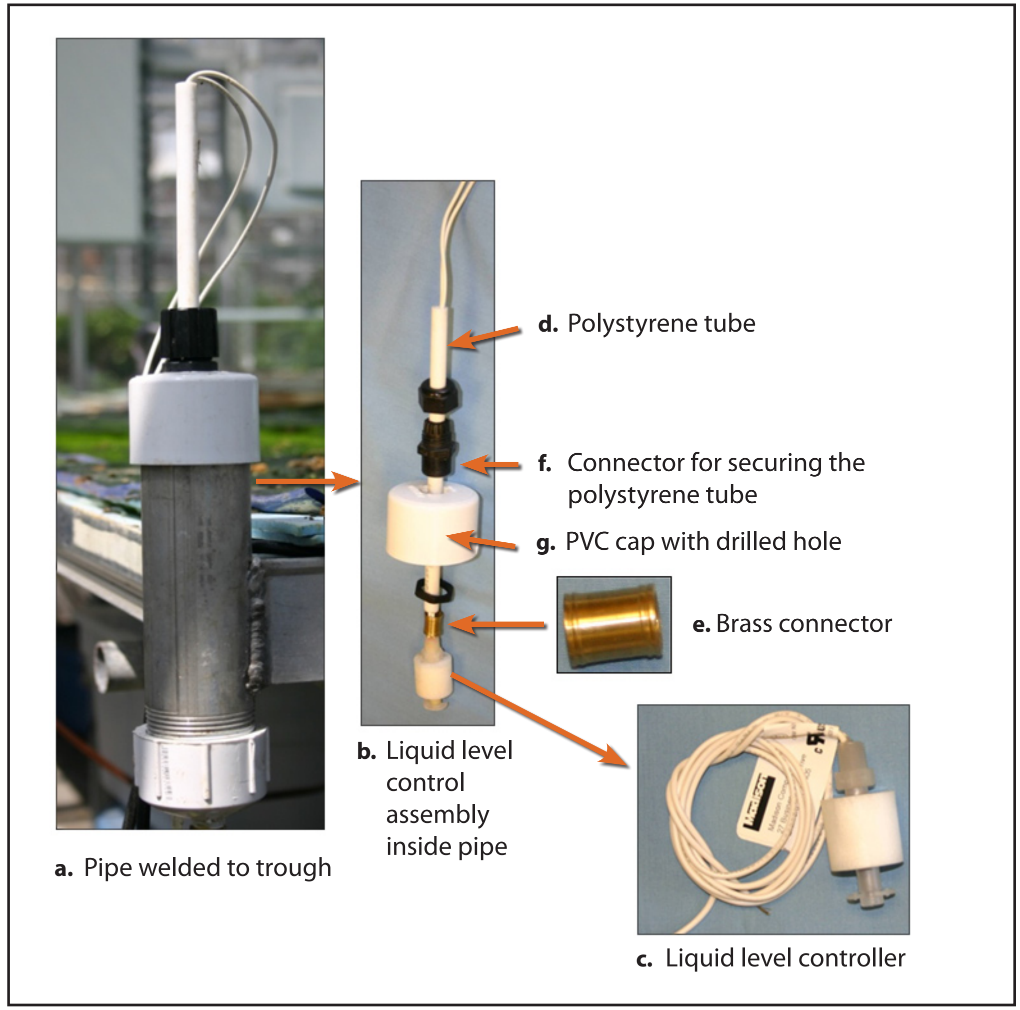



**Figure 5.** Water level control.

## *Solenoid Assembly*

The solenoid (use only 24 volt) is modified with bushing adapters and a brass barb connector (½ inch with 3⁄16-inch od barb) to reduce the opening size for attachment to ¼-inch tubing (Figures 6a–b). Although ¼-inch polyethylene tubing was suitable for our studies, larger tubing may be needed in some production systems to increase rate of water flow. The solenoid is attached to a bench leg (Figure 6c) with a 1¼-inch pipe clamp (Figure 6d). The clamp is attached to the metal leg with a metal screw.

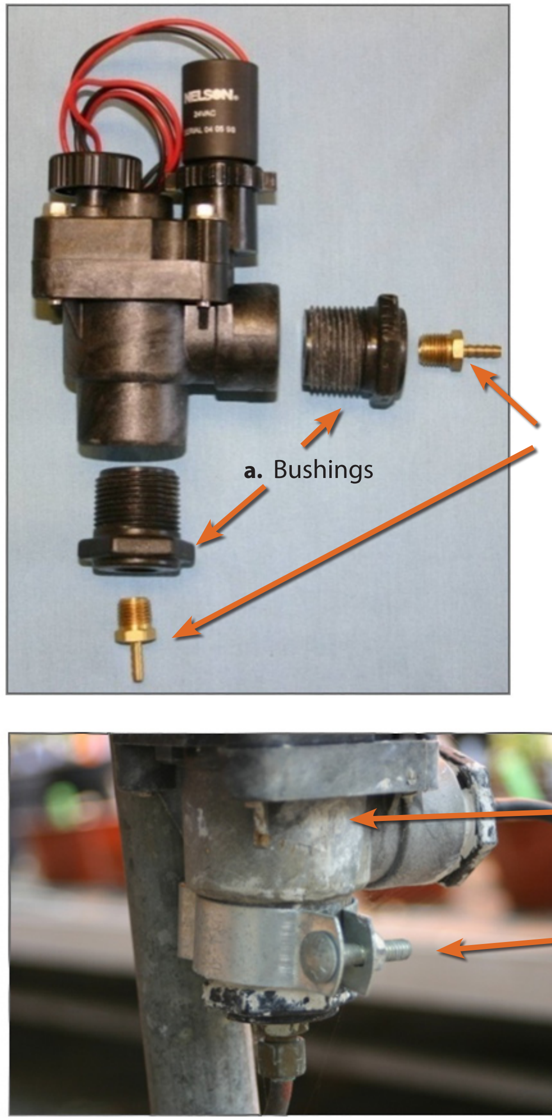



**Figure 6.** Modification and attachment of solenoid to bench.

### *Electrical Supply*

Figure 7 shows the electrical connection between the transformer, solenoid, and water level controller. To insure safety in a wet environment use only a 24-volt electrical supply. The electrical power is provided through the transformer (input 120 VAC, output 24V DC 1A). One transformer can be used for each solenoid, or a large transformer may be used for many solenoids. A metal oxide varistor is required to prevent excess current from destroying the electrical coil in the solenoid. One wire of the resistor is connected to each of the liquid level controller wires. A wire nut is used to connect wiring between the solenoid, the 24-volt electrical supply, and the liquid level controller.

**a.** Liquid level controller

**b.** Transformer

**c.** Solenoid

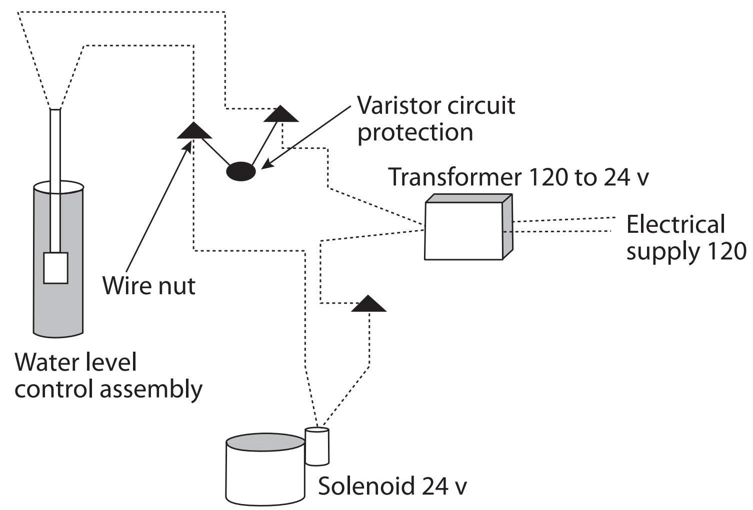



**Figure 7.** Electrical components.

## *Trough and Water Connections*

Figure 8 shows the distribution of water from the water supply line (Figure 8b and d) through the solenoid to the trough (Figure 8e). A brass connector (Figure 8c) is inserted into the punched hole in the polyethylene water line under the bench. A ¼-inch polyethylene tube connects the brass connector to the solenoid. A second ¼-inch polyethylene tube distributes the water from the solenoid to the trough (Figure 8e).

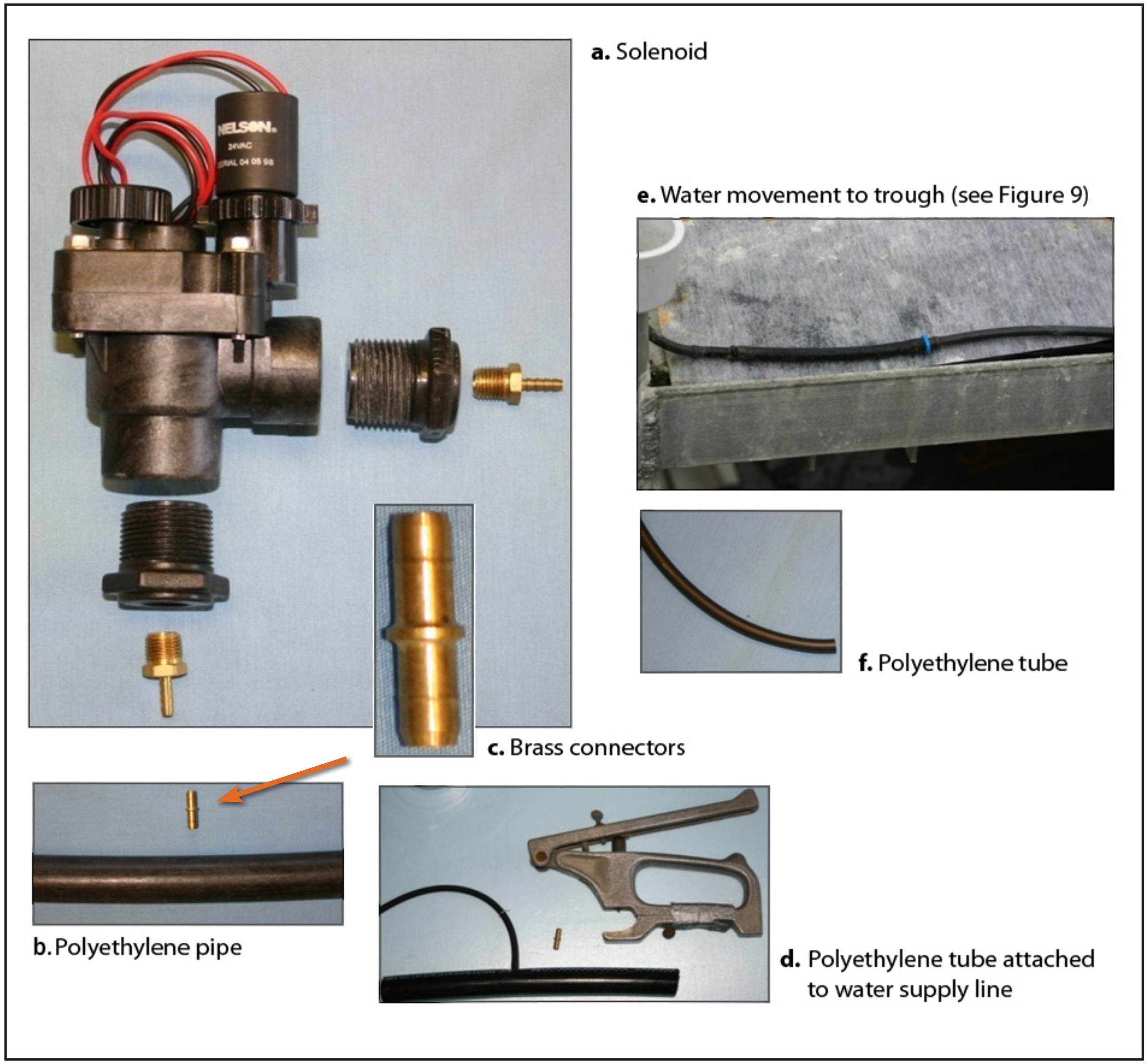



**Figure 8.** Water supply assembly.

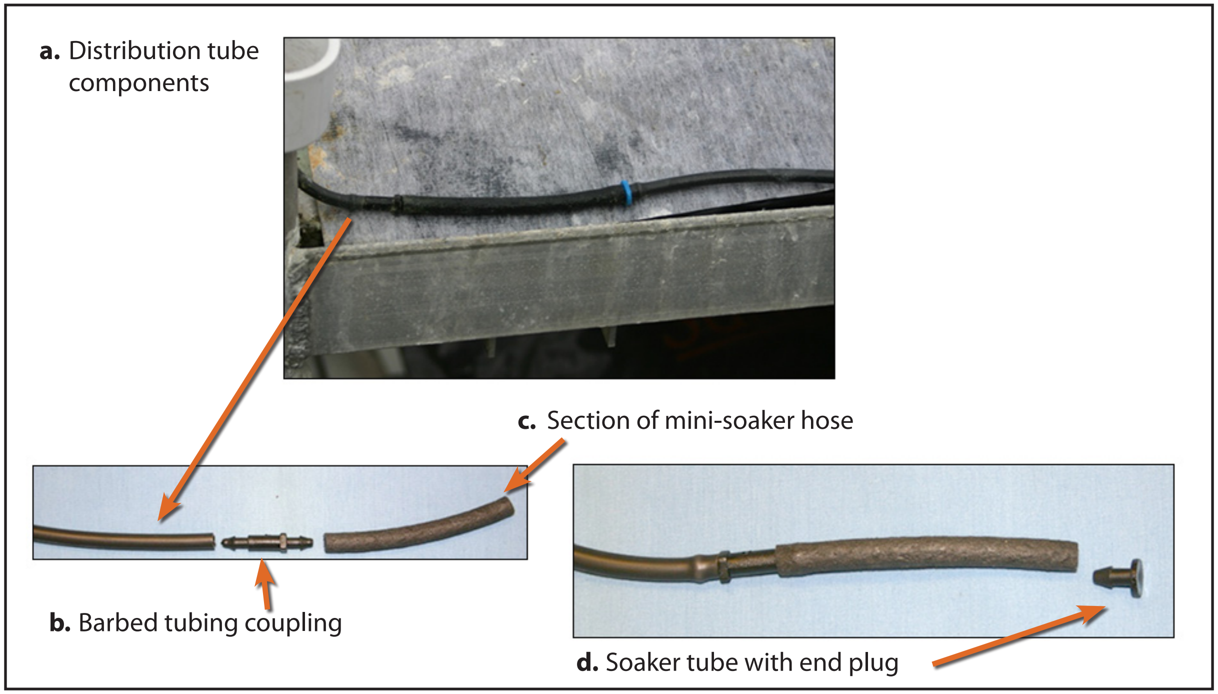



**Figure 9.** Distribution of water in trough.

Figure 9 shows the construction of water distribution tubing to maintain a uniform water level the length of the bench. A 2-inch section of mini-soaker hose (Figure 9c) ¼ inch in diameter is connected by a ¼-inch barbed tubing coupling (Figure 9b) to a ¼-inch polyethylene tube every foot for the length of the trough. The end of the tube is sealed with a plug (Figure 9d). The tube is placed at bottom of the trough. Without the small sections of soaker hose, constant water level cannot be maintained for the length of the trough.

## *Observation of Trough Water Level*

To accurately determine the water level in the trough, the following device is constructed (Figure 10). The syringe (10 ml) and sewing gauge (Figures 10a–c) are attached to a metal plate, and the plate is secured with a metal screw to the side railing on the bench. The top of the ruler (0 inches) is placed at bench level (level with container bottom). The gauge measures the water level in the trough. The assembly should be located as near the tee end of the trough as possible. A hole is drilled into the trough bottom and tapped with reamer (⅜-inch NPT) for a barbed brass connector (½-inch with 3/16-inch od barb) (Figure 10d). A ¼-inch polyethylene tube connects the barb to the syringe.

Because the solution in the syringe is exposed to sunlight, algae will grow and affect observation. The tube must be flushed out or scrubbed with a small brush periodically, or a black plastic tube placed over the syringe will block sunlight and the algae growth.

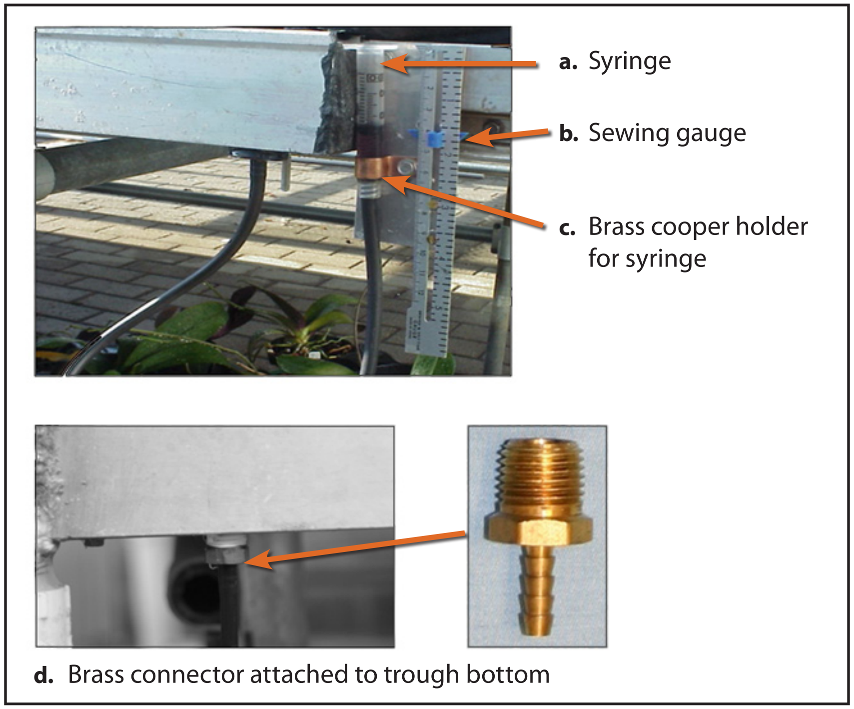



**Figure 10.** Device to determine water level in trough.

## Fertilizer Injector Assembly for CWT

Fertilizer can be added to the water supply, but the standard injector installation usually must be modified. Replenishing the water level each time the liquid level controller detects a drop in water level in the trough requires a relatively small quantity of water. The amount of water is determined by the sensitivity of the liquid level controller and the surface area of the water table. Under low water flow rate the fertilizer injector may not provide the correct ratio between the concentrated fertilizer solution and water, so a ballast (Figure 11a) must be installed for storage of nutrient solution prior to distribution to the bench. The pressure switch (Figure 11c) opens the solenoid valve when the pressure in the ballast drops to set pressure; the solenoid remains open until the pressure in the ballast reaches the higher set pressure. The amount of water to fill the ballast creates a higher water flow rate so the injector works properly. The pressure switch (Figure 11c), injector (Figure 11d), and solenoid valve (Figure 11e) should be located close together along the water line, but far enough apart to allow easy access to individual parts. To insure watertight connections, a ½-inch Carflex conduit system with fittings is used for the electrical wiring.

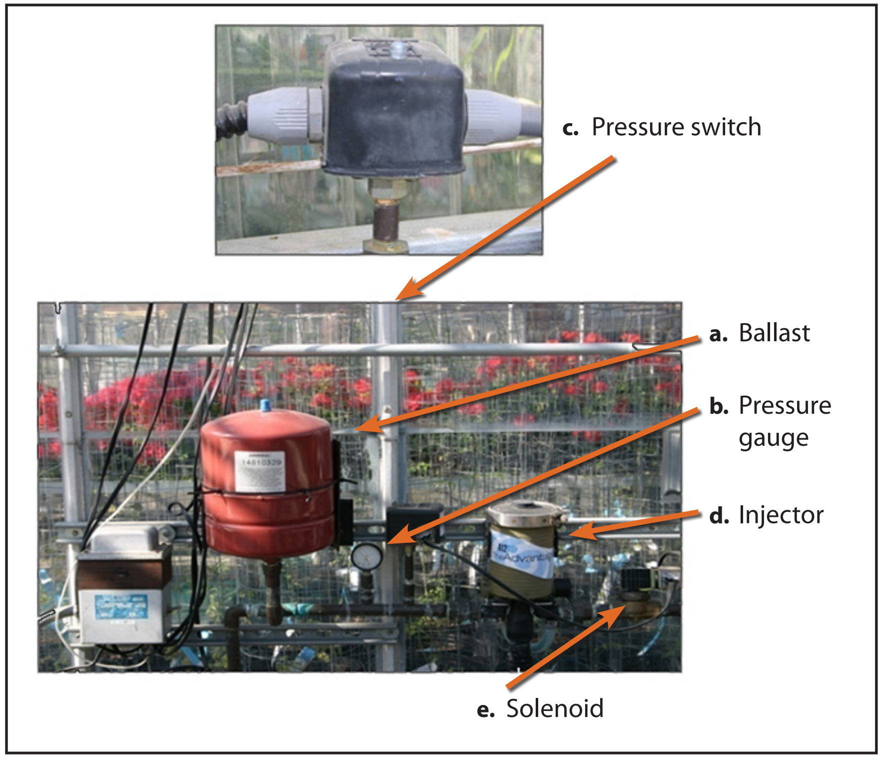


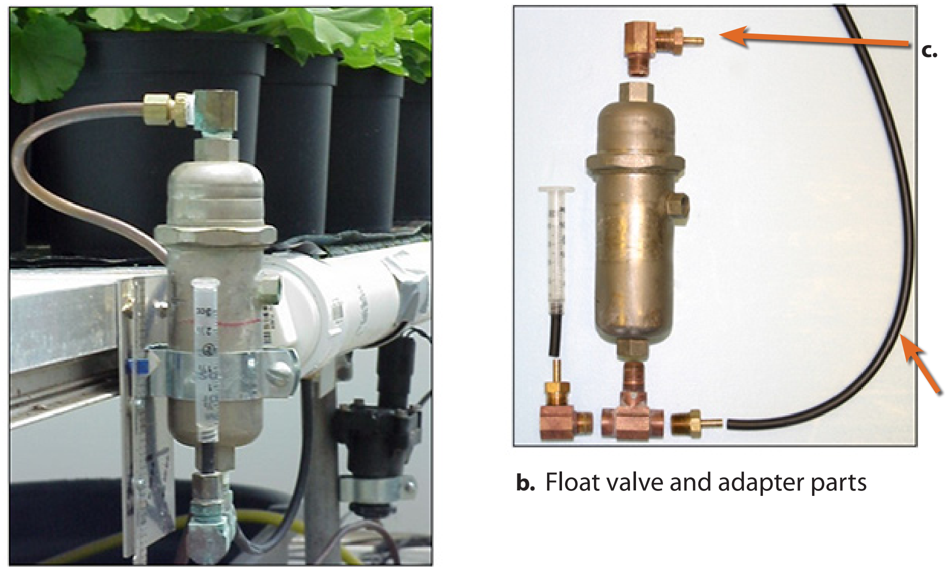

**Figure 11.** Fertilizer injector modification and assembly.

# Alternative Methods for Controlling Water Table

## *Mechanical Float Valve*

In some production locations a mechanical (Water Boy) float valve to control the water level may be convenient (Figure 12) in place of the electrical system described previously. The Water Boy consists of a small float valve inserted in a stainless steel cylinder. Because the water flow rate is not as great as for the electric system, it is more suitable for smaller areas. In the future the company may sell a larger valve.

The water is supplied to the Water Boy as described in Figure 8d. The water inlet and outlet on the float valave are modified with brass fittings (2 ⅜-inch ell, 1 ⅜-inch tee, 2 ⅜-inch NPT with ¼-inch barb end and ⅜-inch nipple). The 3⁄15-inch tube from the water supply line (Figure 12d) attaches to the brass ell and connector (⅜-inch NPT with ¼-inch barb end) at top of the float valve. The brass tee attaches via ⅜-inch nipple to the bottom outlet of the float valve. A brass connector (⅜-inch NPT with ¼-inch barb end) attaches to the bottom of the trough (Figure 12a). A ⅜-inch od tube connects the water outlet on the float valve to the bottom of the bench. The other side attaches to a brass ell and barb. The syringe, for observing water level in the trough, is connected to the barbed end with a short piece of ¼-inch tubing. The Water Boy is attached to the side of the bench with a pipe clamp (Figure 12a). The Water Boy is moved up or down to adjust the water level in the trough.



**c.** Brass insert into polyethylene pipe

**d.** Polyethylene tube

**b.** Float valve and adapter parts

**a.** Non-electrical float valve attached to bench

**Figure 12.** Alternative methods for controlling water table.

## Procedures and Management

The optimum distance between the water table and container bottom must be evaluated for each combination of growing medium texture, depth of growing medium, and plant development stage. In studies, many crops were grown in several growing medium textures and depths ranging from 1-inch-tall plug trays to 1+-gallon containers. In one study with plugs, the placement of the water table for seed germination was ½ to 1 inch below the container bottom to ensure that sufficient water reached the seed. However, after seed germination the water table was dropped to 1 to 1½ inches below the bench to prevent excess water in the growing medium and to provide adequate air supply to the roots. Studies show that the water table should be placed ¾ to 1½ inches below the bench for plants grown in 5- to 6-inch containers. The greater the depth of growing medium, the less critical is the placement of the water table. The roots grow within a range of depth where water and air are optimum for root growth. These results should be used only as a starting point.

After sowing seed or transplanting, place containers on the previously wet capillary mat and manually water the growing medium from above to reach container capacity. This initial irrigation will establish contact between the capillary mat/root barrier and the growing medium. Check drainage holes after initial overhead irrigation to be sure the growing medium is making contact with the capillary mat. Next, adjust the water table in the trough to the optimum distance below container bottom. Continue to check the water level over the next few days and adjust the water table as needed to obtain the desired distance between the water table and container bottom. Remove excess water from the trough if necessary. Once the equilibrium is reached, the water table will remain at this level for the duration of the production cycle or until changes are made in the water table's placement.

## Summary

Attention to detail of construction and management of the CWT is essential. The following points will help ensure success.

- The horizontal distance from the trough should preferably be 3 to 4 feet, but not greater than 6 feet. Studies show the greater distance may affect the nutrient content of solution for plants farthest from trough and the amount of solution available to these plants under high evapotranspiration conditions.
- Pre-wetting of the capillary mat is essential for some brands of capillary mats. If not pre-wet they may never absorb water. Once wet they will remain wet if in contact with a source of water. A surfactant added to the water will initially help in wetting the mat.
- Container bottoms must be flat so the growing medium is in physical contact with the root barrier to achieve continuous capillarity between the mat and the growing medium. Containers with multiple holes in the bottom insure medium/mat contact. Containers with small "feet" on bottom are not satisfactory. Larger particles in a growing medium may prevent contact between the growing medium and the mat. A small strip of capillary mat (½ inch wide) can be inserted into the growing medium. The other end, hanging out of the pot, will then be in contact with the mat. The water will move upward from the mat through the strip into the growing medium.
- Accurate control of water table (water level in trough) is important. Slight changes in the vertical distance between the water surface and container bottom can affect crop growth. The optimum vertical distance will vary depending upon the growing medium, texture, depth of growing medium, and plant size.
- The bench must be level for successful production of uniform plants. Plants will not grow as well if a portion of the bench surface is significantly below or above the optimum vertical distance between the water surface and container bottom for a particular growing medium or container height.
- A root barrier prevents roots from penetrating the mat. Note that the black color of some material may absorb much solar radiation and become extremely hot during sunny weather. Covering areas not occupied with pots or flats with white plastic or other material will reduce temperature, evaporation, and the buildup of soluble salts.
- Water evaporates from the edge of the capillary mat as well as between containers, leaving behind salts that accumulate over time. Cover exposed edges with plastic to reduce evaporation.
- Adjust normal fertilizer regime. The fertilizer concentration for bottom irrigation must be lower than for overhead irrigation systems. Use a minimum of fertilizer. For example, use 50 to 100 ppm N from a complete fertilizer such as Peter's 20–19-20 Peat-lite formulation.
- Roots growing out of the bottom of pots could be a problem. Reduce external root growth by adjustment of the water table and other modifications.
- Providing an optimum amount of water may cause some plants to be too succulent for the market, or they may be stressed when moved into less optimum growing environments. Lowering the water table will increase water stress resulting in less succulent growth.

**Parts list and where to purchase for CWT irrigation (25 ft x 6 ft bench).**

| Item | Components | Unit | Units Needed | Available At |
|---|---|---|---|---|
| Bench | Bench: end, side, supports, legs | 25′ x 6′ | 1 | Rough Bros.* |
| Trough, mat, etc. | Root barrier (Hang Loose) | sq ft | 150 | Hardware store or fabric |
| | Capillary mat | sq ft | 150 | Greenhouse supply |
| | Black plastic (4-6 mm) | sq ft | 150 | Hardware store |
| | Styrofoam (¾ in) | sq ft | 150 | Hardware store |
| | Metal trough | ft | 25 | Rough Bros.* |
| | Aluminum pipe 1 ⅞ in od) | ft | 1 | Hardware store |
| Water level control | Liquid level switch | each | 1 | Industrial supply |
| | Polystyreen tube (¼-in id, ⅜ in od) | ft | 0.5 | Hardware store |
| | Brass connector (⅜ NPT) | each | 1 | Hardware store |
| | PVC cap (with hole) (1 ½ in) | each | 1 | Hardware store |
| | Connector (secure pipe) | each | 1 | Hardware store |
| Solenoid valve | Solenoid valve | each | 1 | Hardware store |
| | Adapter (1 ¼-in m x ½ in f) | each | 2 | Hardware store |
| | Barb ( ½-in NPT with ⅜ in barb) | each | 2 | Hardware store |
| | Pipe clamp | each | 1 | Hardware store |
| Electrical connections | Varistor (metal oxide) | each | 1 | Electrical supply |
| | Wire nut | each | 2 | Hardware store |
| | Transformer (120 v to 24 v) | each | 1 | Hardware store |
| | Electric wire | ft | 50 | Hardware store |
| Water supply and distribution system | Brass barb (½-in NPT with 3⁄16 barb) | each | 1 | Hardware store |
| | Barb coupling (¼ in) | each | 25 | Hardware store |
| | Poly tubing (¼ in) | ft | 14 | Hardware store |
| | soaker hose in ft (¼ in) | ft | 4 | Hardware store |
| | Brass insert (¼ in) | each | 1 | Hardware store |
| | Polyethylene pipe (¾ in) | ft | 25 | Hardware store |
| Water level detection | Brass holder syringe | each | 1 | Hardware store |
| | Syringe | each | 1 | Drug store |
| | Small ruler (sewing gauge) | each | 1 | Hardware store |
| | Barb connector (3⁄16 in) | each | 2 | Hardware store |
| Fertilizer Injector | Injector | | 1 | Greenhouse Supply |

**Parts list and where to purchase for CWT irrigation (25 ft x 6 ft bench).**

| Item | Components | Unit | Units Needed | Available At |
|---|---|---|---|---|
| Fertigation modifications | Pressure gauge | each | 1 | Hardware store |
| | Pressure switch | each | 1 | Hardware store |
| | Electric conduit assembly | each | 1 | Hardware store |
| | Ballast (2 gal) | each | 1 | Hardware store |
| | Solenoid valve | each | 1 | Hardware store |
| | **Alternative Systems** | | | |
| Mechanic Level Control | Water Boy | each | 1 | Maid-O Mist** |
| | Pipe clamp | each | 1 | Hardware store |
| | Syringe | each | 1 | Drug store |
| | Brass fitting barb end (½ in, 3/16 in barb) | each | 3 | Hardware store |
| | Brass fitting tee m x f x f (3/8 in) | each | 1 | Hardware store |
| | Brass fitting ell f x f (3/8 in) | each | 2 | Hardware store |
| Large transformer | For multiple benches/zones | each | 1 | Electrical supply |

* Rough Bros., Cincinnatti, OH

**Maid-O Mist, Chicago, IL 60641

**Estimated cost for a CWT irrigation system**

| | |
|---|---|
| Modifying existing 25 ft x 6 ft bench | |
| Trough, mat, etc. | $255 |
| Water level control assembly | $22 |
| Solenoid valve assembly | $30 |
| Electrical connections | $25 |
| Water supply and distribution in trough | $12 |
| Water level detection assembly | $7 |
| Total Cost | $351 |
| Cost Per sq ft | $2.40 |
| | |
| Converting injector for CWT irrigation | $100 |
| 6′ wide x 25′ long bench | $450 |
| Fertilizer injector | $250 |

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