

Root Zone Heating Systems

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Abstract: Increased earliness and higher quality crops can be achieved using root zone heating. If the root zone temperature is maintained at the optimum, air temperature in the greenhouse can be lowered 5 to 10 °F (about 2 to 5 °C) reducing heat loss and thereby, energy consumption. Root zone temperature is more critical than leaf temperature in achieving good plant growth.

Key Words: seedling production, propagation, water heater, energy savings, temperature management, crop development

System Components

A typical hot water root zone heating system contains piping, a water heater or boiler, circulating pumps, and controls.

The least expensive pipe is polyethylene which is available in 100 ft (30.5 m) and 400 ft (122 m) rolls. Select a pipe made of virgin plastic rather than one having reconstituted resins. It should have a pressure rating of at least 100 psi. Polyethylene will take temperatures up to 130 °F (54 °C). Most growers who use poly pipe operate with a water temperature of 100 °F (37.8 °C) to provide 70 to 75 °F (21 to 24 °C) soil temperature. Nylon fittings and stainless clamps will minimize the potential for leaks. Fittings that are buried below ground should have double clamps. This pipe is best used with glass lined hot water tanks as it does not contain an oxygen barrier.

Semi-rigid polyvinyl chloride (PVC) is also low cost. It is available in 10 ft and 20 ft (approx. 3 m and 6 m) lengths, which makes installation easy. Fittings are connected with pipe cement.

Commercially available systems are available that use ethylene propylene diene monomer (EPDM) rubber tubing either as single tubes or as two or four tubes attached to a web. Diameters of $\frac{3}{8}$ in or $\frac{1}{2}$ in (0.95 to 1.3 cm) have greater heat transfer and eliminate some problems from chemical coating and sedimentation blocking. The tubing is connected to plastic or copper headers with plastic inserts or brass fittings. Some manufacturers offer custom made, ready to install modules with headers sized to fit the row spacing.

Cross-linked polyethylene (PEX) tubing (a cross-linked polyethylene tubing with an oxygen diffusion barrier) will take higher temperature and pressure and protect corrodible components of a closed loop hydronic heating system. It is available in $\frac{1}{2}$ in, $\frac{3}{8}$ in and $\frac{5}{8}$ in (1.3, 1.6 and 1.9 cm) diameter. It is highly tolerant to freeze conditions.

System Layout

PVC pipe is the most common material for the supply piping to bring the water from the heater or boiler to the growing area. A reverse return (3 pipe) system is used so that the water to all the loops travels the same distance. On long runs and in unheated areas, supply and return pipes should be insulated to save energy.

For EPDM rubber installations, follow the manufacturer's recommendations for spacing, length of run and circulating pump size. The tubing can be buried in sand on the floor or placed on top or underneath the bench. Some manufacturers supply a slotted insulation board for placing the tubing on top of the bench.

For soil grown crops, placing the pipe 8 to 12 in (20 to 30.5 cm) deep will allow roto-tilling of the soil above it. This can be done by plowing a furrow and then laying the pipe in the bottom or purchasing a pipe-laying chisel that attaches to the drawbar of a tractor. For surface installation with bags or troughs, the pipe is laid on top of the ground plastic or weed barrier underneath the plants.

For benches, a 6 to 9 inch (15 to 23 cm) pipe spacing covered by 3 to 4 inches (7.6 to 10 cm) of sand will provide even temperature. The sand should be kept wet to transfer the heat and is usually covered with a sheet of plastic or weed barrier. An alternative arrangement consists of laying the pipe in the bottom of the bench and covering it with wire mesh and a layer of plastic. Some growers have attached the pipe underneath the bench to get it out of the way and to allow for better heat spread.

The pipe is installed as loops fed by a supply header with the other end connected to a return header. Using a reverse return system, the flow through each loop travels the same distance giving uniform heating (figure 1). Heat loss from plastic and rubber tubing is relatively slow so lengths up to 200 ft for $\frac{1}{2}$ inch and 400 ft for $\frac{3}{4}$ inch pipe will give good results with minimum friction loss. The size of the loops should be made as large as practical so that the header and pump size can remain small. To keep an even flow of water within the pipes and eliminate air pockets a flow rate of 2 and 2.5 gallons/minute (gpm) is used for the $\frac{1}{2}$ inch and $\frac{3}{4}$ inch pipe, respectively.

Sizing the Heater

For crops grown in rows in the soil or in bags with a single line of pipe under each row, you can estimate that it takes 10 Btu/linear foot of row length. For example, a 30 ft x 100 ft (9 x 30 m) greenhouse with 10 rows of plants would require 10,000 Btu/hr of heat (10 rows x 100 ft length x 10 Btu/hr/linear ft). Add about 10% to this total for heat loss from the supply pipes. The soil around the pipes needs to be kept moist to get good heat transfer.

Heat loss from beds or benches covered with plants growing in the soil is about 20 Btu/sq ft/hr and for beds or benches covered with flats, about 15 Btu/sq ft-hr. This is based on a water temperature of 100 °F (37.8 °C). Some manufacturers of rubber tubing recommend water temperature as high as 140 °F (60 °C), which will increase heat transfer but may cause root damage on some crops.

Heat Source

A tank-type, domestic hot water heater (30,000 to 40,000 Btu/hr) fired by natural gas or propane will provide the root zone heat for 3,000 to 5,000 sq ft (279 to 465 sq m) of growing area (figure 2). Commercial water heaters fired by gas or oil are available in larger sizes. As the root zone heating system does not provide all the heat needed to keep the greenhouse warm on cold nights, a unit heater or other source of air heat is needed.

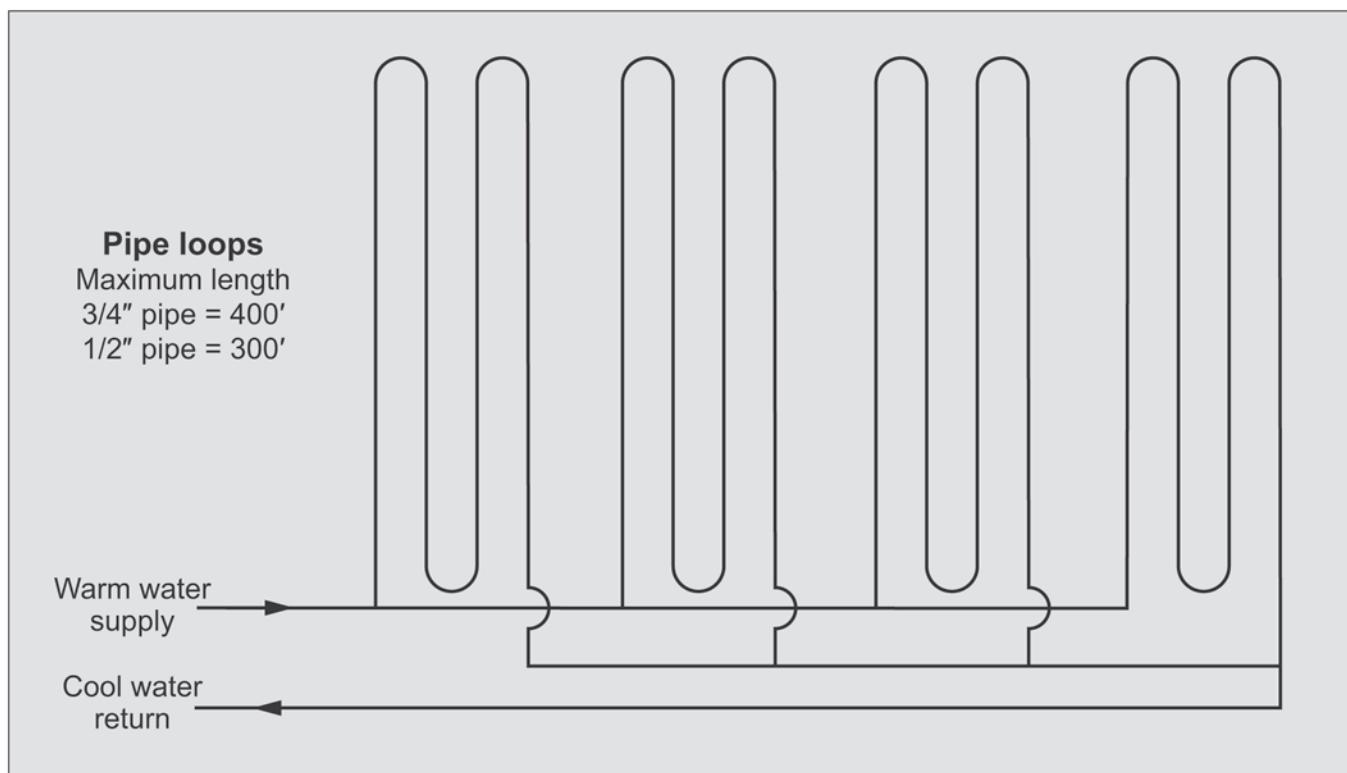


Figure 1. Typical reverse return pipe layout for floor or bench heat.

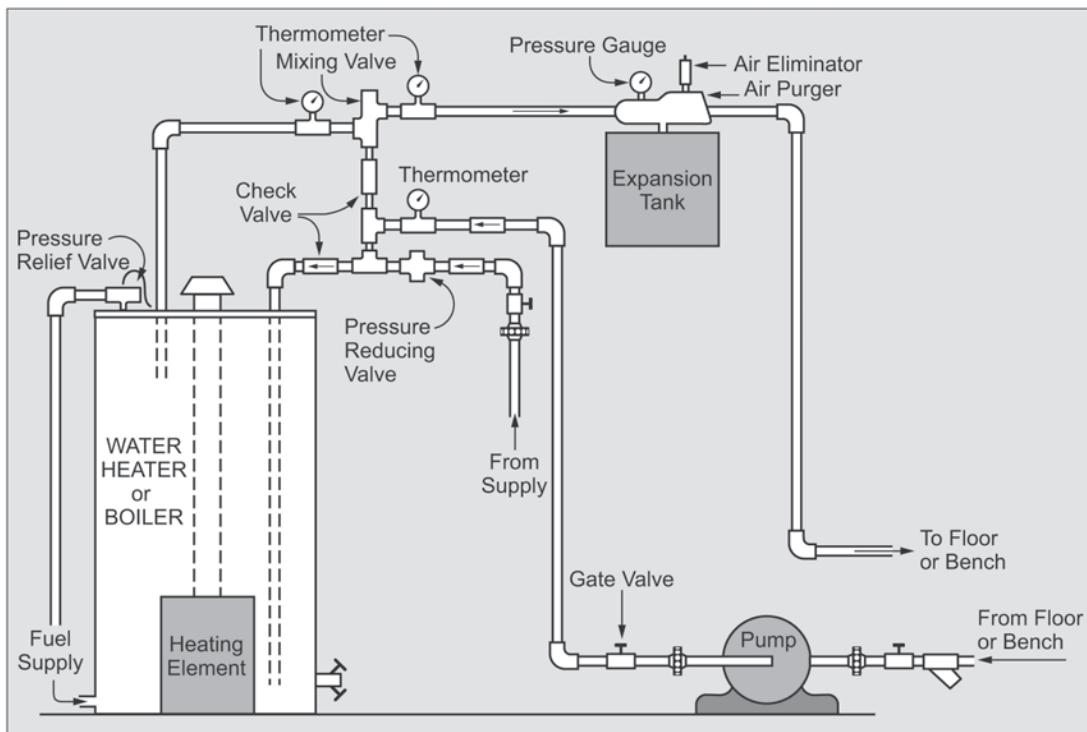


Figure 2. Piping schematic for bottom heat system.

In larger greenhouses, a boiler is usually installed that is large enough to provide both the root zone heat and the air heat. It is best if dual boilers are installed with 1/3 and 2/3 capacities. These can be staged to efficiently handle the heat needs over the entire year. The boiler water temperature is usually maintained at 180 to 200 °F (82 to 93 °C) during the coldest part of the year. A tempering valve installed in the supply line mixes the hot water and the returning cool water from the root zone piping to provide the 100 °F (37.8 °C) water for the system. Boilers are available in sizes from 50,000 Btu/hr and up.

System Plumbing

All closed loop systems require the use of a pre-pressuring diaphragm expansion tank, an air eliminator and vent installed on the supply pipe as close to the hot water source as possible. Valves needed include a pressure relief valve, flow balancing valves, gate valves to isolate parts of the system, pressure reducing valves to fill the piping and zone valves to control individual sections of the system independently.

Water is moved through the system with circulating pumps. The flow rate is based on the number of loops per zone and the size of the piping (figure 3). For example, a system of 10 – 200 ft loops of ½ inch poly pipe will have a flow of 20 gallons/min (10 loops x 2 gpm/loop = 20 gpm). The pump needs to be able to overcome the friction loss in the system. For most root zone systems, a pump having the calculated capacity at a total of 15 to 20 feet of head will meet the system needs. Heat supplied from root zone systems depend on whether the pipe is in the soil or under flats of plants (figure 4). It also depends on whether the soil next to the pipe is moist. Moist soil transmits a greater amount of heat.

Controls

In the simplest system using a water heater, the thermostat on the tank is set at the desired root zone water temperature (usually 100 °F/37.8 °C). Return water from the loops goes back to the tank to be reheated. The same system can be used with most boilers by setting the aquastat that controls the output water temperature. Manufacturer's guidelines for minimum water temperature entering the boiler should be strictly followed. Where a boiler is used for space heating in addition to root zone heat, a higher temperature is usually desired and a mixing valve needed. In most areas of the US, root zone heat will provide less than 25% of the total greenhouse heat needs on the coldest night so an additional heat distribution system is needed. This can be fin or pipe radiation, water to air heat exchangers, or hot air furnaces.

Activation of the circulating pump is done with a sensor inserted in the soil or growing bag. An electronic thermostat is a good choice as the differential between on and off is only a degree or two. Most mechanical thermostats have a higher differential.

In larger greenhouse systems, the water in the supply lines to the root zone system may be circulated continuously. This maintains warm water near the growing area. Solenoid valves on each zone, activated by a sensor in the bed, control the flow to that zone.

Summary

Root zone heat has proven to be an effective way to get better propagation and production. Energy savings due to a lower air temperature can be as much as 10% and help offset the cost of the system.

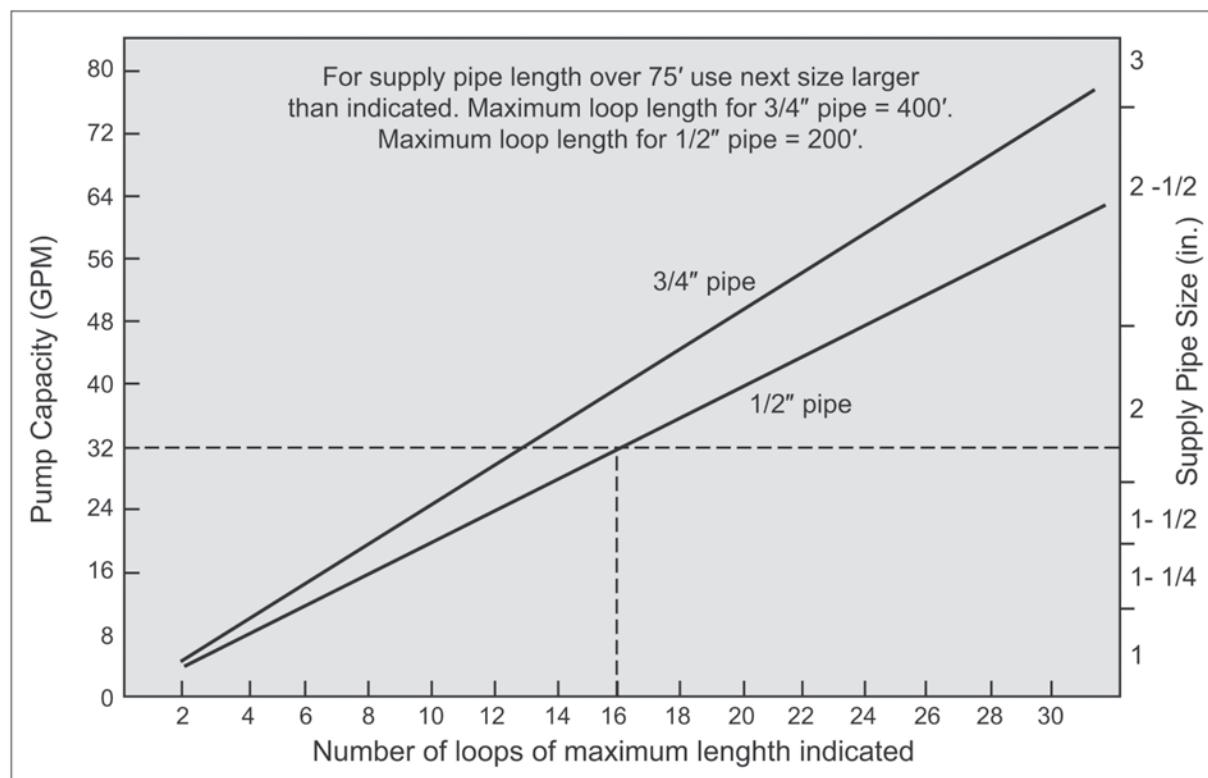


Figure 3. Pump capacity and supply header size for polyethylene pipe bottom heat system.

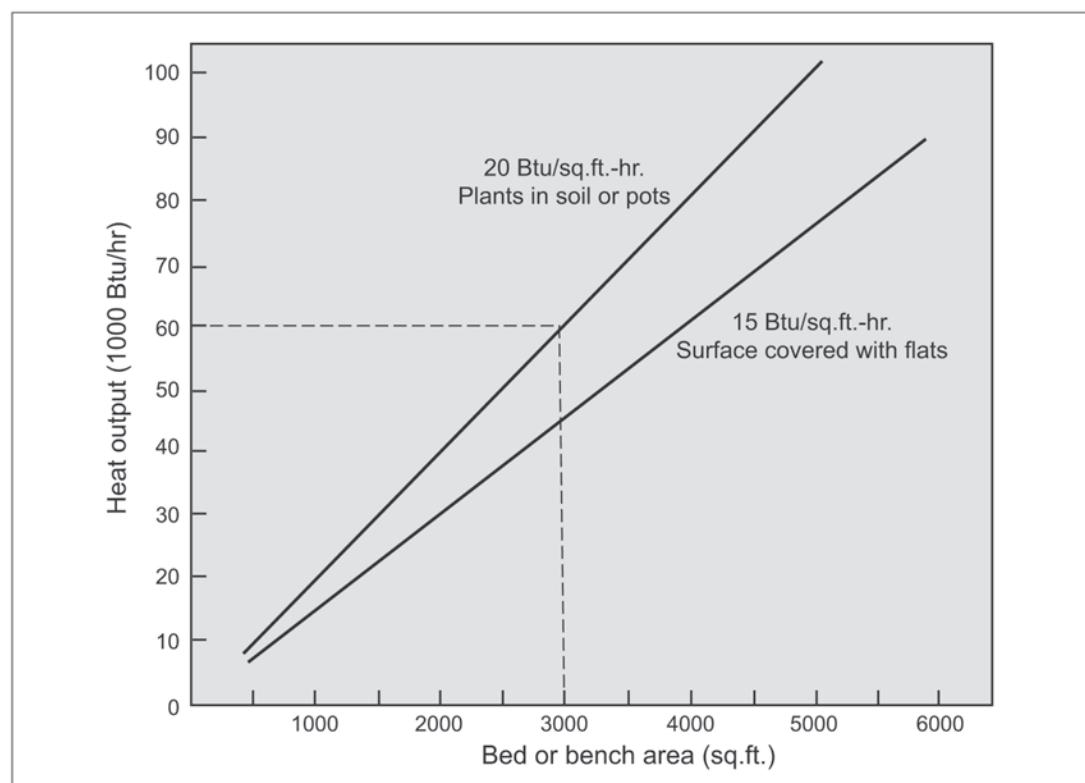


Figure 4. Heat flow from bottom heat in floors or benches.