also start to decline. Our other basic mix is 2 parts of humus to one part of coarse sand. This is made up in two forms, one which we call "low-lime" mix which is used for ericaceous plants (10 lb of ground limestone per cubic yard of mix), and one which we call "high lime" mix for other plants which grow well in a high organic mix but prefer a higher pH (20 lbs/cu yd). In both of these mixes, we would prefer larger particles of humus; the Lindig shredder grinds the humus too fine. A P.T.O. manure spreader does not mix the humus and sand thoroughly enough, and we frankly have not yet found the ideal machine for mixing to our specifications.

In late summer we treat all the mix which will be needed for the following spring's canning. Sterilized mix is stored under cover in a fibreglass-covered building and is ready to use whenever needed throughout the winter and following spring. Having mix, containers, and liners ready for instant use enables us to get much of our canning done at times when the field crews are forced inside by inclement weather. At such periods, what used to be costly "down time" is now converted to useful accomplishment.

Obviously, composted leaves are not available in the quantities required by really large-scale container firms such as those found in California and the southern states. However, there are quantities available and going to waste which are more than adequate for the smaller grower. They are a supply of humus with greater than normal nutrient content. And, in this era of rapidly escalating costs for every kind of supply and material, it is a pleasant surprise to encounter one which is far cheaper today than the conventional organic materials like peat were even a decade ago.

A SOLAR GREENHOUSE FOR PROPAGATION[1]

CARL E. WHITCOMB

Oklahoma State University
Stillwater, Oklahoma 74074

In the last few years much interest and emphasis has been placed on the development of solar heated greenhouses. Nearly all that have been reported to date use a separate solar collector system, then transfer the heat to the greenhouse by some type of heat exchanger. Thus the heat and heat distribution is similar to a conventional greenhouse. By contrast, the self contained, solar heated greenhouse at Oklahoma State University was constructed using the heat collection capacity of the greenhouse as

[1] Patent applied for.

the collector system, storing the heat in water and sand in the floor to stabilize the greenhouse temperature. Our greenhouse, therefore, is entirely bottom heat and well adapated to propagation.

Operation of the Structure. The greenhouse is a Quonset type structure 26 × 72 ft (dimensions can be varied), constructed from 3/4 inch galvanized pipe bows placed on 6 ft centers with one center purlin (Figure 1). Covering is by 3 layers of air inflated polyethylene. The triple layer system gives even greater heat conservation and is essential for heat accumulation between the inner 2 layers. Thus the inner 2 layers of covering constitute the solar collector system as a mist is injected between the two layers using garden type "soaker hoses" on 6 ft centers (Figure 2). Interior shading by the mist is only about 10%. As the mist between the layers of poly is warmed and additional mist is released the moisture flows down the sides of the greenhouse. On each side and one end of the house, double rows of concrete blocks create a gravity return for water back to the floor for storage (Figure 3). Water is pumped from the floor reservoir through the mist lines, between the inner layers of poly and is allowed to return back down the sides to the floor where it is stored. The greenhouse floor is graded so gravity controls the flow of water from the sides to the end where it is picked up by the pump. The sand layer varies from approximately 8 to 12 inches thick depending on the slope of the floor and the relative position in the house. This sand layer, once heated, provides convective heating of the entire floor. Convective heating from the floor is much more efficient in heating containers sitting on the floor than forced air type heaters which primarily heat the air rather than the growing medium in the container.

The sand heat reservoir lays on a sheet of 1-inch styrofoam to stop downward heat loss. A layer of 6 mil black polyethylene provides the waterproof lining. The styrofoam also prevents stones or clods from puncturing the polyethylene and causing leaks. Likewise, there is a layer of 6 mil black polyethylene over the top of the crowned sand layer and below the layer of gravel which is the finished floor of the greenhouse. Thus the double layer of poly on the roof of the house where the mist is injected plus the water return and the sand reservoir in the floor is a closed system. That is, water can be circulated through this system, heat absorbed and heat released, without loss of water. With this system a greater heating efficiency can be realized as opposed to adding cold water or where evaporation could occur. In addition, water and nutrients used in the rooting and growth of cuttings does not mix with the heating system, thus reducing the potential algal and disease problem. However,

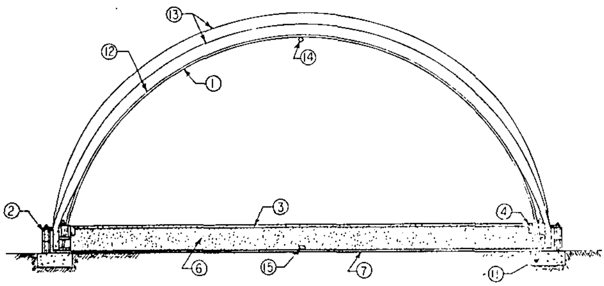


Figure 1. Cross sectional view of quonset type solar greenhouse.

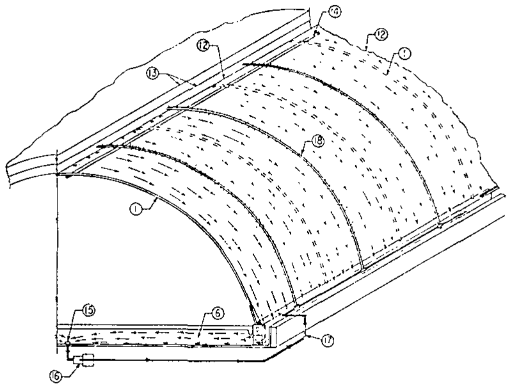
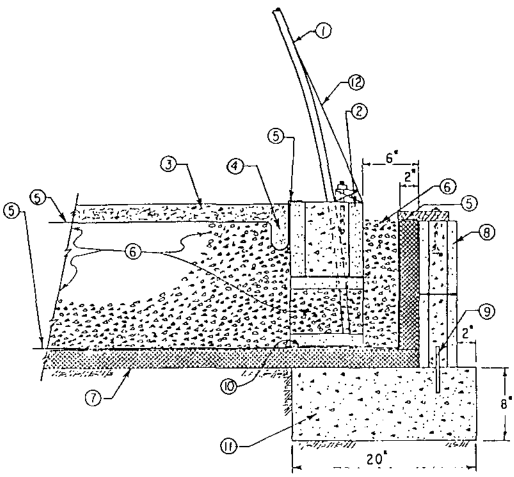


Figure 2. Water flow system between the inner two layers of poly which acts as the solar collector.



Key to Greenhouse Components Shown in Figures 1, 2 and 3.

1. Pipe bows, 3/4" galvanized pipe on 6' centers
2. Concrete blocks, 8 × 8 × 16"
3. Limestone screenings work floor
4. Excess water drain
5. Waterproof poly liners
6. Sand for water storage
7. Styrofoam insulation
8. Concrete blocks, 4 × 8 × 16"
9. Reinforcing dowel
10. Felt paper, 40 lb.
11. Concrete footing
12. Interior poly film
13. Center and exterior poly films
14. Center purlin connecting bows
15. Free water collection tube
16. Centrifugal pump
17. Water distribution lines
18. Soaker hose sprinkler lines

Figure 3. Detail of water return system to the floor.

copper or other chemicals may be required to prevent algae development.

The north end of the greenhouse has been framed, insulated and covered with a permanent building exterior siding to reduce heat loss. In addition, since we have a north primary entrance, the addition of an air chamber type door and small work-room assembly minimizes entrance of outside air into the greenhouse. This type of air chamber door assembly helps a great deal in conserving heat within the greenhouse.

A solar greenhouse of this type will require close management to achieve maximum heating. This management will include the early fall operation of the heat collector system to build up the heat reserve in the sand-water floor. In Oklahoma this means the collection system should be operational by late September or early October in order to raise the floor temperature to 22 to 25°C (70 to 78°F). Subsequent operation of the heat collection system would be whenever the temperature between the inner two layers of plastic exceeded the water temperature of the floor by approximately 3°C (6°F).

The following suggestions and explanations may make this type solar greenhouse more widely adaptable:

1) If additional heat storage is required for more northern areas, the sand layer depth can be increased with, perhaps, an earlier startup time in the fall.

2) Early operation showed that with a floor temperature of 18°C (65°F) and −9°C (11°F) outside temperature, an inside air temperature of 8°C (46°F) could be maintained with no supplemental heat.

3) The water injected between the two layers of polyethylene is not heated directly by the sun's rays, but rather by the warm air. For example, with 4000 ft-c and 10°C (50°F) outside temperature and 21°C (70°F) in the collection chamber the water could be heated to about 18°C (65°F). On a colder day with 4000 ft-c, and −7°C (20°F) outside temperature and 50°F in the collection chamber the water could be heated only to about 4.5°C (45°F).

4) The third layer of plastic over the structure provides the same insulation capacity to the collection chamber as would be provided to the inside air of a standard double poly greenhouse. This third poly layer increased the heat collection capacity by about 10-12°C (20-25°F).

5) The one inch layer of styrofoam beneath the entire greenhouse greatly reduces the downward loss of heat. This would be of even greater importance in more northern climates.

6) The sand used in the storage system must be packed in

order to prevent shifting of the work floor. However, sand size must be sufficiently uniform to allow water to circulate at a reasonable rate. Precise specifications are not currently available.

Temperature of the growing medium in containers sitting on the floor remained the same as floor temperature. The heat is transferred from the floor to the containers (Figure 3). This provides an ideal bottom heat system which has been shown effective in propagating many cuttings. In addition, the lower air temperatures experienced in this greenhouse assist in keeping the cuttings dormant throughout the rooting period. However, a good ventilation system must be provided to prevent excessive heat in late winter and early spring. Because this greenhouse is quite efficient in retaining heat during winter it also accumulates heat readily in the early spring which may stimulate unwanted soft succulent growth. Our experience to date has shown that we can maintain a low air temperature in early spring by simply drawing in cool outside air with thermostatically controlled fans.

This greenhouse is very economical to construct (materials are about $2.00/sq ft) and provides bottom heat and temperature controls more suitable for propagation than other greenhouses. Even in more northern areas, only a small amount of supplemental heat should be needed on very cold nights, reducing or eliminating the expensive fuel bills encountered in recent years.

FACTORS CONTROLLING REGENERATION FROM ROOT CUTTINGS

CHARLES W. HEUSER

Department of Horticulture
The Pennsylvania State University
University Park, Pennsylvania 16802

Root cuttings as a method of reproducing plants are little used in today's modern nursery and probably will be used even less in the future. Modern methods, such as tissue culture appear to represent the future trend. Root cuttings, however, are applicable to a wider number of woody plants than is realized. The ability of root cuttings of many plant species to regenerate whole plants has been recognized and described in the horticultural literature over a long period of time and extensive lists of species have been compiled (7,18). Propagation through root cuttings assumed a more important role before the introduction of propagation aids such as, auxins and mist. Flemer (7) cites two principal reasons for the rarity of this method. 1. Many plants for which it is the best technique are infrequently grown