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# Electric Hotbeds and Propagating Beds

Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS

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## SUMMARY

1. This bulletin discusses the construction and operation of electrically heated beds for starting of vegetable plants for transplanting and for the propagation of plants and shrubs from cuttings.

2. The present price of electric soil-heating cable is $5.00 for 65 feet (120 volts), which is sufficient for a hotbed 6 feet by 6 feet.

3. Electric hotbed thermostats for automatically controlling the soil temperature cost $5.75 to $11.00 at present. Each thermostat will control from one to four 6x6-foot hotbeds.

4. The power consumption for outdoor electric hotbeds of fairly tight construction, with good drainage and covered with glass, may be estimated at 0.5 to 0.7 Kwh. per square yard per day for fall and spring operation and 1.0 to 1.5 Kwh. per square yard per day for winter operation in Western Oregon when maintaining a soil temperature of from 65° to 70° F.

5. The cost of heat to maintain a temperature of from 65° to 70° F. in a 6x6-foot electric hotbed was found to be $1.80 to $2.50 per month during the spring with electricity at 3¢ per Kwh.

6. Vegetable growers report an even and vigorous growth of plants in electric hotbeds constructed as recommended in this bulletin.

7. The electric hotbed has many advantages over the manure hotbed.

8. Propagating benches heated by electric soil-heating cable have been used successfully and economically by propagators of evergreens, Alpine plants, and ordinary soft wood and hardwood cuttings. The time required to root the various cuttings by this method is usually decreased; the percentage of cuttings rooting has been increased.

9. The installation of the electric soil-heating cable is done in the same way for a propagating bed as for an electric hotbed.

10. A metal tray 30 inches by 40 inches with a 200-watt heating element strung open under the metal floor of the tray is recommended for small propagating bed or hotbed installation. This device is equipped with an adjustable thermostat and ordinary lamp cord and may be plugged into a 120-volt outlet.

11. The power consumption for electrically heated propagating benches operated in a greenhouse maintained at an average temperature of 59° F. was found to be approximately 0.8 Kwh. per square yard per day by the bed held at 70° F. and 1.5 Kwh. per square yard per day by the bed held at 80° F.

12. Propagating beds constructed like electric hotbeds and heated with electric soil-heating cable during the winter months operated at temperatures approximately 10° F. less than the beds in the greenhouse with the same power consumption.

13. Propagating benches should have 8 to 12 inches of sand or other medium over the electric heating cable for good temperature distribution.

# Electric Hotbeds and Propagating Beds

By

F. E. PRICE and C. J. HURD

## ELECTRIC HOTBEDS

A HOTBED is a glass-protected bed of rich soil to which heat is applied for hastening the germination of seed and promoting the growth of plants to be transplanted. Heat has heretofore been obtained chiefly from fermenting manure.

Since 1925 soil heating by electricity has been developed by various experimental agencies to the extent that it is now being profitably and conveniently utilized in nearly all types of plant propagation for transplanting. During 1931 and the first four months of 1932 electric hotbeds have aroused interest extensively among growers and there has been an unusual acceptance of this new development. During this period the authors have installed several beds using different methods of construction and have taken detailed records of temperature actually occurring in the beds as well as of the power required for their operation. They have examined and helped to install many beds being used by growers. This bulletin summarizes the results thus far obtained.*

**The heating unit.** The essential parts of an electric hotbed which are different from a manure hotbed are (1) the electric soil-heating cable, which is buried in the soil; (2) an electric thermostat, which is a device to turn the electricity on or off automatically as required to maintain the desired temperature of the soil; and (3) the necessary electric wiring to bring the electric service to the bed.

**Electric soil-heating cable.** Electric soil-heating cable as shown in Figures 2 and 4 is about ¼ inch in diameter and consists of regular electric heating wire covered with a layer of asbestos and protected with a pliable lead or copper sheath. One manufacturer covers the asbestos with a layer of cambric, which is then covered with the lead sheath.

Number 19 nichrome wire is the most common size used in soil-heating cable and must be used in 65-foot units on 120 volts and 130-foot units on 240 volts. It may be used in 60-foot units with 110 volts. If the cable is used in shorter than standard lengths there is an increase in the watts of electrical energy required to operate the unit, with a corresponding increase in the amount of heat produced in the cable. This may be injurious to the insulation around the heating wire which is necessary to insulate the wire from the lead or copper sheath. The unit length of soil-heating

*Practical information by A. G. B. Bouquet, Horticulturist (Vegetable Crops), on the use of hotbeds and coldframes in vegetable growing will be found in Extension Circular 251, *Growing Early Vegetable Plants Under Glass*, and Extension Circular 258, *Construction and Operation of the Coldframe in Vegetable Growing*. The circulars are obtainable from Oregon State Agricultural College, Corvallis.

cable recommended by the manufacturer should be used. The soil-heating cable becomes warm to the touch but not hot when used in the proper lengths.

**Electric hotbed thermostats.** An automatic temperature control called a thermostat is essential to every electric hotbed installation. An attempt to control the heat by a hand switch will result in undesirable temperature fluctuations and less efficient use of the electricity. An electric thermostat

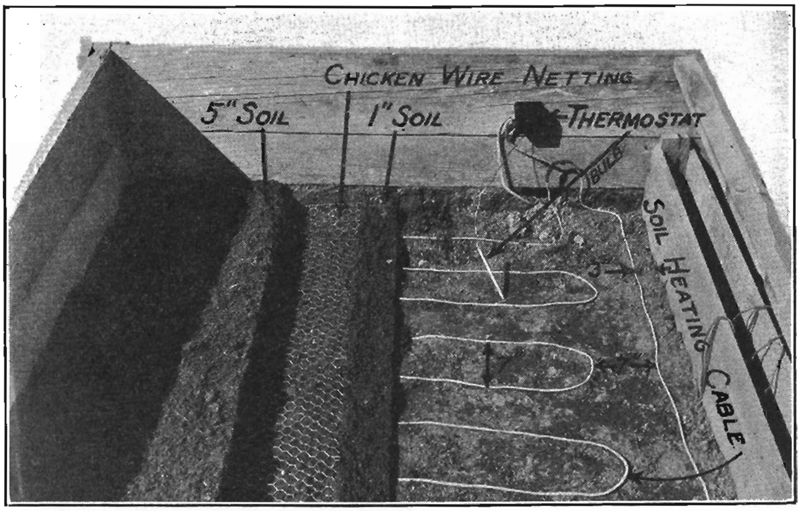


Figure 1. Sectional view of an electric hotbed.

can be set at any desired soil temperature and it automatically turns the electricity on or off as required. An electric soil thermostat should be constructed so that the contact points open or close the electric circuit with a quick movement in order to reduce radio interference and reduce the electric arc and burning of the points. Thermostats of this type cost, according to the make, from $5.75 to $11.00.

Electric hotbed thermostats available on the market at present are shown in Figure 2. Each of these thermostats may be used on 120 or 240 volts and will safely carry 15 amperes.

**Types of thermostats.** Two general types of thermostats for electric soil-heating control are on the market.

The box type has the entire thermostat and switch mounted in a moisture-resisting box. It must be so placed in the hotbed soil that the top of the box is level with the surface of the soil. A knob for adjusting the thermostat to the desired operating temperature is usually provided as shown by numbers 3 and 5 in Figure 2.

The remote-control type of thermostat is in two distinct units, the control box and the thermostat bulb. The control box, which has the electric switch, is mounted on the hotbed frame. The thermostat bulb is buried in the hotbed soil and connected to the control box by a capillary tube 18 inches in length. The thermostat shown in 2, Figure 2 is an example of this type.

Each of these types of thermostat is giving satisfactory service in controlling hotbed temperatures. Lower-priced thermostats than those here listed may be found on the market which are not of the quick-acting

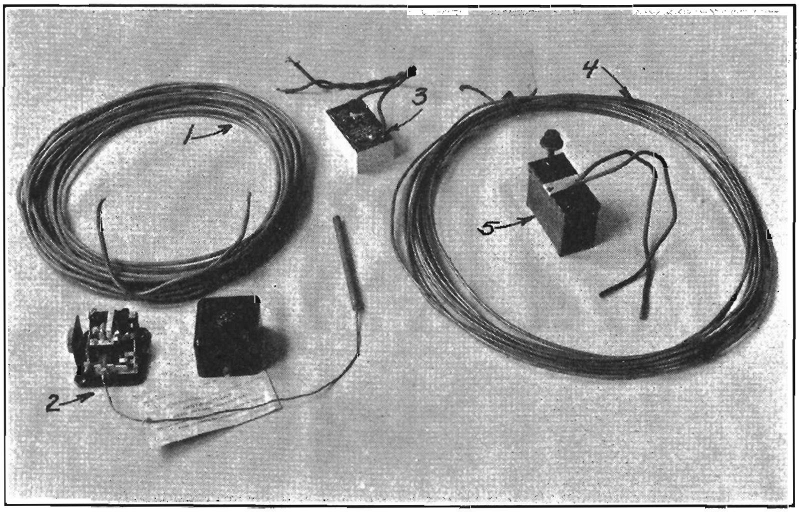


Figure 2. Electric soil-heating cable and thermostats (snap action).

1. Lead-covered cable.
2. General Electric thermostat.
3. Osgood thermostat.
4. Copper-covered cable.
5. Arnold thermostat.

type. These lower-priced thermostats may give satisfactory service for a limited time, but for permanent installation the snap-action type is recommended. New thermostats for use in electric hotbeds which may be sold at prices different from those quoted will probably be developed. These should be given a fair and careful consideration along with the equipment which the writers have described.

**Cost of electrical equipment for hotbeds.** The recent development of soil-heating cable that can be placed in the soil has made the electric hotbed a very inexpensive installation. The cost of this new electric heating cable for soil heating amounts to only $1.25 per square yard of hotbed or $5.00 for a hotbed 6 by 6 feet. Very satisfactory thermostats are available for automatic soil temperature control for $5.75 to $11.00. This makes the total cost of the electrical equipment for a hotbed 6 by 6 feet $10.75 to $16.00 according to the price of the thermostat selected.

The cost of electric equipment for larger installations may be reduced by having each thermostat control a larger area. The soil thermostats have ample capacity to serve 16 square yards of hotbed or four units 6 by 6 feet when operating at 120 volts, or double this size of bed at 240 volts. The cost of the soil-heating cable for four beds 6 by 6 feet or one hotbed 6 by 24 feet would be $20.00. The cost of the thermostat would be the same as for the small bed, $5.75 to $11.00. This would make a total cost of $25.75 to $31.00 for a bed 6 by 24 feet.

TABLE I. COST OF ELECTRIC EQUIPMENT FOR VARIOUS SIZES OF ELECTRIC HOTBEDS, 120 VOLTS

| Size of hotbed | Power | Electric soil-heating cable | | Thermostat | | Total cost of heating cable and thermostat |
|---|---|---|---|---|---|---|
| | | Units* required | Cost | No. required | Range in cost | |
| *Feet* | *Watts* | | | | | |
| 6x6 | 440 | 1 | $ 5.00 | 1 | $ 5.75—$11.00 | $10.75—$16.00 |
| 6x12 | 880 | 2 | 10.00 | 1 | 5.75— 11.00 | 15.75— 21.00 |
| 6x18 | 1,320 | 3 | 15.00 | 1 | 5.75— 11.00 | 20.75— 26.00 |
| 6x24 | 1,760 | 4 | 20.00 | 1 | 5.75— 11.00 | 25.75— 31.00 |

*A unit of No. 19 (nichrome wire) soil-heating cable for 120 volts is 65 feet.

**Location of hotbed.** The hotbed should be located where there is good soil drainage with the low side of the bed to the south so as to get the maximum effect of the sun. Good soil drainage is important in reducing the power consumption. If the soil is heavy and the drainage is not good it is recommended that the hotbed be built up so as to be above the surrounding ground level. Soil should be banked up around the outside of the bed. A location against the south side of a building is an excellent place for the electric hotbed.

**The hotbed frame.** A standard hotbed sash is 3 by 6 feet and the bed is logically built in units of this size. One unit of electric soil-heating cable (65 feet for No. 19 wire for 120 volts) will heat a bed 6 by 6 feet. Standard construction of electric hotbeds of larger size will therefore be in multiples of 6 by 6 feet where 120-volt service is used and double this size when the service is 240 volts. The hotbed frame is usually 12 inches high on the low side and 18 inches high on the high side.

The sides are usually constructed of 1½- or 2-inch material with batting boards to prevent all possible air leakage. Double walls of 1-inch material with building paper between have been used by some growers for hotbed frames and found very satisfactory.

A 2 by 4 should extend across the top of the frame from the high side to the low side at every 3 feet so that the hotbed sash can be slid across the bed on the cross members. They should be flush with the top of the frame and can be notched into the side walls with a dove-tail joint so as to be easily removed when adding or taking soil from the bed.

**Wattage required for electric hotbeds.** The correct wattage of the cable for an electric hotbed is determined by two factors: (1) sufficient heat to maintain satisfactory soil temperature and (2) even distribution of the heat in the soil. An experiment was made at James Gardens near Eugene, Oregon, during April and May of 1931 to determine the amount of soil-heating cable and the wattage necessary for Western Oregon weather conditions. It is not uncommon for night temperatures to get down to 32° F. during April. Soil temperature of 65° to 70° F. at a depth of two inches was considered satisfactory for seed germination and plant growth of vegetables for transplanting.

Three 6x15-foot beds that had formerly been used with manure heat were converted into electric hotbeds. Each bed had a different wattage and spacing between the cable loops. The cable was buried approximately five inches in the soil. The thermostats were set to turn on the power at a hot-

Figure 3. An electric hotbed for starting early vegetable plants built by Blaine Brown near Salem, Oregon.

bed soil temperature of 65° F. and to turn off the power when the soil temperature reached 70° F. Recording thermometers were installed for each bed and special tests were made of the temperature distribution in the hotbed soil. Watt-hour meters were used to record the power consumption of each bed.

The three installations were as follows:

(1) 370 watts or 4.1 watts per square foot with a spacing of 18 inches between each cable loop.

(2) 470 watts or 5.2 watts per square foot with a spacing of 12 inches between each cable loop.

(3) 740 watts or 8.2 watts per square foot with a spacing of 9 inches between each cable loop.

The recording thermometer records indicated that beds 1 and 2 did not have sufficient heating capacity to maintain a hotbed temperature of 65° to 70° F. during April.

Bed 3 with 8.2 watts per square foot and 9-inch spacing between cable loops maintained during April 65° to 70° F. Outside air temperatures at night frequently went down to 32° F. during the month.

The temperature distribution in the hotbed soil was satisfactory.

It is likely that electric hotbeds will be operated during colder weather in Oregon than in the foregoing test. The installation of 65 feet of No. 19 soil-heating cable (440 watts at 120 volts) for each 6x6-foot unit provides 12 watts per square foot, which is ample for Oregon conditions.

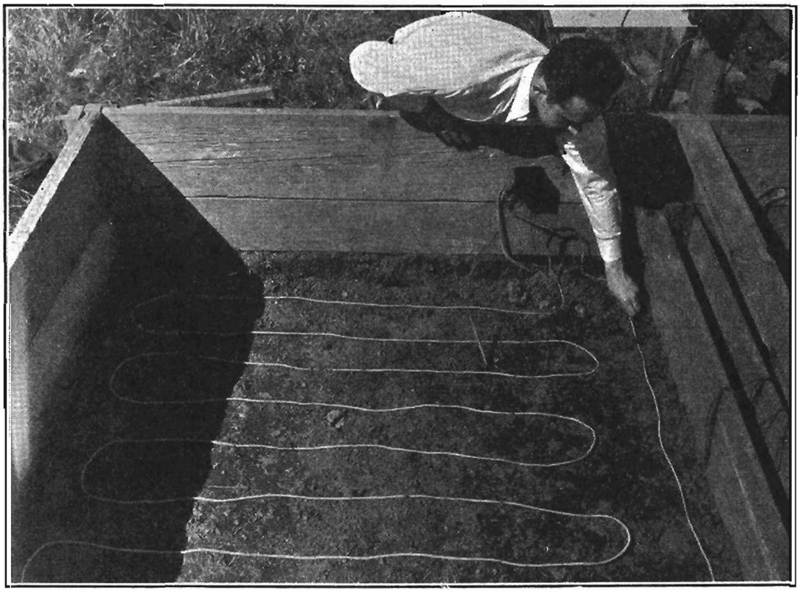

Figure 4. Laying the cable in a 6x6-foot bed.

**Material under the hotbed soil.** It has been quite generally recommended that 6 to 8 inches of cinders be used under the hotbed soil in which the plants are to be grown to serve as a heat insulator and aid drainage and in this way reduce the amount of electricity required to maintain the desired temperature. In sections where coal is not used extensively as a fuel, cinders are not readily available. This condition exists in Western Oregon. An experiment was conducted by the authors to determine the comparative value of cinders, straw, gravel, and sandy loam soil under the hotbed soil.

Four 6x6-foot units of electric hotbeds were constructed, each with 65 feet of soil-heating cable, with a 7-inch spacing between cable loops. All beds were identical in construction except for the insulation material. Bed No. 1 had 6 inches of gravel, Bed No. 2 had 6 inches of straw, Bed No. 3 had 6 inches of cinders, and Bed No. 4 had 6 inches of sandy loam soil beneath the electric heating cable. The heating cable in all the beds was covered about one inch with hotbed soil (sandy loam), then 1-inch-mesh wire netting, and finally a 5-inch depth of soil, making a total depth of 6 inches of soil above the heating cable. See Figure 1.

The beds were kept at a minimum temperature of 65° F. at a 3-inch depth by thermostatic control. Continuous records of the hotbed soil temperatures were kept throughout the test by recording thermometers.

The beds were separated by a 4-inch layer of cinders and the end bed was guarded by an extra hotbed operated at the same temperature as the beds on test.

A variety of plants were grown in the beds during the experiment with the same kinds of plants in each of the beds. The beds were uniformly ventilated during the day and covered with glass sash at night. The weather throughout the test was cool and cloudy with frequent rain, but at no time was there sufficient rain to cause excess moisture to seep into or under the hotbeds.

These hotbeds were operated from April 8 to June 5, 1932. Daily observations were made to assure constant and even operation of the units. Continuous power-consumption records were kept, readings taken every few days.

TABLE II. TEST OF INSULATION MATERIAL FOR ELECTRIC HOTBEDS
6 inches of insulation under heating cable
Each hotbed unit 6x6 feet with 65 feet of No. 19 heating cable—115 volts.

| Days | Power consumed | | | |
|---|---|---|---|---|
| | Bed No. 1 Gravel | Bed No. 2 Straw | Bed No. 3 Cinders | Bed No. 4 Sandy loam |
| | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* |
| 0 | 0 | 0 | 0 | 0 |
| 8 | 46.5 | 24.5 | 21.43 | 12.59 |
| 13 | 58.5 | 31.0 | 24.09 | 21.42 |
| 20 | 81.5 | 47.0 | 42.30 | 33.26 |
| 29 | 104.5 | 61.0 | 73.48 | 60.14 |
| 35 | 112.0 | 65.5 | 88.98 | 69.43 |
| 40 | 118.5 | 74.0 | 106.10 | 77.00 |
| 48 | 134.5 | 86.5 | 124.15 | 89.43 |
| 53 | 150.5 | 97.0 | 136.75 | 95.49 |
| 58 | 164.5 | 112.0 | 145.20 | 105.95 |

The power consumption of the four hotbeds is shown graphically in Figure 5.

The power consumption was consistently highest in the hotbed having an under layer of 6 inches of river gravel.

The hotbed with the under layer of cinders was next highest during the 58-day test. This bed was next to the lowest in power consumption for the first 20 days, but its rate of power consumption increased in the last 38 days of the test. One possible explanation of this might be that as the cinders became damp, the insulation value decreased.

The hotbed having the under layer of straw and the bed having the under layer of sandy loam finished the 58-day test with practically the same power consumption. The bed having the straw layer had a higher rate of power consumption for the first 20 days, but at this time its rate of power consumption began to decrease and at 29 days the two beds were practically tied. At the end of the first 3 weeks it was found that the straw was beginning to decompose. This decomposition may have given off heat sufficiently to reduce the amount of electricity necessary to maintain the required temperature of the hotbed.

These various types of hotbeds under insulation may not give the same results when operated during the rainy winters and limited sunshine of Western Oregon. These tests are being continued to determine the relative value of these materials during the winter.

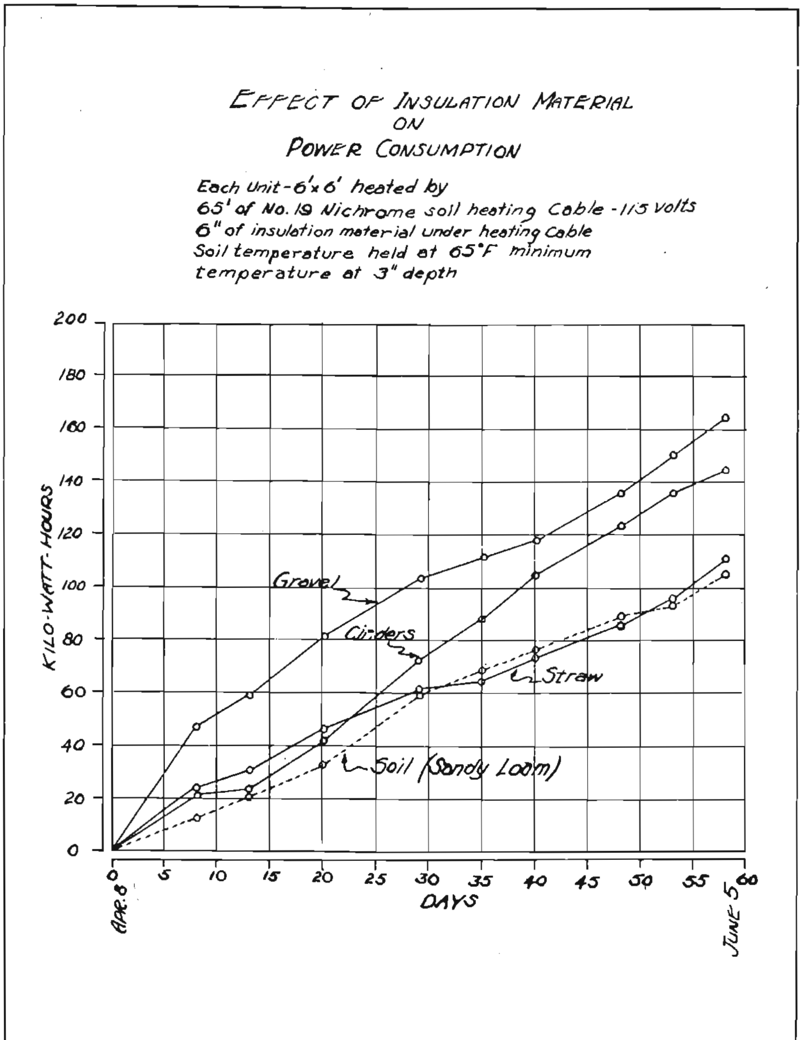


Figure 5.

**Installation of heating cable.** Figure 4 shows 65 feet of No. 19 nichrome electric cable in place in a 6x6-foot hotbed. An inch of soil is first spread evenly over the heating cable. Galvanized chicken-wire netting is then laid on this one-inch layer. The purpose of the netting is to prevent cutting the cable with a shovel when removing the plants or soil. The cost of the wire netting is about 60 cents for a 6x6-foot bed.

Rich soil to be used for growing the plants is placed on the wire netting. The usual depth of this soil is 5 inches.

The completed electric hotbed then consists of the heating cable which is placed on well drained soil or cinders and covered with (1) one inch of soil, (2) the wire netting or screen, and (3) the top layer of 5 inches of rich soil. (See Figure 1.)

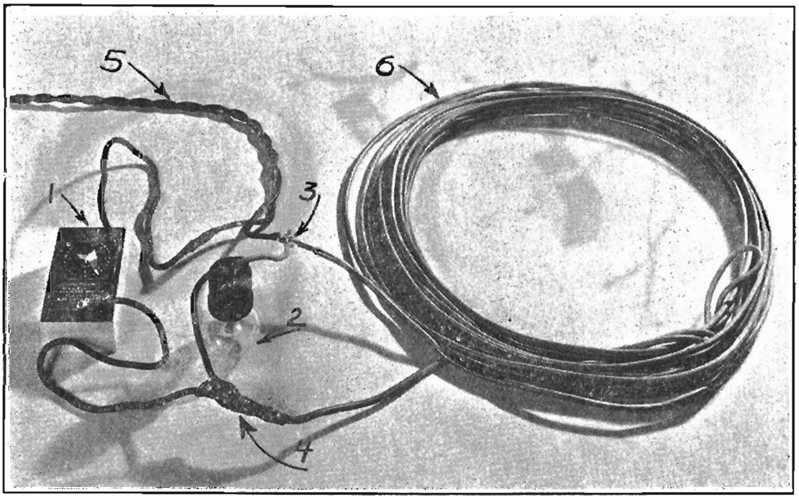


Figure 6. Wiring detail of a hotbed unit. Consists of (1) thermostat, (2) pilot light, (3) connection uncovered to show brass bolt, (4) tape-covered connection, (5) weather-proof electric wire (brewery cord) to power supply, (6) soil-heating cable.

**The electric wiring.** The electrical work should be done by one who is experienced in electrical wiring. The wiring should be completed and the circuit tested before the soil is placed on the heating cable. The wiring of one or two 6x6-foot units can be connected to the house or barn lighting circuit without a separate fuse. Larger hotbed installations should have a separate fused switch box.

The electrical connections of the heating cable to the thermostat and power supply should be made with brass bolts to prevent the development of rust and the resulting inferior electrical connection. These connections should be insulated and made waterproof by first winding with rubber tape followed by a top covering of friction tape. Figure 6 shows the brass bolt connection (3) before it is taped and (4) the completed connection.

**Location of the thermostat in the hotbed.** The thermostat should be located in the hotbed so that it will not be shaded by the sides of the hotbed during the day. Soon after the sun rays strike the thermostat the power will be automatically turned off. The thermostat or thermostat bulb should set in at least 8 to 12 inches from the border of the bed.

The thermostat bulb of the remote-control type of thermostat can be placed in the hotbed soil either horizontally or at an angle. When placed horizontally it should be at a depth of 2 to 3 inches. Some operators prefer to put the thermostat bulb in at a slant with the tip of the bulb at a depth of 2 to 3 inches and the back of the bulb just covered. The temperature at which the bed is maintained may be changed several degrees without changing the thermostat adjustment by placing the bulb nearer to or farther away from the heating cable. When the bulb is placed nearer the heating cable the average temperature of the hotbed will be lowered.

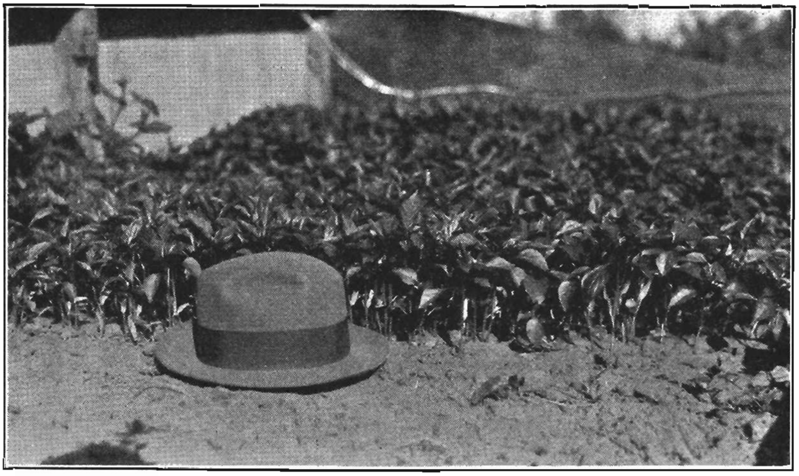

Figure 7. Approximately 10,000 pepper plants of high quality were grown to the hardening stage in 37 days in a 6x15-foot electric hotbed. A soil temperature of 70° F. was maintained in the soil. The plants were hardened in the same bed for about two weeks before transplanting to the field.

The box type of thermostat should be embedded in the hotbed soil so that the top of the box is just flush with the surface of the soil.

**How to adjust the thermostat.** Directions on how to make the thermostat adjustment come with the remote-control type of thermostat. Regulation of soil temperature with the box type is accomplished by turning the adjusting knob.

The pilot light shown in Figure 6 is used to simplify the thermostat adjustment. When the pilot light is on it indicates that the thermostat contacts are closed and the power is connected to the heating cable. When the pilot light goes off it indicates that the thermostat has turned off the power to the heating cable. After the thermostat is adjusted, the pilot light can be turned off by unscrewing the lamp slightly.

Figure 8. Starting celery inside the greenhouse with electric soil-heating cable. Two 50-foot sections are used. (Binn Bros., Milwaukie, Oregon.)

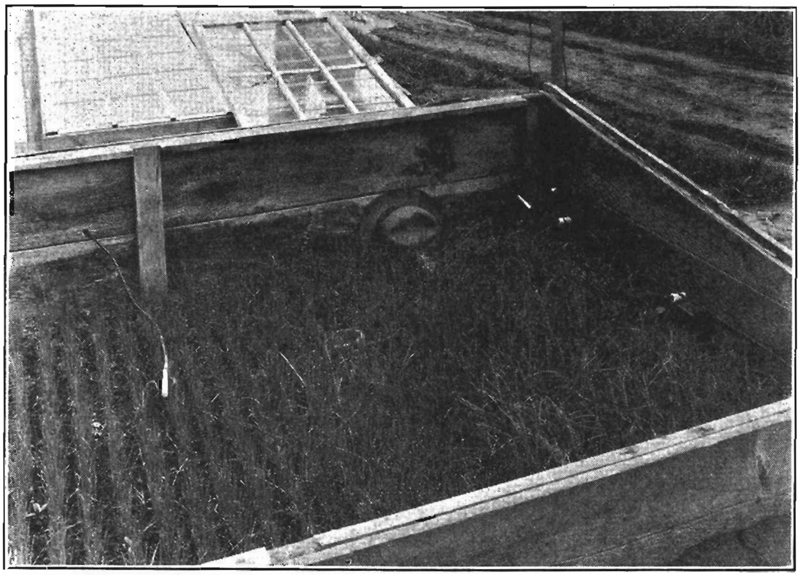

Figure 9. 22,000 Bermuda onion sets grown from seed in a 6x15-foot hotbed at James Gardens, Eugene, Oregon.

A thermometer is essential for regulating the thermostat. The bulb of the thermometer should be at a two- to three-inch depth in the hotbed soil. The thermostat can then be adjusted to regulate the electric heat to the desired soil temperature.

**Temperature distribution in the hotbed soil.** Temperature distribution tests were made of an electric hotbed unit constructed as described on page 13. Copper-constantan thermo-couples were used to determine the temperature of the soil. This made it possible to read the temperatures at any desired depth without disturbing the soil. Recording thermometers were also placed in the hotbed soil, the thermometer bulbs being placed horizontally and at right angles to the cable loop. These thermometer bulbs were located at 3, 4, 5, and 6 inches below the soil surface and were left in these positions throughout the test.

The thermo-couples were spaced 2 inches apart across the bed, starting at a point 4 inches from the border of the bed. Readings of temperatures were taken at each inch of depth to a depth of 9 inches below the soil surface.

TABLE III. TEMPERATURE DISTRIBUTION IN ELECTRIC HOTBEDS
Cable 6 inches below soil surface, 440 watts of heat, outside air tempearture 50° F. Cable spacing 7 inches.

| Time (a.m.) | Recorder temperature at various depths | | | | Depth of thermo-couples | Thermo-couple temperature at various distances from border of bed | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3″ | 4″ | 5″ | 6″ | | 4″ | 6″ | 8″ | 10″ | 12″ |
| | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Inches* | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* |
| 12:22.... | 67.0 | 73.5 | 87.0 | 92.0 | 1 | 60.0 | 60.0 | 62.0 | 60.0 | 59.0 |
| 12:32.... | ...... | ...... | ...... | ...... | 2 | 65.0 | 63.0 | 64.0 | 63.0 | 62.0 |
| 12:42.... | 69.0 | 74.0 | 88.0 | 93.0 | 3 | 70.0 | 67.0 | 69.0 | 68.0 | 65.5 |
| 12:52.... | ...... | ...... | ...... | ...... | 4 | 78.0 | 70.0 | 75.0 | 73.0 | 69.5 |
| 1:05.... | 69.5 | 74.0 | 88.5 | 93.5 | 5 | 80.0 | 72.0 | 80.5 | 77.0 | 72.0 |
| 1:15.... | ...... | ...... | ...... | ...... | 6 | 90.0 | 72.0 | 77.0 | 81.0 | 72.0 |
| 1:25.... | 70.0 | 74.0 | 89.0 | 94.0 | 7 | 82.0 | 71.0 | 69.0 | 74.0 | 69.0 |
| 1:35.... | ...... | ...... | ...... | ...... | 8 | 74.0 | 69.0 | 66.0 | 72.0 | 67.0 |
| 1:45.... | 72.0 | 76.0 | 90.0 | 95.0 | 9 | 65.0 | ...... | 65.0 | 68.0 | 66.0 |

Heat on for 5 hours before start of test.
Air temperature 3 inches above hotbed soil 52° F. throughout the test.

TABLE IV. SUMMARY VALUES OF TEMPERATURE DISTRIBUTION
(From data given in Table III)

| Depth in soil | Maximum temperature difference across bed | Average of temperature at 5 points across the bed | Increase in temperature in each inch of depth | Remarks |
|---|---|---|---|---|
| *Inches* | *Degrees F.* | *Degrees F.* | *Degrees F.* | |
| 1 ........ | 3.0 | 60.2 | ...... | ........ |
| 2 ........ | 3.0 | 63.5 | 3.3 | ........ |
| 3 ........ | 4.5 | 67.9 | 4.4 | ........ |
| 4 ........ | 8.5 | 73.1 | 5.2 | ........ |
| 5 ........ | 8.5 | 76.3 | 3.2 | ........ |
| 6 ........ | 18.0 | 78.4 | 2.1 | Approximate depth of cable |
| 7 ........ | 13.0 | 73.0 | –5.4 | ........ |
| 8 ........ | 8.0 | 69.6 | –3.4 | ........ |
| 9 ........ | 3.0 | 66.0 | –3.6 | ........ |

It is seen from the data in Table IV that in an electric hotbed constructed as recommended in this bulletin there is good temperature distribution in a horizontal plane in the first 3 inches of the soil.

The temperature variation across the bed at 4- and 5-inch depths was found to be as much as 8.5° F. when the heat was on continuously for 5 hours. This is not an excessive temperature variation according to the plant growth in the hotbeds operated during these experiments. There is a gradual increase in the soil temperature as the depth is increased until the depth of the heating cable is reached, following which there is a decrease in the soil temperature at approximately the same rate to the depth of 9 inches.

**Cost of operation and power consumption.** The average power consumption of three 6x15-foot electric hotbeds operated from April 8 to May 23 in Western Oregon was 4.96 Kwh. per day, or .496 Kwh. per square yard per day. Temperatures of 65° to 70° F. were maintained. The hotbed frames were of single thickness of one-inch material of fairly tight construction. No insulation was used below the heating cables, but there was good soil drainage.

The average power consumption during the winter months from January to March in four 6x15-foot hotbeds maintaining from 60° to 70° F. was 12.8 Kwh. per day or 1.28 Kwh. per square yard per day.

When maintaining a temperature of 65° to 70° F. in the hotbed soil power consumption for outdoor electric hotbeds of fairly tight construction, good drainage and covered with glass, may be estimated at 0.5 to 0.7 Kwh. per square yard per day for fall and spring operation and 1 to 1.5 Kwh. per square yard per day for average winter operation in Western Oregon. Little or no power is required during the daytime when there is sunshine. This is an important factor in the total power consumption.

At the foregoing rate of power consumption a 6x6-foot electric hotbed operated in the spring or fall would use 60 to 84 Kwh. per month, which would cost $1.80 to $2.52 at 3¢ per Kwh.

**Some advantages of electric over manure hotbeds are:**

1. Automatic temperature control at any desired temperature.
2. Better quality of plants can be produced because of uniform temperature.
3. Rate of growth of plants can be controlled according to the time they are needed for transplanting.
4. Plants can be grown to transplanting size more quickly.
5. Seasonal job of building manure hotbed is eliminated.
6. Difficulty of obtaining manure for hotbeds is eliminated.
7. Electric hotbeds can be used two or more times in one season.
8. Soil-heating cable costs $5.00 for a 6x6-foot bed and a thermostat costs from $5.75 to $11.00. Hence the electric hotbed is inexpensive to install. The thermostat could be used to control a bed as large as 6 by 24 feet.

The advantages of electric hotbeds over greenhouses for plant growing are as follows:

1. The initial cost of the installation is much less.
2. Extra coldframes for hardening the plants for transplanting are not needed.
3. It is not necessary to use plant boxes or "flats" to grow the plants in the hotbed as is commonly practiced in the greenhouse.
4. Less labor is required to produce plants in hotbeds than in a greenhouse.

The ordinary procedure in growing plants in a greenhouse for transplanting in the field is to start the seed in flats and then transplant the seedlings when they are of suitable size to other flats where they grow until they are moved to the coldframe to be hardened before being set out in the field. Plants are being grown successfully in electric hotbeds by sowing the seed in the hotbed soil without the use of "flats" and growing them to a size ready for transplanting to the field without moving them (see Figure 7). They are hardened in the same place by turning off the electric heat, thus changing the hotbed to a coldframe.

## ELECTRICALLY HEATED PROPAGATING BEDS FOR CUTTINGS

A propagating bed* is similar in construction to a hotbed, arranged to keep a high humidity when necessary and maintain a relatively constant top temperature while roots are forming on cuttings. Hotbed frames covered with glass sash or with various kinds of cloth or with lath are commonly used. Rooting of many kinds of cuttings is hastened by maintaining the sand or rooting media at the base of the cuttings at a warmer temperature than the air surrounding the top of the cuttings. "Bottom heat" is heat thus applied to the soil and has been used in plant propagation for many scores of years. Hot air, hot water and steam have all been used and all are practicable when temperatures are carefully controlled by constant attention.

**Advantages of electrical equipment.** The use of electricity to furnish bottom heat for propagating beds is new, but it has already been used successfully and economically by propagators of evergreens, alpine plants and ordinary soft and hardwood material in Oregon and by others in other regions. Advantages offered by the electric equipment over other equipment for furnishing bottom heat are:

(1) In maintenance of the constant temperatures which have been found best for different material.
(2) In ease of operation.
(3) In the absence of danger of overheating.

*A propagating bed is often called a propagating bench when the bed is arranged on a table or bench as in a greenhouse.

While electric heat has been found advantageous for winter use, it may be even more advantageous for summer use when relatively small amounts of heat are necessary for short periods.

**Equipment recommended** for propagating beds falls into two general classifications. For the small installation a propagating tray 30 by 40 inches in size with a 200-watt heating element strung open under the metal

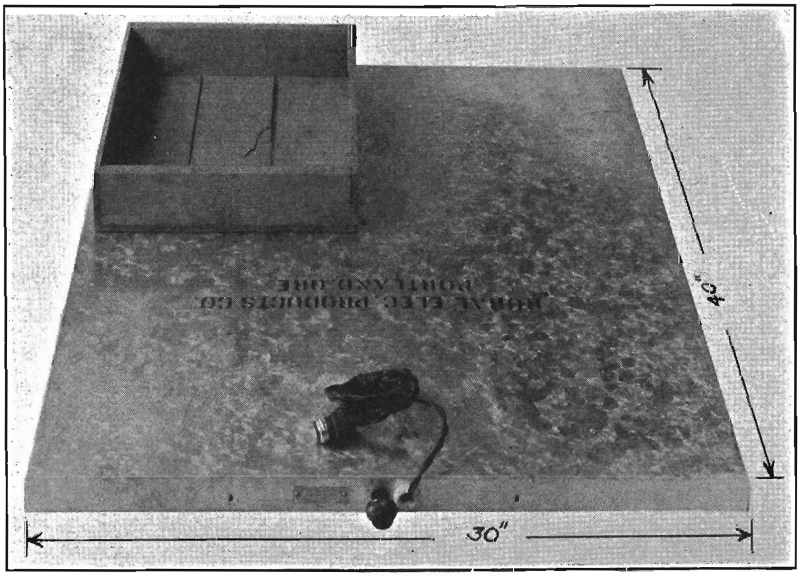


Figure 10. 200-watt thermostat-controlled heater used for propagation of plants from cuttings.

floor of the tray (see Figure 10) is advised for growers who have need for only enough heating surface for four plant boxes. This device is equipped with an adjustable thermostat and is connected by an ordinary lamp cord to any 120-volt outlet. This tray can be set on a bench or table in the greenhouse or used in any location where electricity is available and there is sufficient light to grow plants.

For larger indoor installations standard soil-heating cable is recommended. The bottom of the ordinary greenhouse bench should be covered to the depth of one to two inches with coarse sand, gravel, cinders, or anything that will assure good drainage. The heating cable is laid directly on top of this. The cable should be spaced 6 to 7 inches apart as shown in Figure 11. The soil-heating cable should be covered with sand or other propagating medium to a depth such that the cable will be 4 inches below the base of the cuttings.

It is advisable to insulate the underside of the propagating bench with one or two layers of building paper or close-woven burlap to restrict the loss of heat. This insulation should in no way restrict the drainage of surplus water from the propagating bench. Lath can be used to space the building paper away from the bottom of the bench and provide a dead air space.

The temperature of the propagating bed can be controlled by an electric soil thermostat in the way explained on page 14.

**Making cuttings.** Evergreen cuttings are made from 3 to 8 inches, usually 5 to 7 inches long. They are made by cutting across the wood with

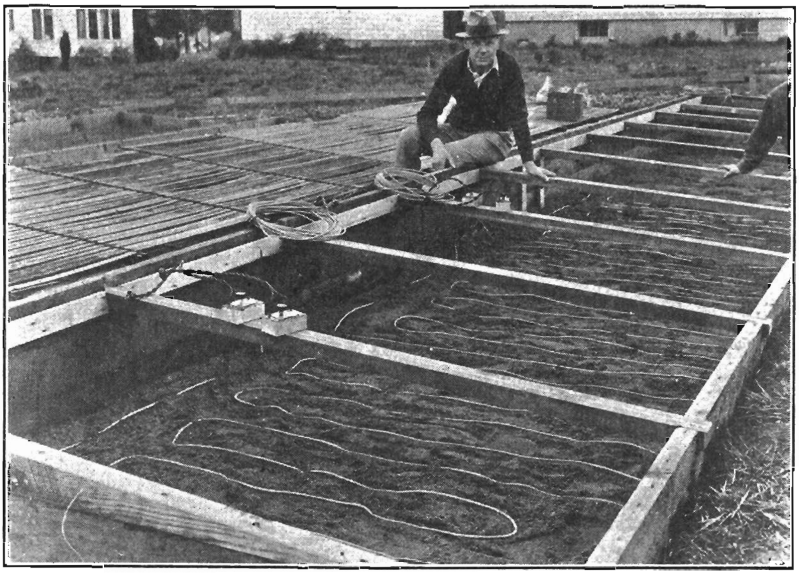

Figure 11. A 6x30-foot electric propagating bed under construction by Theodore Van Veen of Portland, Oregon.

a sharp knife or pruning shears. For most material, the bottom of the cutting should be made just below a bud. The largest cuttings of many evergreens form the best root systems. Heel cuttings formerly favored are not now considered better than ordinary cuttings. The foliage is removed from the lower part of the cutting, leaving several leaves or parts of leaves at the top.*

The cuttings are inserted in the sand so that one-half to three-fourths of the stem is under the soil and are spaced from ½ to 1½ inches apart according to their size. Space should be left so that the sun can reach the sand or rooting media between the cuttings. The cuttings should be packed very firmly in the sand or other medium first with the hand or wooden strip and later by watering down thoroughly.

Little shade is needed in the Northwest in midwinter in most years, as a little sunlight is helpful. Midsummer shading is necessary. The beds should be kept closed most of the day to keep the air moist at all times. Occasionally on material which takes several weeks to root, the bottom

*Farmers' Bulletin 1567, *Propagation of Trees and Shrubs*, U. S. Department of Agriculture.

soil near the cables may dry out, in which case the whole bed should be soaked.

After rooting, the cuttings are usually potted (see Figure 13) or planted in flats. With many evergreens, however, the cuttings may be rooted in flats instead of beds and the cuttings left in the flats until large enough to be transplanted to out-of-door frames.

## EXPERIMENTS WITH EVERGREEN HUCKLEBERRY CUTTINGS

The following pages summarize the observations and experience in the use of six units of electrically heated propagating beds at the Oregon Agricultural Experiment Station.* Three were operated on a green-

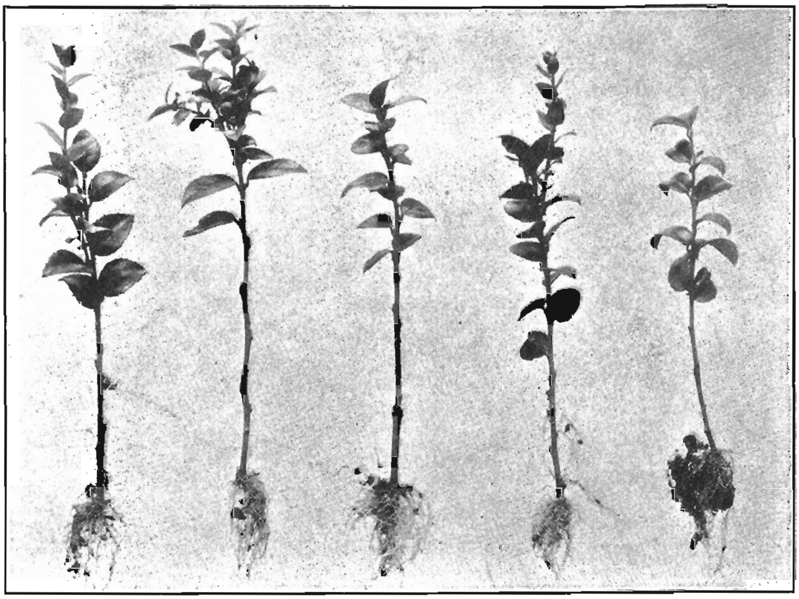

Figure 12. Huckleberry cuttings rooted in electric propagating beds.

house bench, one each at a soil temperature of 60°, 70°, and 80° F., and three were out-of-doors at temperatures of 50°, 60°, and 70° F. These units were chiefly in experiments with the root cuttings of the *Vaccinium ovatum,* the Evergreen huckleberry.

Cuttings 6 to 8 inches long were used. Cuttings with all leaves taken off rarely rooted. Cuttings with 1, 2, 4, 6, and 8 leaves each rooted well, those with 4 to 8 leaves better than those with fewer leaves.

The experiments briefly reported here were made with winter cuttings of the Evergreen huckleberry. Cuttings in all cases were of one-year wood

*These experiments were conducted by Dr. Geo. M. Darrow, Senior Pomologist, United States Department of Agriculture.

collected in the wild near the coast south of Newport. The first collection was made December 5, the second January 28. It was found that the huckleberry was relatively easy to root, the first roots appearing in about a month and a considerable percentage of the cuttings having rooted by the end of two months. By the end of the third month, up to 64 percent had rooted. Both dates were satisfactory for taking cuttings, but cuttings taken at other dates may be found to root still better.

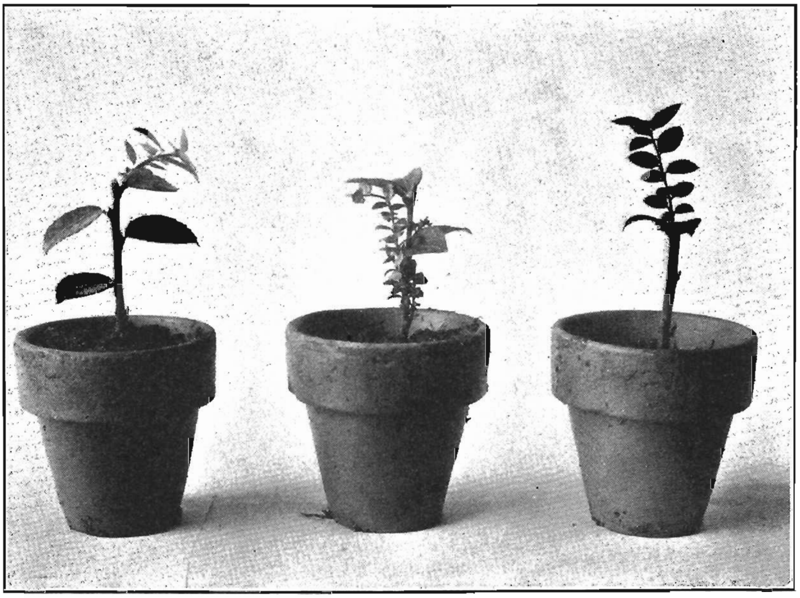

Figure 13. Huckleberry cuttings rooted in electric propagating beds transferred to pots.

As is the common practice with all cuttings, they were kept moist until put in the cutting beds. Tests were made of rooting in seashore sand, river sand and peat, and peat alone, together with tests of no-leaf cuttings, 1-, 2-, 4-, and 8-leaf cuttings, of tip cuttings, and of secondary and basal cuttings, as well as the effects on rooting of temperatures of 50°, 60°, and 70° F. out-of-doors and of 60°, 70°, and 80° F. in the greenhouse.

**Equipment used.** The propagating beds in the greenhouses were placed on benches and covered with 3x6-foot glass sash. The sashes were hinged to the frame for convenience. The ones out-of-doors were coldframes where the sashes were loosely laid on the frame.

Each unit (36 square feet) was heated by a single 60-foot unit of electric soil-heating cable. The temperature was controlled by a thermostat. The cable was placed one inch from the bottom of the bed on a layer of sand with 7½ inches between loops. Both types of thermostats as described on page 6 were used.

By means of recording instruments continuous records were kept for each unit as to soil temperatures, air temperatures, and air humidity. Detailed studies were made as to the variation of temperature in different sections of the bed and at varying depths in the medium.

Records were kept for each unit on consumption of power and the cost of heating each unit under the varying conditions.

**Temperatures maintained.** The greenhouse used in these experiments was held at an average temperature of 59° F. from December 7, 1930, to March 25, 1932. The average temperatures of the propagating beds were taken at 9 a.m. and 5 p.m. at a point four inches below the surface where the cable was eleven inches below the surface with a total depth of sand of twelve inches. These temperatures were:

*Average temperature (Degrees F.)*

60° bed........................ 63°
70° bed........................ 72°
80° bed........................ 79°

For more than 70 percent of the time the temperature in the 60° F. bed was actually between 60° and 65° F. For more than 80 percent of the time the temperature in the 70° bed was actually between 68° and 74° F. For more than 70 percent of the time the temperature in the 80° bed was between 78° and 84°. It was apparent, however, that with more experience in handling the frames and equipment, more uniform temperatures could be maintained. Flats of sand and peat placed in the beds on sand 3 and 6 inches deep over the cable held temperatures close to those in the deep sand.

The out-door electric hotbeds used for propagating beds were old coldframes loosely constructed. For an 8-inch depth of half sand and half peat from February 1 to March 26, the average temperatures, taken as stated before, were as follows:

*Degrees F.*

50° bed........................ 53°
60° bed........................ 62°
70° bed........................ 70°

**Temperature gradient in beds.** In order to determine actual conditions in the beds, temperatures were taken at different depths over the

TABLE V. AVERAGE TEMPERATURES IN BEDS WITH 11 INCHES OF SAND ABOVE CABLE, OUTSIDE TEMPERATURE 67° F.

| | 80° Bed | | 70° Bed | | 60° Bed | |
|---|---|---|---|---|---|---|
| Detph | Over cable | Midway | Over cable | Midway | Over cable | Midway |
| | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* | *Degrees F.* |
| 1 inch | 78.0 | 77.0 | 75 | 76 | 65 | 65.5 |
| 3 inches | 79.5 | 80.5 | 77 | 78 | 62 | 62.0 |
| 5 inches | 83.0 | 83.5 | 79 | 79 | 62 | 62.0 |
| 7 inches | 84.5 | 85.0 | 80 | 80 | 61 | 60.0 |
| 9 inches | 85.0 | 85.0 | 81 | 80 | 62 | 62.0 |
| 11 inches | 93.0 | 87.0 | 83 | 81 | 63 | 62.5 |

cables and midway between the cables. The variations were slight, but greatest on the same level with the cable. On any level more than four inchs above the cable, the heat distribution was fairly uniform.

The records given in Table V were taken when the power was off. A series of temperatures was taken throughout the day with the power on and off as controlled by the thermostat to get the extreme variations in the 70° and 80° beds, which were as follows:

TABLE VI. TEMPERATURE RANGES IN THE 80° F. AND 70° F. BEDS

| Depth | 80° Bed | | 70° Bed | |
|---|---|---|---|---|
| | Over cable | Midway | Over cable | Midway |
| 3 inches | 75 to 78 | 73 to 77 | 79 to 79 | 70 to 76 |
| 7 inches | 81 to 86 | 82 to 86 | 78 to 83.5 | 75 to 80.5 |
| 11 inches | 95 to 121 | 82 to 94.5 | 83.5 to 87.5 | 78 to 83 |

Temperatures taken at the 11-inch depth over the cable were essentially temperatures taken in contact with the cable.

Temperatures taken in the 70° and 80° beds where there were only 5 inches of sand over the cable showed the danger of shallow beds. The power was turned on or off by the thermostat as the records were being taken.

TABLE VII. AVERAGE TEMPERATURES IN BEDS WITH 5″ OF SAND OVER CABLE, OUTSIDE TEMPERATURE 67° F.

| Depth | 80° F. Bed | | 70° F. Bed | |
|---|---|---|---|---|
| | Over cable | Midway | Over cable | Midway |
| 1 inch | 78.0 | 76.0 | 73.5 | 74.0 |
| 3 inches | 88.0 | 82.0 | 79.0 | 77.5 |
| 5 inches | 106.0 | 84.0 | 85.0 | 78.0 |

All cuttings 5 inches deep in the 80° F. bed were killed at their bases if they were close to the cables.

It was concluded that 8 to 11 inches of sand above the cables was advisable to insure relatively uniform temperatures.

Because of (1) the more uniform temperatures desired and (2) the depth of the cuttings, the depth of the sand or other medium should be such that the base of the cutting is at least 4 inches above the heating cable.

It was also evident that the underside of the bench should be screened with building paper or close-woven burlap to restrict the circulation of air and conserve heat.

**Experimental results.** In most of the experiments the Evergreen huckleberry cuttings were placed in flats, 60 cuttings per flat with duplicate flats in each of the 6 beds. Because of damage by a strain of Rhizoc-

TABLE VIII. POWER CONSUMPTION OF PROPAGATING BEDS IN GREENHOUSE

Three 3x12-foot units, each with 60 feet of No. 19 nichrome heating cable, 400 watts at 110 volts. Average greenhouse temperature 59° F.

| Period | Duration | 60° F. Bed | | | 70° F. Bed | | | 80° F. Bed | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Power consumed | Power per day | Power per square yard per day | Power consumed | Power per day | Power per square yard per day | Power consumed | Power per day | Power square per yard per day |
| | *Days* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* |
| Dec. 3-Jan. 4 | 32 | 27.0 | .844 | .211 | 112.0 | 3.50 | .87 | 193.5 | 6.05 | 1.51 |
| Jan. 4-Feb. 13 | 40 | 15.5 | .390 | .097 | 138.0 | 3.45 | .86 | 193.2 | 4.83 | 1.21 |
| Feb. 13-Mar. 25 | 40 | .5 | .0125 | .003 | 128.0 | 3.20 | .80 | 150.8 | 3.78 | .94 |
| *Total* Dec. 3-Mar. 25 | 112 | 43.0 | .384 | .096 | 378.0 | 3.38 | .84 | 537.5 | 4.78 | 1.19 |

TABLE IX. POWER CONSUMPTION OF OUT-DOOR PROPAGATING BEDS

Three 6x6-foot units each with 60 feet of No. 19 nichrome heating cable, 400 watts at 110 volts.

| Period | Duration | 50° F. Bed | | | 60° F. Bed | | | 70° F. Bed | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Power consumed | Power per day | Power per square yard per day | Power consumed | Power per day | Power per square yard per day | Power consumed | Power per day | Power per square yard per day |
| | *Days* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* | *Kwh.* |
| Jan. 16-Feb. 13 | 28 | 13.3 | .475 | .119 | 92.40 | 3.30 | .827 | 167.5 | 5.98 | 1.49 |
| Feb. 13-Mar. 25 | 40 | 10.0 | .250 | .060 | 126.88 | 3.17 | .79 | 139.0 | 3.47 | .87 |
| *Total* Jan. 16-Mar. 25 | 68 | 23.3 | .343 | .086 | 219.28 | 3.22 | .805 | 306.5 | 4.50 | 1.12 |

tonia a considerable number of cuttings were discarded. Comparable records were obtained as follows:

In a comparison of different media the following record was made with Evergreen huckleberry cuttings on March 25:

Peat ............28 rooted, 20 left—58% rooted
Half peat, half sand.........51 rooted, 16 left—76% rooted
Sand ............17 rooted, 31 left—35% rooted

As with so many other evergreens a mixture of sand and peat gave the highest percentage of rooted cuttings.

In regard to the number of leaves per cutting, the following comparative record of the rooting of 90 cuttings of each of six classes was obtained:

| | | |
|---|---|---|
| 0 leaf, secondary cutting | 1 rooted— 1.11% | rooted |
| 1 leaf, secondary cutting | 19 rooted—21.11% | rooted |
| 2 leaves, secondary cutting | 42 rooted—46.66% | rooted |
| 4 leaves, secondary cutting | 58 rooted—64.44% | rooted |
| 8 leaves, secondary cutting | 68 rooted—75.55% | rooted |
| Tip cutting | 53 rooted—58.88% | rooted |

It seems probable that 4 to 8 leaves per cutting is most desirable. The tip cuttings which had 4 to 8 leaves rooted a relatively large number and were probably about equally as good as the 4- to 8-leaf secondary cuttings.

The effect of the temperature of the media on rooting is shown in Table X.

TABLE X. EFFECT OF TEMPERATURE OF THE MEDIA ON ROOTINGS

| Temperature | Rooted | Not rooted | Percentage rooted |
|---|---|---|---|
| | | | % |
| *In greenhouse* | | | |
| 80° F. | 46 | 32 | 59 |
| 70° F. | 64 | 19 | 77 |
| 60° F. | 56 | 39 | 59 |
| *Out-door frames* | | | |
| 70° F. | 42 | 85 | 33 |
| 60° F. | 49 | 40 | 55 |
| 50° F. | 5 | .... | .... |

The 80° F. temperature may have been too high; however, if Rhizoctonia had been controlled, there were early indications that it might have been satisfactory. In these tests, the 70° F. bed in the greenhouse gave the highest number rooted after 3 months and 18 days. This temperature was readily maintained by the equipment used, but until more is known of the best temperature for rooting different kinds of cuttings, it is impossible to recommend any one temperature.

## EXPERIMENTS WITH FILBERT CUTTINGS*

Nine hundred hardwood cuttings of filberts (*Corylus avellana*) were made December 5, 1931. These cuttings were 6 to 9 inches long. One-half of this number were placed in .001 percent solution of manganous chloride for 24 hours, and the remainder were left untreated.

In each unit, part of the cuttings were placed in deep sand and part in shallow sand. Equal numbers of treated and untreated cuttings were used in each section.

Out of the 900, 3 cuttings rooted. Those in the 80° F. bed calloused first and had the first leaf growth. In this bed a great many were dried out or overheated by being placed too close to the cable. Under lower temper-

*These experiments were conducted by C. E. Schuster, Horticulturist, United States Department of Agriculture.

ature the callousing was slower and leaf growth was later, with a consequent longer life in the propagating beds. The cuttings in the beds out of doors were much slower in reaching the same stage of development reached by the cuttings in the greenhouse.

Recently some new information on propagation by cuttings has become available. In tests of different rooting media a mixture of half sand and half peat is favored for many evergreens and coincides with our experience as given on page 25. This mixture is well aerated and holds moisture well. It is sufficiently acid for the rooting of rhododendrons, azaleas, the blueberries or huckleberries and other plants which require acid soil. Clean river sand is still preferred for some plants, while cinders have given good results with others.

## EXPERIMENTS WITH OTHER CUTTINGS

Small numbers of cuttings of varieties of the Eastern blueberry, *V. carymbosom*, cuttings of the Florida blueberry, *V. virgatum*, and of the red huckleberry, *V. pariolium*, were taken December 7 and tested in some of the same frames.

In the 60° F. frame outside in sand, 9 red huckleberry cuttings were rooted and 40 were not rooted. In the 70° F. frame inside, 24 Eastern blueberries were rooted and 24 were not. In the 60° F. frame 15 were rooted and 53 were not. In the 70° F. frame inside, 6 Florida blueberries were rooted and 1 was not.

## RESULTS WITH ELECTRIC PROPAGATING BEDS REPORTED BY GROWERS

A large number of electrically heated propagating beds have been installed by growers since equipment became available for this purpose. Most of these growers are specializing in ornamental shrubs and therefore have had experience in the use of this equipment in propagating ornamentals from cuttings. This section reports some of the findings in regard to the propagation of various plants from cuttings.

*Gardenias* have rooted in six weeks that formerly required six months with greenhouse methods. Soil temperature of 80° F. and clean sand were used.

*Rosa Rouletti*, an Alpine rose, formerly required all winter to root in a greenhouse. Put in electric hotbed on November 30, the cuttings were ready to be transferred into pots for market on January 1. In addition, each cutting struck.

*Viburnum Carlessi*. This fragrant, slow-growing viburnum that never rooted before in the greenhouses rooted with bottom heat. Similar results with two Alpines—*Romanda* and *Haberli*.

*Daphnes* have lost their leaves and required from three to six months to root 50 percent in heated greenhouses. In electric hotbeds they were rooting 100 percent in 45 days.

*Magnolias* have rooted in 60 days, camellias in 45 days. Many of the *rock plants* have rooted in two weeks.

*Junipers* and some of the evergreens that have taken from six months to two years in heated greenhouses, have definitely rooted in a month and a half in beds with bottom heat.

*Rhododendrons* in electric hotbeds will root in from 45 to 90 days, according to the variety and the condition of the cuttings. Cuttings from old wood have taken longer. Best media are peat and sand.

The shrubs that are easily rooted take from two weeks to a month. These include Laurustinus, Pyrocanthea, Hydrangea, Laurel, and other evergreen and deciduous shrubs.

## OPEN OR FIELD SOIL HEATING

Investigations have been conducted by different experimental agencies to determine the cost and value of electric heating of soil in the open under conditions of field production. Many private growers also have used electric soil-heating cable to force plants being grown in the open. More heat is required, thus increasing the costs. Open field heating is largely in the experimental stage at the present time (1932) although some very striking results have been obtained.

According to Emsweller and Tavernetti in their report on *The Effect on Gladioli of Heating the Soil with Electricity,** the Prince of Wales variety in University of California studies opened on April 22 in a heated plot, whereas in the check plot (unheated) it did not begin blooming until May 8. By this time 90 percent of the plants in the heated plot had bloomed. The Shaylor variety bloomed somewhat later in the heated plot than the Prince of Wales. The first flower opened on April 26 while in the check plot the first flower opened May 15. By this time 80 percent of the plants in the heated plot had bloomed. It was also found that the heated plots produced larger corms and a higher yield of cormels. This was particularly true of the Prince of Wales variety.

Experiments have been conducted at the Western Washington Experiment Station in cooperation with the Puget Sound Power and Light Company at Puyallup, Washington, during 1931 and 1932. In the 1932 experiments the beds were covered with a very cheap grade of unbleached muslin supported by a wooden frame and water-proofed with a commercial preparation for this purpose. This experiment has therefore been somewhat changed from entirely open-field heating to the use of an inexpensive covering of the plots in order to reduce the amount of heat required. In the experiment to determine the effect of electric heat on the blooming of narcissus it was found that the blooms from the heated plot were 12 to 19 days earlier but the most outstanding result was in the finer quality of the flowers. Tomatoes, rhubarb, and asparagus were planted in plots similar to the narcissus.

Tests of open-field heating of soil with electricity in Oregon have included narcissus, Dutch Iris, and celery. The tests will be continued in order to determine more definitely the costs and increased value of the crop before recommendations can be made.

*Progress Report No. 17, California Committee on Relation of Electricity to Agriculture.

## ACKNOWLEDGMENTS

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F. A. Cuthbert, M.L.D.....Assistant Landscape Architect
B. S. Pickett, M.S.....Assistant Horticulturist (Pomology)
D. Cooter.....Orchard Foreman

Plant Pathology

H. P. Barss, S.M.....Plant Pathologist in Charge
S. M. Zeller, Ph.D.....Plant Pathologist
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L. N. Goodding, B.A., B.S.....Associate Plant Pathologist*
F. P. McWhorter, Ph.D.....Associate Plant Pathologist
P. W. Miller, Ph.D.....Associate Plant Pathologist, Hor'l Crops and Diseases*
G. R. Hoerner, M.S.....Agent Office of Drugs and Related Plants*
T. P. Dykstra, M.S.....Assistant Plant Pathologist*
R. Sprague, Ph.D.....Assistant Pathologist*
H. H. Millsap.....Agent, Bureau of Plant Industry*

Poultry Husbandry

A. G. Lunn, B.S.....Poultry Husbandman in Charge
F. L. Knowlton, B.S.....Poultry Husbandman
F. E. Fox, M.S.....Associate Poultry Husbandman

Publications and News Service

C. D. Byrne, M.S.....Director, News Service
E. T. Reed, B.S., A.B.....Editor of Publications
D. M. Goode, B.A.....Associate Editor of Publications
J. C. Burtner, B.S.....Associate Director, News Service

Soil Science

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C. V. Ruzek, M.S.....Soil Scientist (Fertility)
M. R. Lewis, C.E.....Irrigation and Drainage Engineer, Division of Irrigation*
R. E. Stephenson, Ph.D.....Associate Soil Scientist
E. F. Torgerson, B.S.....Assistant Soil Scientist

Veterinary Medicine

B. T. Simms, D.V.M.....Veterinarian in Charge
W. T. Johnson, D.V.M.....Poultry Pathologist
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R. Jay, Ph.D.....Associate Veterinarian, Bur. of Anim. Ind.*
E. M. Dickinson, D.V.M.....Assistant Poultry Pathologist
F. M. Bolin, D.V.M.....Assistant Veterinarian
O. H. Muth, D.V.M.....Assistant Veterinarian
O. L. Searcy, B.S.....Technician, Veterinary Medicine

Branch Stations

D. E. Stephens, B.S.....Superintendent Sherman County Br. Expt. Station, Moro
L. Childs, A.B.....Superintendent Hood River Br. Expt. Station, Hood River
F. C. Reimer, M.S.....Superintendent Southern Oregon Br. Expt. Station, Talent
D. E. Richards, B.S.....Superintendent, Eastern Oregon Br. Expt. Station, Union
H. K. Dean, B.S.....Superintendent Umatilla Br. Expt. Station, Hermiston
O. Shattuck, M.S.....Superintendent Harney Valley Br. Expt. Station, Burns
A. E. Engbretson, B.S...Superintendent John Jacob Astor Br. Expt. Sta., Astoria
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