September 1937 CIRCULAR 183

AGRICULTURAL EXPERIMENT STATION

KANSAS STATE COLLEGE OF AGRICULTURE
AND APPLIED SCIENCE

MANHATTAN, KANSAS

DEPARTMENTS OF HORTICULTURE AND AGRICULTURAL
ENGINEERING

PICTURE TAKEN ON THE FARM OF MR. A. A. VANDEKERCHOVE IN WYANDOTTE COUNTY.

HOTBEDS FOR KANSAS[1]

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USE OF HOTBEDS

Many vegetable plants are started in specially prepared beds and the young plants later transplanted into the field or garden. Among the crops started in this way are cabbage, cauliflower, Brussels sprouts, celery, tomato, eggplant, pepper and sweet potato. The advantages in starting plants in hotbeds include: (1) increasing the length of the growing season by planting

1. Contribution No. 139 from the Department of Horticulture and No. 81 from the Department of Agricultural Engineering.

2. Credit is given to C. A. Logan, a former member of the staff in Agricultural Engineering, who supervised the studies on the electric hotbeds in 1933, and to Walter C. Hulburt who took the data on these projects during the years 1934 and 1935.

seeds several weeks before weather would permit of outdoor planting; (2) making it possible to grow long-season, tender crops such as tomato, pepper, eggplant, melons, and even lima beans in regions having a relatively short growing season; (3) production of an earlier crop, thereby getting advantage of the early market; (4) enabling gardeners to produce a larger number of crops on the same land; (5) protecting young plants from unfavorable conditions, disease, wind, and insect injury; (6) obtaining larger yields of many crops especially the tender, long-season plants, such as tomato, eggplant, pepper, melon, cucumber, and lima bean, which continue to bear until killed by frost.

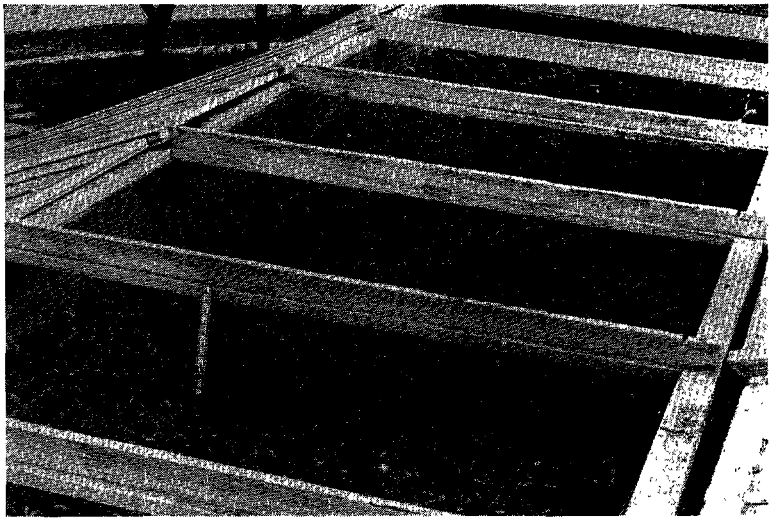

FIG. 1.—A well constructed hotbed used for starting tomato and cabbage plants.

The principal use for hotbeds (fig. 1) is for starting plants to be grown in the garden or field, although they are used to a considerable extent to grow crops to maturity out of the normal growing season. Before greenhouses came into such general use, nearly all market gardeners depended on hotbeds for starting plants such as cabbage, tomato, eggplant, and pepper.

LOCATION OF HOTBEDS

The main considerations in locating hotbeds are: (1) nearness to buildings so they can be cared for with the least trouble; (2) proximity to a reliable water supply; (3) protection from the cold winds by locating them on the south or southeast side of a hill, on the protected side of buildings, or in places protected by board fences or walls. Where no suitable protection is already available, a light fence about 5 feet high is often constructed on the north and west sides of the frames. (Fig. 2.)

Southern and southeastern exposures are preferable because beds will secure more sunshine with these exposures than with others. Where there are several rows of frames, they should be parallel to each other, with ample space between the rows for the handling of the sashes and mats. Eight to ten feet of space between the rows of frames is desirable, if the land is not too valuable.

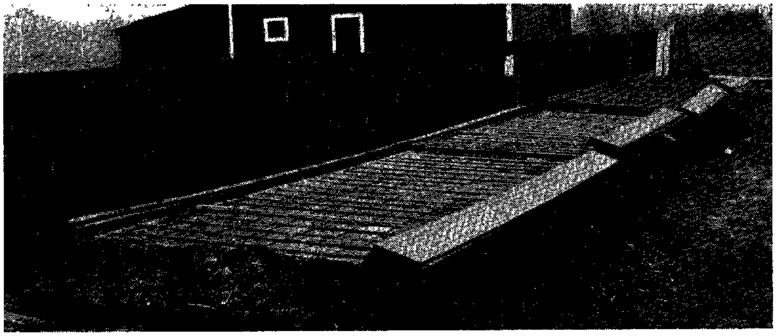

FIG. 2.—A manure-heated hotbed protected by a board fence.

CONSTRUCTION OF HOTBEDS

The Hotbed Pit.—Many hotbeds are heated by the fermentation of horse manure in pits made for the purpose. The pit should be well drained so that water will not collect in it and prevent fermentation of the manure. The pit should be about the same width as the frame, which is usually 6 feet, although it will sometimes carry two rows of hotbed sash sloping in opposite directions. The depth of the pit depends on the length of time the bed is to be used, the longer THE period the deeper the pit should be because more manure is needed for a hotbed to be used for three months than one used only for one or two months. Most pits are 24 to 30 inches deep. For starting tomato, eggplant, and pepper plants, more manure is needed than for cabbage, lettuce, and celery plants, because the latter crops do not require as high temperatures as the former.

The Hotbed Frame.—The frame (fig. 3) may be made of brick, stone, wood, or concrete, the last two materials being the more common. Where wood is used in making a permanent hotbed, 2-inch by 4-inch lumber is used for posts. These posts are driven into the ground at the corners of the bed and at intervals of 4 to 6 feet along the sides of the bed. Boards or planks are nailed to these posts. It is desirable to use a double layer of 10-inch boards or one layer of 2-inch planks for the frame. The frame may or may not extend to the bottom of the pit, but in any

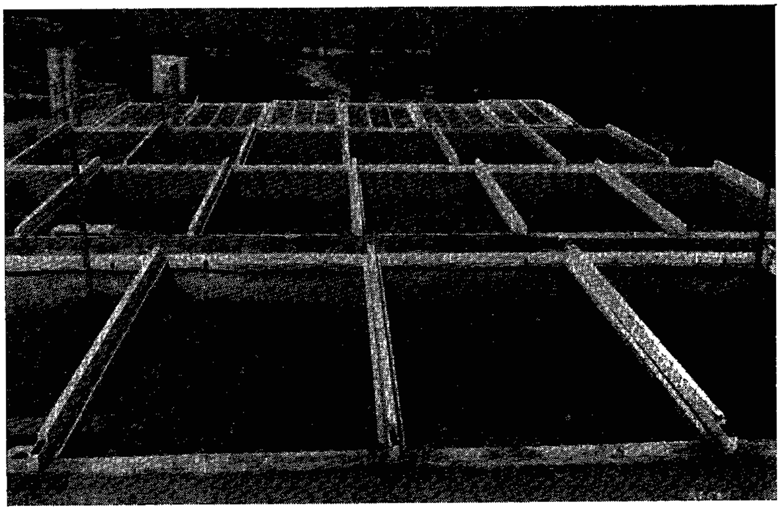

FIG. 3.—General view of the hotbeds used in the experiment. Side walls are made of concrete.

case it should extend 12 to 18 inches above the surface of the ground on the rear side (usually the north side) and 6 to 12 inches on the front, thus affording a south slope. Every 3 feet a crossbar or slide should be placed for the sash to rest upon. For these cross bars 2-inch by 3-inch pieces are satisfactory. A 1½-inch strip nailed in the center of these crossbars to prevent binding of the sash is an advantage. In all permanent hotbeds durable wood should be used. Cedar, locust, or hedge for the posts and cypress or redwood for the frame are satisfactory. Concrete is being used by many gardeners for hotbed frames. This is much more durable than wood and is cheaper in the long run. In making frames of concrete, the mixture is placed in forms in the usual way.

Sash.—Only the most durable wood should be used in making hotbed sash. Cypress and cedar are popular for this purpose. Sashes differ in size, but the most common size is 3 by 6 feet. A larger sash is too heavy to handle and is more subject to breakage. Most gardeners buy the sash already made, and this practice is usually wise, although it is advisable to inquire into the type of construction and the wood used.

The sash should be painted before being glazed. A good grade of glass is always desirable. The glass is generally lapped about 1/8 inch. Some prefer to butt the glass, but if the ends do not fit closely there will be considerable heat leakage. Each 3- by 6-foot sash is usually made for three rows of 10- by 12-inch glass, requiring 18 panes for each sash. Putty is applied in the rabbet of the sash bar, then the glass is pressed into it and held in place by glazing points. These materials prevent water from running down under the glass. After glazing, the sash should be painted again. Each year a coat of paint should be given to protect frames and sash against decay.

Hotbed Covers.—The hotbed covered with sash needs some protection during cold weather, especially when the sun is not shining. It is necessary to cover the beds every cold night and sometimes during the entire day in early spring, especially for tender plants, such as tomato, eggplant, pepper, and melon. Old matting, carpets, or heavy burlap may be used, but straw mats or loose straw are more commonly used. The mats are available from dealers in garden supplies, but they may be woven at home. (Fig. 4.)

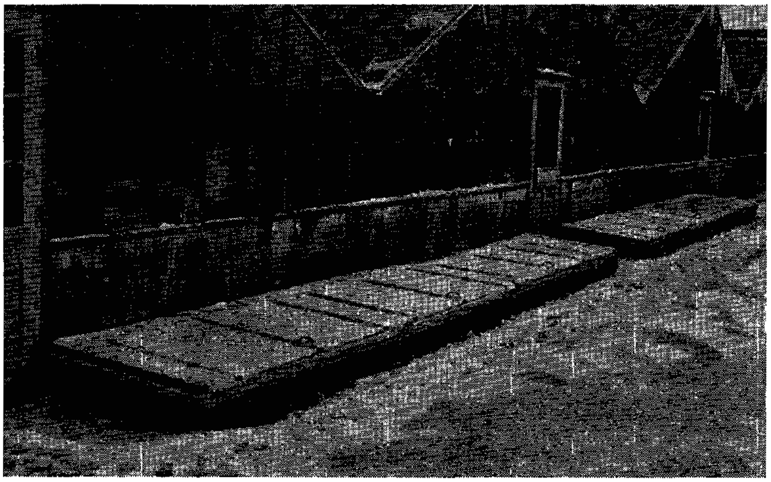

Fig. 4.—Covers which during cold weather may protect the plants and save large amounts of heat.

MANURE-HEATED HOTBEDS

Fresh horse manure is used to a large extent for heating hotbeds, although steam, hot water, hot air, and electricity are also used. The manure must be fairly fresh or very little heat will be generated, Two parts excrement to one part straw or other litter will give good results. Manure with wood shaving or saw dust as a litter is not satisfactory. Horse manure is preferable, although other manures are used.

Preparation of manure for the hotbed should begin 10 days to 2 weeks before the beds are to be needed. If fresh manure from the stable is used, it should be placed in a flat pile about 4 feet high, 5 to 6 feet wide, and the desired length. If dry at the time of piling, the manure should be moistened in order to start fermentation. Chicken droppings are sometimes added to start fermenting. In two or three days the manure should be turned to insure uniform heating throughout. In turning the manure, that from the interior of the pile should be placed on the exterior of the new pile. Two or three days after turning, the manure should be in condition for placing in the pit. (Fig. 5.)

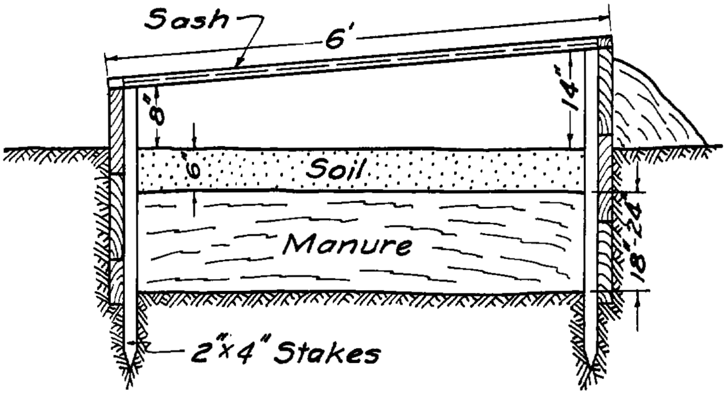

FIG. 5.—Cross section of a manure-heated hotbed with wooden walls.

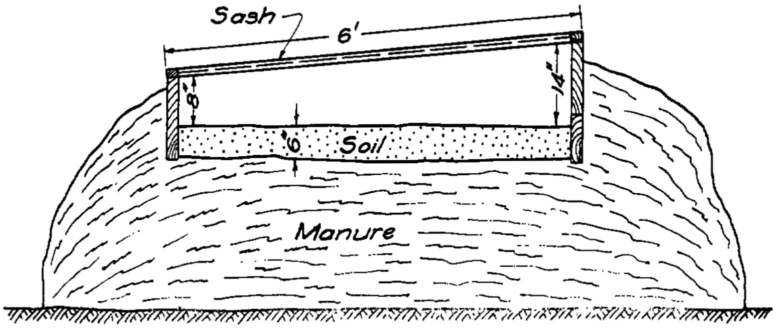

FIG. 6.—Cross section of a temporary manure-heated hotbed.

When filling the pit, the manure should be thrown in layers of 5 or 6 inches and each layer tramped well, especially along the sides and ends of the pit. The manure will settle several inches and allowance should be made for this. Sometimes a layer of 3 or 4 inches of straw is put over the manure in order to have a more even distribution of heat and prevent "hot spots" in the soil. A layer of 4 to 6 inches of sandy soil is put on the manure or straw, although 2 inches of soil is sufficient if the seeds are sown in flats instead of in the soil of the bed.

Temporary hotbeds (fig. 6) are made by placing the frames on the top of a pile of fermenting manure. The frames are usually banked with manure as protection from cold. More manure is required where the frame is set on the pile, because the pile must be considerably wider and longer than the frame. This type of hotbed is desirable only where drainage is poor and manure abundant.

FLUE-HEATED HOTBEDS

Hotbeds may be heated by hot air (figs. 7 and 8) conducted through flues from a fire box located at one end of the beds as illustrated in figure 8. Wood, coal, gas, or oil may be used as fuel, though wood is most commonly used.

A common type of open flue-heated bed used in Kansas is 6 feet wide and 30 feet long. A fire box is built at one end,

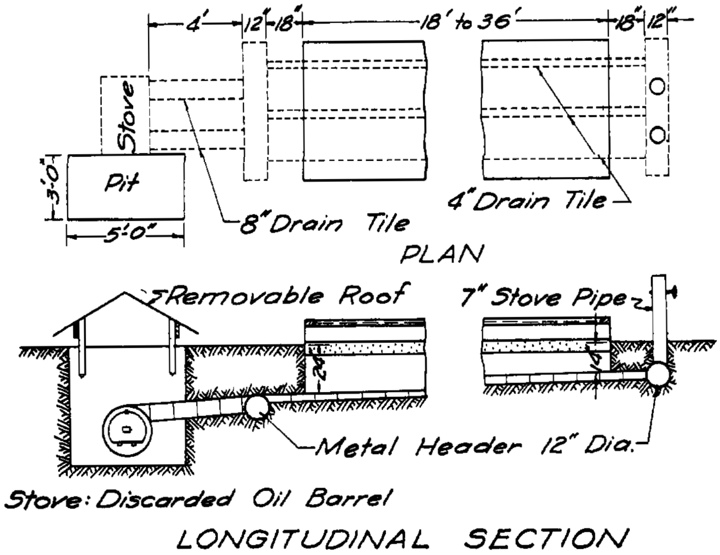

FIG. 7.—Plan and longitudinal section of a flue-heated hotbed showing oil barrel, stove, and sheet iron headers.

preferably at the end facing the cold winds, and deep enough to insure a good circulation of air under the bed. An oil barrel makes a desirable fire box for a flue-heated bed of 20 to 30 feet in length. (Figs. 7 and 8.) The fire box can also be constructed of bricks or concrete blocks and with these materials a rectangular shape could be used. The size of the fire box could be larger than the ordinary oil barrel.

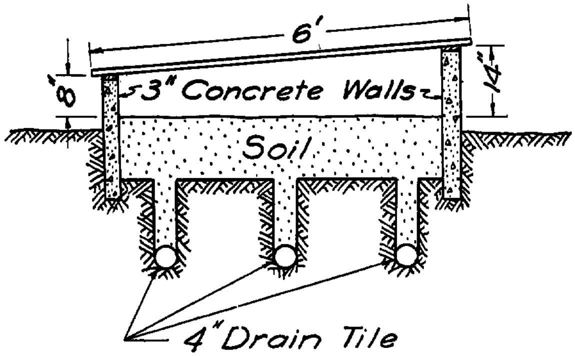

FIG. 8.—Cross section through a flue-heated hotbed showing the four-inch drain tile.

The important requirement of the fire box, regardless of the materials of which it is constructed, is a good, tight-fitting door and a draft adjustment on the door to control the amount of air entering the fire box. During mild weather the fire can be controlled and the heat reduced by reducing the draft on the fire.

The hot air from the fire box passes through two 8-inch pipes to a drum or header which is 12 inches in diameter and 6 feet long. The purpose of this header is to equalize the flow of warm air and distribute it more evenly through the flues under the bed. This header may be made of sheet metal and in this case would be circular in shape. It could also be constructed of concrete in which case it would be easier to make with a rectangular shape. (Fig. 9.) For permanence the concrete and tile are to be recommended in preference to the sheet metal. It is also believed that the concrete construction would be more nearly within the ability of the average grower.

After leaving the header, the hot air passes through three flues made of 4-inch drain tile (fig. 7) which are laid beneath the bed. In order to provide draft, these flues are given a gradual slope upward toward the end opposite the fire box. The depth of soil over the flues is usually from 24 inches at one end to 14 inches at the other. This depth in the soil is necessary in order to allow the heat to spread and heat the surface evenly. At the upper end the tile flues connect to a header similar to the one described at the opposite end. From this header a stove pipe or chimney extends upward to a distance of 5 to 6 feet in order to give added draft to the fire. Added height to the chimney may be needed in the longer beds to give the necessary draft. A damper should be installed in the chimney pipe to permit reducing the draft when this is desirable.

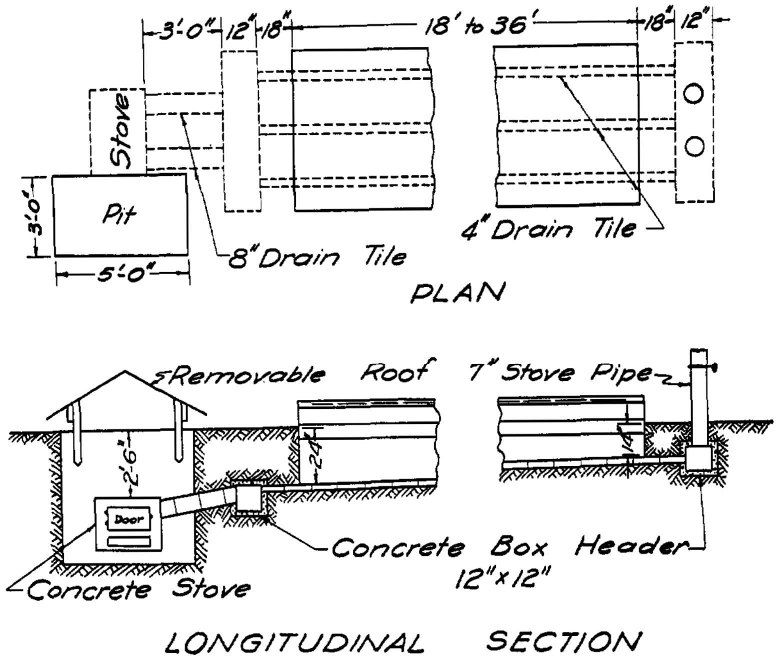

FIG. 9.—Plan and longitudinal view of flue-heated hotbed showing concrete stove and headers.

The smoke and hot air from the fire box pass through the tile and out through the chimney, warming the soil as they pass along. When the fire is first kindled, most of the smoke is likely to come out of the fire box door until enough heat is produced to cause a draft through the flues.

The flue-heated bed is able to maintain proper temperatures in the bed during the spring growing season. The rate of firing must be adjusted to the coldness of the weather and the kind of fuel may also be dependent upon the amount of heat needed. Cobs or scrap wood may be used but good quality wood will reduce the time and labor required to keep the fire going. With the flue-heated bed, the fire should be started a week or ten days before planting in order to bring the soil up to the desirable temperature.

HOT WATER-HEATED HOTBEDS

A hot water circulating system is in many respects an ideal method of heating hotbeds. Since the installation of a hot water heating system is much more expensive than other systems, it is not treated in this bulletin. Where greenhouses or other structures are heated by hot water, it is often possible to extend the system of pipes and use the same boiler for heating the hotbeds.

THE ELECTRICALLY-HEATED HOTBEDS

The use of electricity to heat hotbeds is a development of the last 10 years. Although this method of heating has been used quite extensively in other states and foreign countries, it has made but little progress in Kansas. The first electrically-heated hotbeds used by the Kansas State College were installed in 1932 by the Department of Horticulture, cooperating with the Department of Agricultural Engineering and the Kansas Committee on the Relation of Electricity to Agriculture. These beds have been used during the past six seasons to determine whether they are practical and under what conditions they can be recommended to the growers in Kansas.

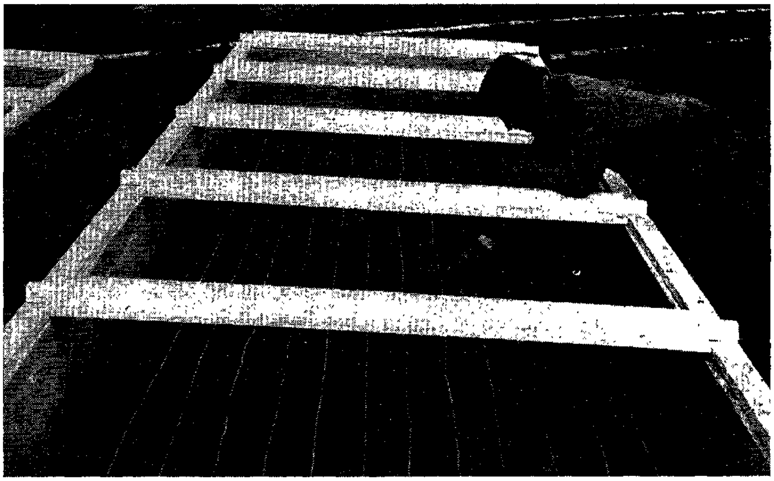

FIG. 10.—An electrically-heated hotbed with cable in place and ready for covering with six inches of soil.

How Electricity Heats the Soil.—Heat is supplied to the soil of the hotbed by means of flexible, insulated, lead-covered wire which has been manufactured for this purpose. (Fig. 10.) The wire or cable is so made that a proper amount of heat is furnished for hotbed heating when 60 feet is connected to a standard 110-volt circuit. The cables are laid in the soil near the plants to be grown, and the current turned on to produce the heat. A 60-foot length of wire is enough to heat the soil under average conditions in a 6-foot by 6-foot bed, of 36 square feet.

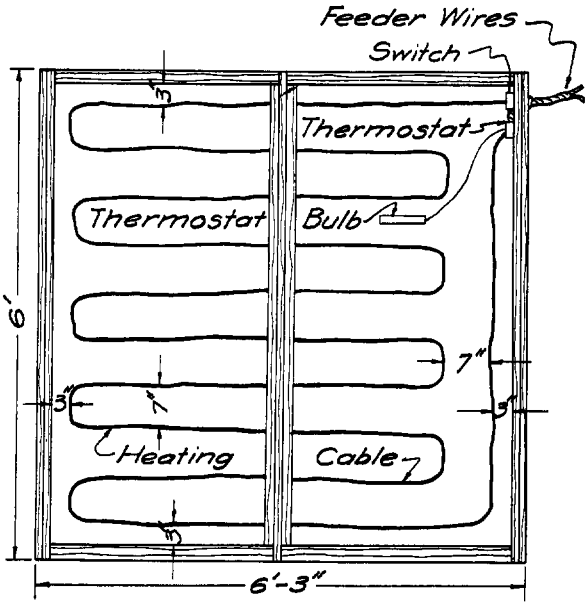

FIG. 11.—Standard spacing of sixty-foot cable in 6-foot by 6-foot bed with 110-volt circuit.

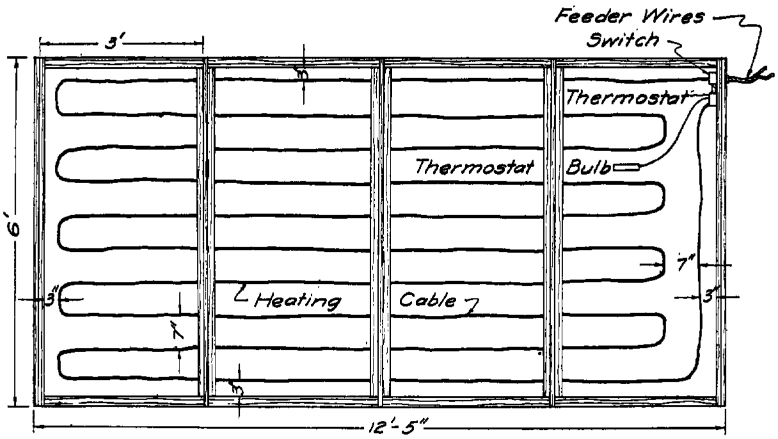

FIG. 12.—Standard spacing of 120-foot cable in 6-foot by 12-foot bed with 220-volt circuit.

If 220-volt current is used, a 120-foot length of wire should be used, which is adequate for a bed of 72 square feet. (Fig. 11.)

How to Control the Heat.—A greater or lesser amount of heat per square foot may be secured by varying the spacing of the cable in the soil. A wide spacing of the cable will distribute the heat over a larger area, while of course a closer spacing will give greater heat per unit area and permit growing plants under colder weather conditions. The closer spacing of cable is more expensive to install and uses more electric energy per bed. Figure 12 shows a standard spacing of a 120-foot length of cable in a 6-foot by 12-foot bed, with wires parallel and 7 inches apart over most of the area. This arrangement of cable will give enough heat for any weather conditions in Kansas if the beds are properly covered. A 10-inch spacing was found to be adequate during the months of March and April at Manhattan during the seasons 1936 and 1937. With this spacing, 120 feet of cable was adequate for a bed 6 by 18 feet.

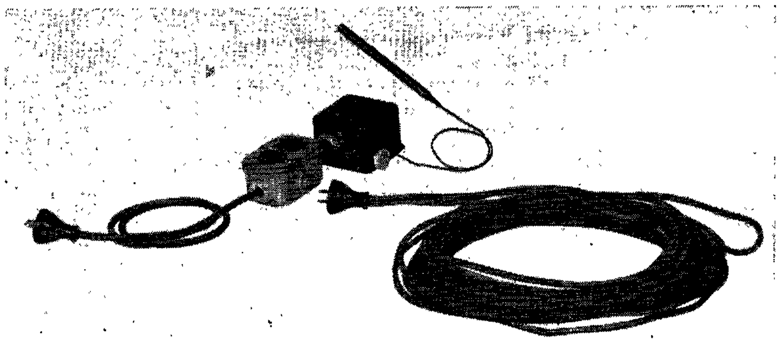

FIG. 13.—Essential parts of an electrically-heated hotbed unit. This can be purchased as a unit from electric supply stores. It consists of at least 60 feet of cable, a thermostat, plug, and switches.

Another method of controlling the heat is by turning off the current when heat is not needed. This may be done by hand or automatically by a thermostat. (Fig. 13.) The thermostat can be set to control the temperatures in the soil or air above the bed within narrow limits. For example, it can be set to turn on the current when temperatures fall to 40 degrees and to turn it off when they rise to 50 degrees, although a slightly higher temperature is desirable for a few days after sowing the seeds. By setting the thermostat, the grower is free from worry about proper temperature control. Although it is possible to turn the current on and off by hand and secure good temperature control, the use of a thermostat would probably be a good investment because of the saving of electricity. For a small hotbed, a thermostat would probably not be justified, but for any installation in a large bed or several beds, a thermostat will save enough current to pay for itself. Table I shows the effect of hand control on bed temperatures and current consumed. In the hand-controlled beds the temperature was higher and more electrical energy was used than in those where the current was controlled by thermostat.

TABLE I.—EFFECT OF HAND CONTROL AND AUTOMATIC THERMOSTAT CONTROL ON ELECTRIC ENERGY CONSUMPTION (1932)

Period of test.	Bed.	Av. Temperatures. Soil in bed.	Av. Temperatures. Air in bed.	Av. Temperatures. Outside air.	Total K. W. H.	Cost at 3c per K. W. H.	K. W. H. per day.	K. W. H. per day per 3'x6' sash.
Jan. 18—Feb. 18, 31 days	3'x21' Small beds, hand control	......	61.0	32.3	507	$15.21	16.3	4.66
	3'x21' Thermostat control	......	56.0	32.3	424	12.72	13.6	3.88
Feb. 18—Mar. 19, 30 days	3'x21' Small beds, hand control	......	61.7	35.6	382	11.46	12.73	3.63
	3'x21' Thermostat control	......	56.1	35.6	306	9.18	10.2	2.90
Mar. 19—Apr. 11, 23 days	3'x21' Small beds, hand control	......	70.8	53.6	135	4.03	5.87	1.67
	3'x21' Thermostat control	......	68.5	53.6	114	3.42	5.0	1.43
Nov. 12—Dec. 27, 45 days	6'x18' No. 1 Electric, hand control	65.3	49.4	32.7	858	25.74	19.0	3.16
	No. 2 Electric, Thermostat control	67.2	56.7	32.7	754	22.62	16.7	2.78

Depth of Heating Cable in the Soil.—The standard installation for the heating cable is 6 inches below the surface of the soil in the hotbed. (Fig. 14.) In this location the cable is below the depth of ordinary cultivation, although care must be taken when spading or removing soil from the bed. By placing the cable nearer to the surface, a saving of electric energy can be effected if the bed is carefully protected by coverings during cold weather. During the springs of 1935, 1936, and 1937, heating cable was laid on top of the soil between the rows of plants. With this arrangement there was less energy consumed and a larger number of salable plants produced than with the cable placed 6 inches deep. The cable on top of the soil is a nuisance in planting and cultivating. It is very likely to be damaged by garden tools and there is also a serious danger of electric shock when the insulation of the cable is cut through. The location on the surface is not recommended, although savings in electricity may be possible. (Fig. 15.)

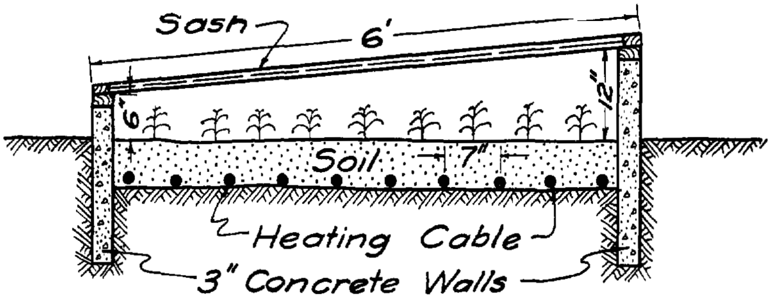

FIG. 14.—Cross section of an electrically-heated hotbed showing cable six inches below surface of soil.

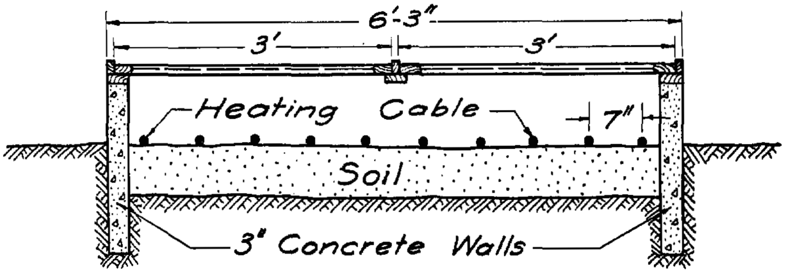

FIG. 15.—Sectional view showing cable on surface of soil. The cable should be parallel with the rows of seedlings.

THE INSULATION OF THE HOTBEDS

Because heat from electricity represents cash, the problem of preventing losses of heat is an important one. Heat is lost into the soil and upward through the glass into the colder air. Some experimental work has been done on the desirability of using cinders or sand under the bed to reduce the loss of heat. Little evidence is available to show that this is valuable. If drainage conditions require a gravel or cinder base this layer should be put under the bed, but it would hardly be needed for insulation.

Loss of heat through the side walls is large. This can be decreased by putting the hotbed as low in the ground as possible. The south side should be not more than 6 inches above the ground, while the north should be 12 inches. Banking the space around the bed with straw would prevent loss of heat through the walls. However, in 1934 the banking of the side walls with straw did not result in any noticeable saving of electricity.

Much saving of heat can be effected by the use of covers over the glass. The loss of heat is quite rapid upward through glass and any use of electric heating in cold weather should be accompanied by the use of covers. The covers are kept on the beds in cold weather or whenever the sun is not shining, and especially at night. These covers may be constructed of straw and burlap to form a quilt. A coarse matting is available for this purpose and is sold on the market.

Covers made of Celotex cut into 3-foot by 6-foot sizes to fit one sash were used with success at Manhattan. The Celotex was water-proofed with two coats of asphalt to prevent water absorption and to act as a preservative.

COMPARISON OF FLUE-HEATED AND ELECTRICALLY-HEATED HOTBEDS

There was not a great deal of difference in the number and quality of the plants grown by the two methods of heating. Although the flue-heated bed had a greater variation in temperatures, sometimes rather close to the freezing point, no serious damage resulted to the plants.

The flue-heated bed required more labor to attend to the fire, but the cash cost was consistently lower. In calculating the cost of operating the flue-heated bed, the wood was calculated on the basis of 10 and 15 cents per 100 pounds, or about $3.50 per cord, which is a very low figure. If wood were to be bought it would probably cost $5 to $6 per cord. On the other hand, much scrap fuel having little cash value could be used in many cases.

After three years in service, including about two months use each spring, the 4-inch tile flues beneath the beds were stopped up and nearly closed by a deposit of black substance, probably wood creosote. This material had closed the tiles so completely that little draft could be secured and consequently little or no heat transferred to the beds. It was necessary to take up the tile in the bed and chisel out the hard black creosote and relay the tile before normal operation could be secured.

The cost of electric energy was calculated at 3 cents per kilowatt-hour (K. W. H.) in all of these tests. In all electric service rates in Kansas, the 3-cent rate is reached after consuming from 50 to 75 K. W. H. It is believed that where hotbed heating is likely to be used, the higher current costs would already be passed by other uses. If a large number of hotbeds were to be heated by electricity, a rate lower than 3 cents per

TABLE II.—COMPARISON OF ELECTRIC AND FLUE-HEATED BED, 1934 to 1937. (Energy requirements and cost of operation.)

Period of test.	Bed description.	Total current or fuel.	Cost of operation.		
			Cash.	Labor.	Total.
1934 Mar. 5 to Apr. 7 All beds 6'x18' in size	Electric—Thermostat on at 46° F. off at 54° F.	268 K. W. H. at 3c	3c per K.W.H. $ 8.04	$ 4.74	$12.78
	Electric—Thermostat on at 56° F. off at 64° F.	374 K. W. H. at 3c	11.22	4.74	15.96
	Flue-heated bed, wood for fuel	4,125 pounds at 10c per 100 lbs.	4.13	14.22	18.35
1935 Mar. 9 to Apr. 18 All beds 6'x18' in size	Cold electric—Thermostat on at 40° F. off at 50° F.	146 K. W. H. at 3c	4.26	1.38	5.64
	Warm electric—Thermostat on at 50° F. off at 60° F.	216 K. W. H. at 3c	6.48	1.38	7.86
	Surface cable electric—Thermostat on at 50° F. off at 60° F.	150 K. W. H. at 3c	4.50	1.38	5.88
	Flue-heated bed, wood for fuel	2,100 pounds at 10c per 100 lbs.	2.10	6.13	8.23
1936 Mar. 24 to Apr. 16 All beds 6'x18' in size (Air temperature above normal much of time)	Electric—cable 6 inches beneath surface. Thermostat on at 50° F. off at 60° F.	185 K. W. H. at 3c	5.55	3.25	8.79
	Electric—cable 6 inches beneath surface. Thermostat on at 40° F. off at 50° F.	140 K. W. H. at 3c	4.20	3.24	7.44
	Electric—cable on surface of soil. Thermostat on at 40° F. off at 50° F.	112 K. W. H. at 3c	3.36	3.24	6.60
	Flue-heated bed, wood for fuel	1,800 pounds at 15c per 100 lbs.	2.70	9.80	12.50
1937 Mar. 15 to Apr. 22 All beds 6'x18' in size (Weather about normal)	Electric—cable on surface of soil. Thermostat on at 40° F. off at 50° F.	193 K. W. H. at 3c	5.79	3.78	9.57
	Electric—cable on surface of soil. Thermostat on at 50° F. off at 60° F.	280 K. W. H. at 3c	8.40	3.78	12.18
	Electric—cable on surface of soil. No thermostat, current left on during most of period.	632 K. W. H. at 3c	18.96	3.78	22.74
	Flue-heated bed, wood for fuel	2,200 pounds at 15c per 100 lbs.	3.30	11.62	14.92

kilowatt-hour might be secured in some localities. The hotbed load is desirable from the power company standpoint because much of the current is used at night during off-peak loads.

CURRENT CONSUMED BY ELECTRIC HOTBEDS

A soil-heating cable 120 feet long connected to a 220-volt circuit consumes 800 watts of electrical energy. A 60-foot length on the 110-volt circuit consumes 400 watts, If these cables are placed in the bed with a 7-inch spacing (fig. 11) there will be 200 watts per sash of 3-foot by 6-foot size or 1,200 watts in a 6-foot by 18-foot bed. This 1,200 watt heating element will consume 1,000 watt-hours or 1 K. W. H. for every 50 minutes that it is connected. If the current were kept turned on during the entire 24 hours, the energy consumed would be 28.8 K. W. H., which would be too high a cash cost to be practicable. During one test in December 1932, one bed actually consumed 19 K. W. H. per day or a total of 858 in a period of 45 days. (Table I.) This represents a cost of $25.74 for heating one 6-foot by 18-foot bed, which would be entirely too expensive.

In order to be cheap enough to be practicable for the average grower, the use of the electric heating cable seems to be limited to the warmer spring months of March and April. During these months the current may be turned off during much of the time. In both of the years 1934 and 1935 the beds were heated for 30 to 40 days during March and April with a consumption of 150 to 260 K. W. H. (Table II.) It is believed that with careful attention to the methods of reducing current consumption, these beds can be heated with around 200 K. W. H. or from 30 to 40 K. W. H. per 3-foot by 6-foot sash.

COMPARATIVE CONSTRUCTION AND OPERATION COSTS OF FLUE-HEATED AND ELECTRICALLY-HEATED HOTBEDS

The same type of frame and sash construction was used whether the hotbed was electrically heated or flue-heated. Therefore the following comparisons include only the cost of the materials and labor necessary to heat the bed.

COST OF ELECTRIFYING ONE HOTBED (6' x 18')

Necessary Equipment:

Nichrome (No. 19) lead-covered heater cable, 120 ft. at 6c....	$ 7.20
Switch, fuses, and wire for connecting to the power line. (This cost per bed would be lower if several beds are electrified)........	10.00
Labor, 4 hours at 30c........	1.20
	$18.40

Optional Equipment:

Thermostat, varies	$5.00 to 11.00
(Hail screen, ½ inch mesh, 108 square feet at 4½c	4.86)
Total necessary + optional,	$28.26 to $34.26

COST OF EQUIPPING FLUE-HEATED BED

Drain tile, 60 pieces of 4-inch at 6c	$ 3.60
Tin work and material*	12.50
Labor in making furnace headers and pipe*	19.50
Labor in laying tile and placing headers	5.00
Hail screen, ½-inch mesh, 108 square feet at 4½c	4.86
	$45.86

*These were the actual costs of constructing the experimental bed. If the grower were able to do this sheet metal work himself, he could no doubt reduce this cost to a considerable extent.

HOW TO KEEP DOWN THE COST OF ELECTRICITY WHEN USING THE ELECTRIC HOTBED

1. Do not heat the beds to a higher temperature than needed by the growing plants. Higher temperatures increase the losses of heat and consume much larger quantities of current. For example, in 1934, heating one 6-foot by 18-foot bed to an average temperature only 5 degrees higher than another bed, consumed 106 more K. W. H. Again in 1935, maintaining a 3-degree higher temperature in one bed, consumed 74 more K. W. H.
2. Do not attempt to grow plants during the winter months. Although it was possible to maintain adequate temperatures during below zero weather, the consumption of electricity was too high to be practicable.
3. Reduce ventilation of the beds except during warm days when the current is turned off. Have tight fitting sash.
4. Do not water the plants excessively. Water has a cooling effect.
5. Keep the sash well covered with good insulating mats or covers at night, during cloudy dark days, or during excessively cold spells.

ADVANTAGES OF ELECTRICALLY-HEATED HOTBEDS

1. Heating cable is easy to install in a hotbed, provided electric current is available near the beds.
2. The cost of installation is reasonable.
3. It is possible to control the heat more accurately.
4. Electricity can be turned off whenever the weather becomes warm enough to make heat unnecessary.
5. Heating cable can be taken out and placed in another bed without much labor.
6. The cost of operation can be kept down to a reasonable figure if proper precautions are taken.

7. No gases or fumes are added to the air and thus little ventilation is needed.

ADVANTAGES OF THE FLUE-HEATED HOTBED

1. Can be constructed anywhere.
2. Uses cheap fuels which on some farms represent little or no cash outlay.
3. The operation of the flue-heated bed is easily understood by most growers.

COLD FRAMES

Use of Cold Frames.—There are four general purposes for which cold frames are used: (1) for starting plants in the spring, (2) for hardening off plants which have been started in the hotbed or greenhouse, (3) for wintering hardy plants started in the fall, (4) for growing crops such as lettuce, radishes, beets, and parsley to maturity. In many sections, especially in the South, nearly all kinds of plants are started in cold frames, but frames are not so satisfactory as hotbeds for most crops.

Cold frames are constructed in much the same way as hotbeds except that no pit is required. In fact the main difference between a hotbed and a cold frame is the absence of any form of heat in the latter except that provided by the sun. Permanent cold frames are commonly made of concrete, while temporary ones are made of boards. They are usually protected from the sun on the south and are used primarily to hold plants back in the spring.

Cold frames are covered with glass sash, canvas, or cloth. In the North glass is mostly used, while in the South, canvas or cloth is commonly used. In Kansas both or either are used. Where sash is used, the frames are as a rule 6 feet wide, although frames 12 feet wide are not uncommon. When cloth is used, the beds are usually 12 feet wide.

In some sections of the East, where cloth-covered frames are used for growing lettuce and other crops to maturity, the sides and ends of the beds are made of 1-inch by 12-inch boards. The beds are 12 to 14 feet wide and of any length desired, sometimes as much as 100 yards. The boards are held in place by stakes driven into the ground. Stakes for supporting the cross strips are driven in the center of the bed about 4 feet apart, making a row the length of the bed. These stakes extend above the surface of the ground about 18 inches so that when the cross strips are nailed to them and to the sides of the frames there is a fall of about 6 inches from the center to the sides. Unbleached muslin is used for covering these frames. Most of these frames are removed each year and the land plowed and harrowed before setting up the frames for the next crops.

Care of Cold Frames.—The general care of cold frames is about the same as that given hotbeds. In the North it is often necessary to cover the sash during cold weather to protect the plants against freezing. Mats of various kinds or loose marsh hay may be used for this purpose.

PLANT GROWING

Good plants are essential to success in vegetable growing. (Fig. 16.) To have good plants one must get good seed and use judgment and care in sowing the seed, in the management of the seedbed, in transplanting the seedlings, and in hardening

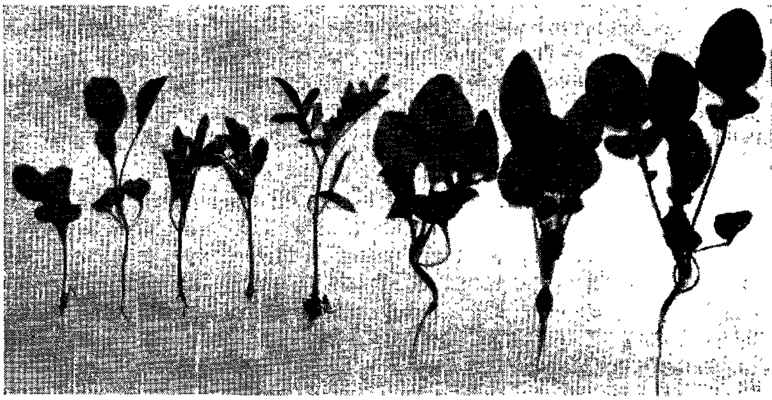

FIG. 16.—Well grown hotbed plants.

off the plants before they are planted in the open. Plant growing calls for skill and care. Any neglect may cause a serious loss due to delayed maturity or to a decrease in yield, or both, as well as increased susceptibility to the attacks of insects and diseases. Perhaps no factor is more commonly neglected than the selection and the preparation of the soil for the plant bed.

Soil for the Plant Bed.—A good soil for plant growing is of good physical character, friable, retentive of moisture, and free from disease organisms, especially the "damping off" fungi. Soil for this purpose must carry an abundance of nutrients if satisfactory growth is to be obtained. The demand for nutrients is heavy, since a 3-inch layer of soil often must support a thick stand of sizable plants before time for setting in the field.

The base soil should be sandy loam, well supplied with humus. A bluegrass sod grown on a good sandy loam soil makes an excellent base. An area may be specially prepared for a year by use of fertilizer and soil-improving crops. At least a year in advance of use, a compost pile should be built, using one part of manure to two or three parts of soil according to need. If the soil is heavy, some sand should be added, either to the compost pile or the compost at the time it is used. A compost heap should be moist for rapid decomposition and should be turned once or twice for thorough mixing of the ingredients. Poorly blended soils often produce uneven plants.

Fine sifting is not necessary, but a coarse revolving screen, often home-made, is an excellent mixer. Special machines for soil shredding are on the market. The soil should be so stored in the fall that it will be available when needed regardless of the weather.

If the soil is contaminated with disease organisms, it may be sterilized by means of formaldehyde or by steam.

Sowing Seed.—Moisture, oxygen, and congenial temperature are the requisites of germination of viable seed. In greenhouses and hotbeds, moisture and a congenial temperature are easily provided, but to maintain the proper moisture, the soil must be of good texture. The soil for the seedbed should be light and friable, but not so light that it dries out quickly. A heavy soil, one containing considerable clay, is not satisfactory, because when the surface becomes dry it gets hard and cracks and if kept wet it puddles. These conditions are not favorable for good germination and growth. A sandy loam soil is most generally used for seedbeds, but muck is considered almost ideal for celery, lettuce, and some other crops.

The time for sowing seed in hotbeds or cold frames depends on the kind of crop and the subsequent treatment it is to receive before the plants are to be set in the field. If they are to be set directly from the seedbed, less time is given than when they are to be transplanted once or twice. In general the length of time between seed sowing and setting the plants in the field varies from 3 or 4 weeks to 12 weeks. When the plants are not transplanted prior to setting in the field 4 to 6 weeks are usually allowed between the sowing of the seed and setting the plants. When one transplanting is to be made and the usual spacing is given, the seed of most crops should not be transplanted more than 6 weeks prior to time of planting in the field. Many growers start plants too early for best results. When started too early, the plants are likely to become stunted or allowed to get too tall and spindly. Early planting also increases the cost of growing the plants. Plant-growing requirements for specific crops are given under the discussion of individual crops.

Seeds are planted in flats or directly into the soil of the hotbed or cold frame. If the flat is used, it is filled with a good, friable soil which should be firmed to prevent too much settling. It is particularly important to firm the soil in the corners and along the edges. The firming of the soil is done with a board to leave the surface level and smooth. The surface of the soil should be below the top of the flat to prevent water running off.

When seed are sown in flats the rows are spaced about 2 inches apart, but in hotbeds the rows are usually 3 to 6 inches apart, the wider spacing being used when the seedlings are not to be transplanted before being set in the field. A convenient method of measuring and marking the rows to receive the seed in flats is to use a stick about 2 inches wide, ¼ inch thick, and of a length to fit the flat. The edge of the stick may be pressed into the soil to the depth desired. After all the rows are made, the seed is planted thinly and is covered by sifting fine soil over the rows and firming it lightly. Flats are not extensively used in Kansas but their use could be extended with generally increased satisfaction.

When sowing seed direct to the soil of the hotbed or cold frame, a rake-like marker is often used. After the seed is sown it is covered by hand by brushing it lightly back and forth over the row to fill the little furrow. There are small hand seeders which may be used for sowing seeds in greenhouse benches and in hotbeds. These machines are pulled across the bed by the hand in much the same way as one would use a hand weeder. Small seeds are sometimes sown broadcast and covered very lightly with fine soil, or merely covered with a piece of cloth or burlap. The latter method is often used for celery seed and for other small seed.

The depth of soil over the seed depends, to a considerable extent, on the size of seed and the kind of soil. Very small seeds should be covered lightly, if at all. Cabbage seed and others of similar size are covered to a depth of not over ¼ inch, while beets are covered about 1/8 inch in light soil. In heavy soil seeds should have less covering than in light soils.

Care of the Seedbed.—Very close attention must be given the seedbed if good results are to be obtained. Only by experience can one learn just how to care for the seedbed under the artificial conditions that prevail in hotbeds and cold frames. The gardener wants good stocky plants ready at the required season and to get them, great care must be given to the temperature, moisture, ventilation, transplanting, and "hardening off." Things to avoid are: (1) chilling the plants, (2) overheating and lack of ventilation which make the plants soft, (3) overwatering, which makes the plants soft and very susceptible to "damping off," (4) wilting of the plants due to too much heat or too little water, and (5) protecting from moles. (Fig. 17.)

Watering.—Caution should be exercised in watering the seedbed. Before the seedlings come through the surface there is danger of washing out the seed or of puddling the soil. At this time the seedbed should be watered with a fine spray from a sprinkling can or with a fine rose on a garden hose. Water

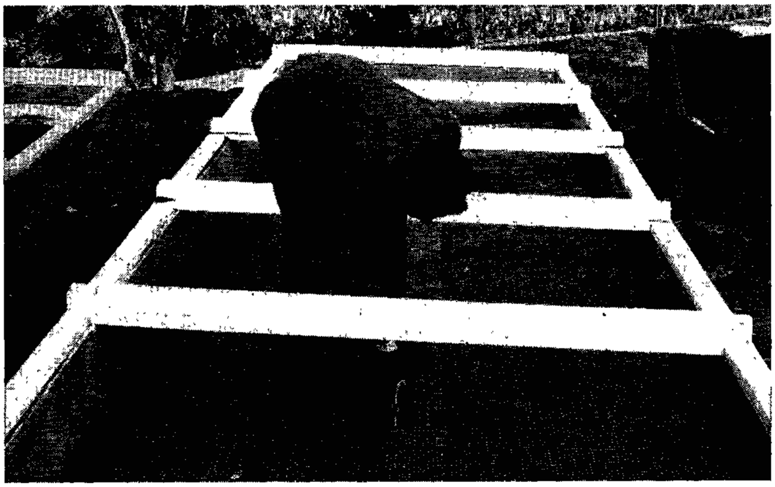

FIG. 17.—Installing hardware cloth to protect bed from moles.

dashed on the seedbed through an ordinary hose nozzle or through a rose with large holes is likely to wash out the seed. The seedbed should never be allowed to dry out, nor should it be kept soaked, but sufficient water should be applied to wet all of the soil in it. Until the plants are well established, the soil should be kept fairly moist but never wet. After the plants are well established, the watering should be done thoroughly, but not too often. There is usually more danger of overwatering than underwatering. Keeping the surface wet after the plants are up is favorable to "damping off," hence it is best not to water often but to soak the soil thoroughly and then withhold water until the plants show the need of it. Of course more water is required on a bright day than on a cloudy or rainy day because of greater evaporation and transpiration. Usually plants should not be watered on cloudy days unless absolutely necessary. Watering should be done early enough in the day to allow the foliage of the plants to dry before night, and if done late in the afternoon the plants may not dry off before night. Watering reduces the temperature in the hotbed, and for this reason it should be done early enough to allow the bed to get warm before the sun goes down. Before the plants are to be taken up to set in the field, the plant bed should be thoroughly soaked so as to have as much soil as possible adhere to the roots.

Controlling Temperature.—In steam, electric, or hot-water-heated hotbeds the temperature is controlled by turning on or turning off some or all of the heating units, and by regulating the ventilation. During bright days in spring it is often necessary to turn off all of the heat and ventilate thoroughly to keep the temperature down. The temperature that should be maintained depends on the kind of crop. Tomatoes, peppers, eggplants, cucumbers, and melons thrive best in a relatively high temperature — about 60 degrees — while cabbage, cauliflower, lettuce, celery, onions, and beets do best in about 10 degrees less. Slow, steady growth is preferable; therefore the temperature should not be high enough to make rapid, succulent growth, or low enough to check growth until time for hardening the plants.

Ventilation of hotbeds and cold frames where young plants are growing needs careful attention. Ventilation dries the air and aids in the control of the temperature. In greenhouses ventilation is obtained by opening the ventilators, while in frames the sashes are raised at one end or pulled down a short distance. The tendency is to ventilate too little rather than too much. As plants grow, more and more ventilation should be given until finally on bright warm days the sash may be removed. In ventilating during cold weather, the wind should not be allowed to strike the plants. In greenhouses this is obviated by opening the ventilators on the side of the house opposite the direction of the wind. In frames the wind is prevented from striking the plants by raising the end of the sash on the side of the frame opposite the direction of the wind.

Transplanting.—Plants started in the hotbeds or cold frames are often transplanted at least once and sometimes twice or three times prior to setting them out in the field. The common practice is to sow seeds thickly in flats, or directly in the soil of the hotbed or cold frame. When the first true leaves are fairly well developed, the seedlings are usually transplanted or "pricked off" either into flats or into the soil of the cold frame. The soil should be loose and friable. When flatted the flat is filled with soil, which is firmed a little in the corners and along the sides. A leveling strip is used to remove the surface soil and to leave the surface level, then the soil is compacted lightly. Holes to receive the plants may be made with the finger, with a small dibble, or with a spotting board. The use of the spotting board is desirable in order to get the plants evenly spaced. For best results the soil must be moist, but not wet enough to stick to the pegs.

When not flatted, seedlings are spaced 1 to 2 inches apart each way, depending on the size of the plants and the length of time they are to remain in the bed. Sometimes plants are transplanted twice before being set in the field. As soon as they begin to crowd after the first transplanting, they are taken up and transplanted again, spacing them farther apart. If the plants have been planted 2 by 2 inches the first time, they may be spaced 3 by 3 by 4 by 4 inches at the second transplanting. Tomatoes and some other plants are often put in paper bands, veneer bands, flower pots, tin cans, or other containers at the second transplanting, one plant to each receptacle. The main advantage in using containers is that the roots are not disturbed when the plant is set in the field, as all of the soil around the roots remains intact.

The advantage of pots over flats for the growing of tomato plants has been shown. With paper pots 4 inches square there has been a gain of 29.5 percent in total yield, and 63 percent in early yield as compared to flats. Other gains for large plants were 15.8 percent in total yield and 40.1 percent in early yield, while for small plants the gains have been 17.7 and 27 percent, respectively.

In transplanting, the soil should be pressed down around the roots, taking care to see that the hole is closed at the bottom. Young, succulent plants are sometimes injured by pressing against the stems with the fingers in transplanting. The pressure should be exerted downward rather than against the plant. After each transplanting the plants should be watered thoroughly to settle the soil around the roots. When the plants are soft, it is an advantage to shade them until they become established. Bright warm sunshine is likely to cause wilting since the roots cannot take up moisture as fast as it is transpired from the leaves.

Seeds of cucumbers, melons, lima beans, and sweetcorn are sometimes planted in pots or plant bands a few weeks before time for setting in the open. Several seeds are planted in each receptacle and the young plants thinned to the desired number either before or after planting in the field. In planting in the field all of the soil is kept around the roots so as to check the growth of the plant as little as possible.

Hardening Plants.—The term hardening or "hardening off" is applied to any treatment that results in a firming or hardening of the tissues of the plants, thus enabling them better to withstand unfavorable environmental conditions. Many persons speak of hardening only in connection with the processes which enable plants to withstand frost injury, but it is as important to harden them so that they will withstand insect injury, whipping, hot drying winds, or other unfavorable conditions. All experienced gardeners know that soft tender plants are injured by unfavorable soil or atmospheric conditions, and an effort is made to prevent this injury by subjecting them to some hardening treatment before planting in the open. (Fig. 18.)

Any treatment that materially checks growth increases hardiness. With plants which possess natural hardiness, as cabbage and related crops, hardiness increases in proportion as growth is checked. With tender plants like tomatoes, peppers, eggplant, and cucumbers, checking growth results in only slight resistance to cold.

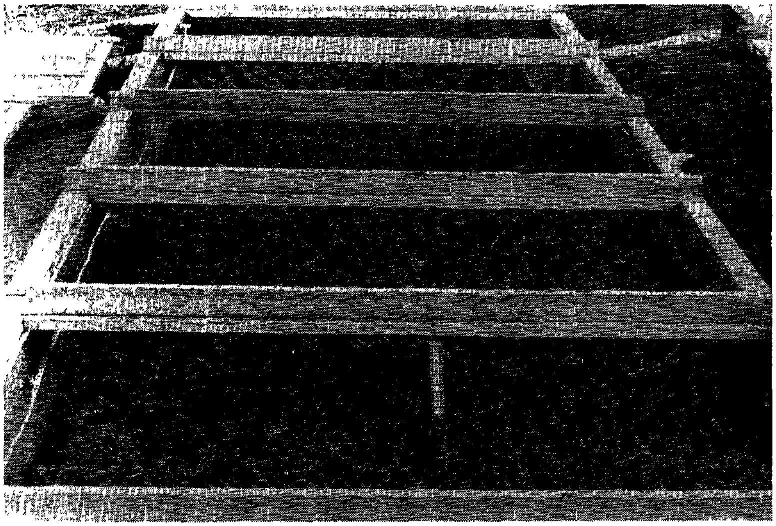

FIG. 18.—Plants in this bed are being exposed to lower temperatures as a hardening treatment in preparation for transplanting.

The treatments commonly used to harden plants are exposing them to relatively low temperature for a week or more and allowing the soil of the plant bed to become dry, or a combination of the two. Exposing plants to relatively low temperature is perhaps the most common method employed and this is usually accompanied by withholding water. Exposure to low temperature is done by reducing the heat and increasing the ventilation in hotbeds, or by removing the plants to a cold frame. Since any treatment which checks growth results in hardening, it is evident that low temperature is not essential, therefore, removing plants to cold frames is an unnecessary expense unless the hotbed is needed for other plants. In other words, plants can be hardened as well in the hotbed by withholding water as by exposing them to low temperature in the cold frame. It is easier to control the water supply than to control the temperature. With some plants, notably celery, onions, cabbage, and probably others, exposure to a relatively low temperature (40 to 60 degrees F.) for two weeks may result in serious loss due to premature development of the seed stalk.

The most important changes occurring during hardening are those which increase the water-retaining power of the plant tissues. The decrease in water and the increase in the colloid content are important factors in increasing the water-holding power. The thickening of the waxy covering on the leaves of cabbage is important in protecting plants against freezing. Under-cooling of the cell solution is of considerable importance and it has been found that those plants which have the most "bloom" on the surface of the leaf are the most resistant to the formation of ice within the tissue.

Hardening should be gradual in order to prevent a severe check to growth, or possible killing of the plant. It is better to maintain a moderate rate of growth throughout the plant-growing period than to have rapid growth up to the time of hardening and then to check it suddenly. Many growers over-harden their plants and this results in delayed growth after the plants are set in the field. Severe hardening of tomato plants decreases the yield of early fruit in the greenhouse, and it seems probable that this would be true of tomatoes grown in the open. Forcing plants after they have been hardened does not overcome the check suffered in the hardening treatment.

OUTLINE AND GENERAL INDEX