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Hotbeds and Coldframes
Michigan State University Extension Service
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HOTBEDS *and* COLDFRAMES

Including PRINCIPLES OF PLANT GROWING

By H. L. Seaton, D. E. Wiant and J. H. Muncie

MICHIGAN STATE COLLEGE :: EXTENSION DIVISION

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Title page illustration, courtesy Detroit Edison Co.

HOTBEDS AND COLDFRAMES

H. L. SEATON, D. E. WIAINT, AND J. H. MUNCIE

Hotbeds, coldframes, and small greenhouses are used extensively in Michigan for starting certain vegetable crops. The short growing season prevailing in many sections of the state requires their use if certain warm season crops such as tomatoes, peppers, eggplants and cantaloupes are to be grown successfully. These structures are employed with other crops such as early cabbage, early celery, broccoli and leaf lettuce to obtain earlier maturity than that obtained by sowing the seed directly in the field. Cauliflower and head lettuce are frequently injured by hot weather, but when they are seeded early in plant beds and the transplants set in the field early in the season the plants will usually mature their crops before the arrival of hot weather.

Frequently growers contend that it is easier and cheaper to depend on southern-grown plants than to produce their own. However, these plants may give disastrous results if they are poorly grown, or if diseases and insects are present on them. Large yields and high quality in most vegetable crops are too dependent on one's starting with well grown plants to entrust this operation to someone else.

During recent years the equipment used and the methods followed in the production of vegetable plants have changed. It is the purpose of this bulletin to suggest plans for the construction of various types of hotbeds and coldframes and to discuss the principles underlying the production of good plants.

DETERMINING THE KIND AND SIZE OF STRUCTURES

When plant growing structures are being considered, the grower should give careful thought to his immediate and anticipated requirements before any materials are ordered or actual work is started. The great diversity of vegetables grown in Michigan makes this an individual problem for nearly every case considered. The grower of early celery is confronted with the possibility of a large portion of his crop's going to seed prematurely if the young plants are exposed to low temperatures. The most satisfactory structure for his needs is a small greenhouse where the temperatures may be controlled. The grower who specializes in cantaloupe production uses his plant growing facilities for only four to six weeks during late April and May, when little protection is needed. Consequently his requirements are best met with a layout of sash-covered coldframes. The grower who produces a variety of crops frequently uses the same equipment for several crops. He may seed early cabbage, cauliflower or head lettuce in his greenhouse or hotbeds during late January or early February. The

young seedlings are transplanted to flats or other beds in order to make room for the seeding of warm season crops such as tomatoes, peppers, and eggplant during March. In turn, the cabbage transplants are set in the field in April and the coldframes in which they were grown are used for tomatoes. With this type of gardening it is usually advisable to use a combination of hotbeds or small greenhouses to start the seedlings and coldframes for caring for the transplants.

The methods to be followed in growing the plants should be considered. It is desirable to plan on having (1) adequate facilities for starting the seedlings and (2) sufficient room for growing the transplants. If the seedlings are grown in a common sized flat (3" x 12" x 18") from 800 to 1,000 cabbage, tomato or pepper seedlings may be grown in a single flat; from 2,000 to 3,000 celery seedlings; and from 500 to 800 lettuce and eggplant seedlings. One standard sash (3' x 6') will cover 12 such flats. Plans for a small sash greenhouse (10' x 19') which will hold approximately 75 standard flats are given in Michigan Extension Bulletin 130: *Small Sash House for Growing Vegetable Plants*. Often the seed is sown directly in the soil of the hotbed in rows 3 to 4 inches apart, and in such a manner that from 10 to 12 seedlings develop for each inch of row. Between 6,000 and 7,000 seedlings may be grown under a single sash when this practice is followed. Much more room is needed for the transplants, and this is largely determined by whether the plants are grown in the soil of the beds, in flats, pots, veneer bands, or other containers. Similarly the spacings given the plants when they are set in the field must be considered. In Table 1 these data are given for the crops usually started under glass. The information given is based on perfect stands and it is suggested that the space needed be over-estimated because the plants grown on the shaded side of the beds are seldom usable.

LOCATION OF STRUCTURES

The site selected for hotbeds and coldframes should be on a well drained piece of land, preferably with a southern exposure and where some protection from the prevailing winds may be utilized. A site near the dwelling is desirable because considerable attention is required for proper ventilation and watering. The frames should be near an adequate water supply and proximity to an electric outlet is desirable if electric heat is to be used. Frequently it is possible to select such a location near the farm buildings where all of these conditions can be met. Protection from north and west winds is sometimes provided by evergreens, windbreaks, or especially constructed board fences 5 to 6-feet high.

CONSTRUCTION OF THE FRAME

The main difference between hotbeds and coldframes is that the former are provided with some means of artificial heat such as fermenting manure, hot water, steam or electricity, while the only source of heat for the coldframe is that provided by the sun's shining through the glass cover. The details of construction of the frame and the coverings used on the two structures are essentially the same.

Table 1. General data on growing vegetable transplants

Crop	Field spacing	Time to grow, once transplanted (weeks)	No. Plants Required per Acre	Transplanting distance in frames	Actual No. of plants per sash** (3' x 6')	No. of sash to grow transplants for 1 acre**	No. of transplants per standard flat (3' x 12' x 18')	Approximate dates to start seedlings in Southern Michigan
Early Celery	3' x 4'	10-14	43,560	1½' x 1½'	1,152	37.0	96	Jan. 25 to Feb. 10
Cabbage and Broccoli	3' x 12' 3' x 15' 3' x 18' 3' x 24'	6-7	14,520 11,616 9,680 7,260	1½' x 1½'	1,152	12.6 10.1 8.4 6.3	96	Jan. 25 to Feb. 15
Eggplant	3' x 3'	8-10	4,840	3' x 3'	288	16.8	24	Mar. 15 to Apr. 1
Lettuce	18' x 12'	5-7	29,040	1½' x 1½'	1,152	25.2	96	Mar. 1 to Apr. 1
Melons and Cucumbers	6' x 6' 4' x 6'	4-5 Seeded in bands not transpl.	1,210 4,840	4' x 4' 3' x 3'	162 288	7.46 6.3	Bands used	Apr. 21 to May 1
Peppers	3' x 18' 3' x 24'	8-10	9,680 7,260	2' x 2'	648	14.9 11.2	54	Mar. 15 to Apr. 1
Tomatoes	3' x 4' 3' x 5' 4' x 4' 4' x 5'	8-10	3,630 2,904 2,792 2,178	4' x 4'	162	22.4 17.8 16.8 13.4	3' x 3' = 24	Mar. 15 to Apr. 1
Watermelons	7' x 7' 8' x 8' 9' x 9'	4-6 Seeded in bands not transpl.	880 hills 680 hills 537 hills	3' x 3'	288	3.1 2.4 1.9	Bands used	Apr. 15 to May 1

*Based upon plants growing in soil or wood veneer bands. If flats are used the number will be somewhat less.

**No allowance made for rejection of poor plants or for losses due to various causes.

85
3 x 18
Beard 3' x 18'
Beard 3' x 24'

12000 units

Print
Print

4 x 6 - 1815
3 x 12 1/2

om
B

The frame may be made of wood, brick, hollow tile or reinforced concrete. Reinforced concrete is probably the most lasting and most satisfactory material, but frames made of wood are generally more applicable to the conditions on the average vegetable farm. If properly constructed a wooden frame will last several years and can be taken apart and stored when not in use.

Details of construction for one of the most satisfactory types of frames and one that is easy to make and handle are shown in Fig. 9. It is made of standard 2" by 12" and 2" by 4" planks of almost any kind of good lumber that is available. It is designed to make use of 16-foot planks with a minimum waste of lumber and is covered with five standard hotbed sash. The south side is made of a single 16-foot 2" by 12" plank and the north side is made 16 inches high by using a 2" by 4" in addition to the 2" by 12". This gives a slope to the south which allows the sun to penetrate easily. The ends are made from 2" by 12" material and made 16 inches high at the north end by ripping a 2" by 4" diagonally. The end planks and the center rails are fastened with pins so that the frame may be taken apart and stored. The center rails are necessary to hold the frame in shape. When set on edge, they are less likely to warp, are stronger, and cast less shadow than when placed flat. The frame may be fitted over a pit of fermenting manure for a hotbed or placed on level ground for a coldframe. This type of frame makes it possible to change the location of the frames to avoid the cumulative effects of diseases. Where manure is used it is possible to remove the spent manure after the plants and the frame are taken away. Modification of this type of frame may be made in sections to hold any number of sash. The most common sizes are those holding two, three, four, or five sash which would be approximately 6, 9, 12, or 15 feet long. When electricity is to be used as a source of heat, it is important that the frame be insulated against heat losses.

When steam or hot water heat is employed it is frequently advisable to construct permanent beds of concrete or hollow tile. These beds are often made 12 feet wide, any desired length, and covered with two rows of sash. Plans for a bed of this type are shown in Fig. 8. With any type of permanent construction it is essential that some provisions be made for soil sterilization (see page 15) and in this bed eight lines of hollow tile under the soil are suggested for this purpose.

SASH AND OTHER COVERINGS

Virtually all hotbeds and coldframes used in Michigan are covered with standard (3' x 6') hotbed sash made of California redwood, clear gulf cypress or white pine. The sash are $1\frac{3}{8}$ to $1\frac{3}{4}$ inches thick, have mortised joints, and are made up of three rows of seven panes each of 10" x 12" glass. They are reinforced across the center with a $\frac{3}{8}$ -inch metal rod or a metal or wood strip. These sash are procurable from dealers in greenhouse supplies and may be purchased unglazed and unpainted, unglazed and painted with one or two coats, or fully glazed and painted. The B grade of 10" by 12" double strength glass is generally used and may be purchased by the box of 60 panes. The price of the sash varies according to the type purchased and the

cost of the materials and labor going into their manufacture. If the sash are kept well painted and are stored in a dry place when not in use they should last for at least 15 or 20 years.

In states farther south the frames are often covered with unbleached muslin or light canvas. Strips of these materials are sewed together in sheets large enough to cover the entire bed. One side of the cover is fastened securely to one side of the bed and the other side is tacked to a pole the length of the bed. The bed is uncovered on sunny days by rolling the cloth around the pole. This type of structure is seldom used in Michigan except in a few instances in the most southern counties.

Numerous substitutes for the glass sash are offered and many unwarranted claims have been made as to the value of these materials for growing plants. While the initial cost of covering a plant bed with the substitutes is less than for glass sash, the covers are light and are frequently blown from the beds and damaged by wind. These materials must be replaced annually. In tests made at the Michigan and Ohio agricultural experiment stations it has been shown that a good grade of window glass will transmit more than 95 per cent of the total light. Certain of the substitutes transmitted only 25 per cent of the total light and none of those tested transmitted more than 60 per cent. It is true that most of the substitutes transmitted an appreciably greater portion of the ultra violet rays than did the ordinary glass. However, no recognizable benefits of these rays on growing plants have been demonstrated. The tests at the two stations showed that in all cases better plants were grown under the glass than were grown under the substitutes.

METHODS OF HEATING HOTBEDS

Until recent years virtually all hotbeds depended upon fermenting manure as the chief source of heat, and even today on many farms where there is sufficient manure they are often the most practical type to construct. However, during the past 25 or 30 years the increasing scarcity of good manure has been responsible for the development of other methods of heating. Various systems have been devised where the beds are heated by hot air conducted in flues under the soil of the bed, various types of installation using steam and hot water heaters and still more recently the use of the cable type of electrical heaters, "soil heating cable". Satisfactory plants have been grown under each type of heating and all are practical systems when installed and operated properly. The major differences between these systems are largely economic, in cost of installation and operation, and in convenience and dependability.

MANURE HEATED HOTBEDS

In a recent investigation of the various methods of heating hotbeds conducted at the Pennsylvania State College,* it was shown that manure was probably the cheapest means of heating hotbeds on many

*Penn. State College Exp. Sta. Bul. 338—Methods of Heating Hotbeds—1936.

farms, especially where the fertilizing and soil improving value of the spent manure was considered. When properly managed it maintains a steady source of heat and supplies some plant nutrients. The chief disadvantage of manure is that considerable care and skill are required for its most efficient use.

Surface versus Pit Hotbeds—Two general types of manure hotbeds are in common use; namely, the surface and pit types. With the more common surface hotbeds the fermenting manure is scattered in layers over an area about 8 feet wide. Each layer is tramped and another added until it is from 14 to 18 inches deep. The frame (page 4) is set in place over the manure and a layer of compost (page 20) 4 inches deep is spread over the manure. The sides are banked with manure and the frame covered with sash. This type of hotbed may be used in poorly drained locations. After the season is over the frame and sash may be stored and the spent manure used for fertilizing purposes or piled for use in next year's compost. More manure is required for the surface beds than is used in the pit type.

Care should be exercised in selecting the location for a pit hotbed and if a well drained location is not available a tile drain should be laid from the bottom of the pit. The pit, slightly larger than the hotbed frame, is excavated to a depth of 18 to 24 inches. It may be lined with boards or left unlined. The fermenting manure is placed in the pit in thin layers and tramped carefully, especial attention being given to the edges and corners. From 12 to 18 inches of manure is usually sufficient to provide heat for a four- to five-week period. The frame is set over the pit, banked around the edges, the soil compost layer put in and the whole covered with the sash. Because less manure is required for the pit type of hotbed, this type is suggested where there is a limited quantity of manure.

Selection and Preparation of Hotbed Manure—The best manure for hotbed use is from grain-fed horses. None of the other farm manures is suitable. It should contain about two-thirds of the pure excrement and one-third straw bedding. Where wood shavings or sawdust has been used for bedding the manure is unsuitable as it does not ferment rapidly. If the manure and bedding are not in the proper proportions fermentation may not occur or it will be violent and of short duration. Preparation of the manure for hotbed purposes should start about two weeks before the beds are to be made. The fresh manure from the stables should be stacked in a flat pile about 4 to 5 feet wide, 3 to 5 feet high and of sufficient length to fill the beds. About one cubic yard of manure is required for each sash. If the manure appears dry it should be dampened with warm water but it should never be soaked. After three to five days, depending on the weather, the manure will start to ferment and after it has heated for a day or two it should be repiled. In repiling the outsides of the old pile should be placed in the center of the new pile. Any lumps should be broken up and if portions seem dry more water added. The repiling insures a uniform rate of fermentation and consequently more uniform heating in the hotbed. Some growers turn the piles two or three times but once is usually sufficient. During extremely rainy and cold weather it is sometimes necessary to cover the pile in order to start fermentation. When manure is fermenting evenly throughout the pile it is ready to spread

out for the surface bed or to be put in the pits. In filling the pits, a layer 4 to 5 inches thick is put in, and tramped especially around edges and at the corners, another layer added and given the same treatment. The process is continued until the pit is filled. The frame is set in place, and the manure is covered with 4 to 6 inches of prepared soil. If the seedlings are started in flats, 2 inches of soil over the manure will suffice.

Management of Manure Hotbeds—The operator of manure hotbeds should provide himself with a good soil or dairy thermometer. After the manure and soil have been put in the hotbed the soil temperatures should be watched carefully before any seeds are planted. The normal behavior, if the hotbed is working properly, should be as follows: The temperature of the soil will rise rapidly within a few hours after the bed is started. It will continue to rise and may be as high as 110° to 120° F. but it will fall rapidly after the peak heat is reached. Finally the soil will remain at a fairly uniform temperature for a period of several weeks. No seeds should be planted until after the peak heat has been reached and the soil temperature has fallen to below 85° F. Usually this point is reached three to four days after the bed is started.

Considerable quantities of water vapor and ammonia fumes are given off during the fermentation of the manure. These should be released from the beds. The common practice is to insert a small block between the sash and the lower side of the frame. Sun shining directly through the glass warms the small amount of air in the frames very rapidly and constant care is required to avoid overheating the seedlings. "Sweating" of the glass indicates a need for ventilation, which is regulated by raising or lowering the sash on the side away from the wind.

ELECTRIC HOTBEDS

Convenience, cleanliness, a controlled temperature, and an even and vigorous growth of plants are the advantages of electrically heated hotbeds. Electric soil heating cable has been used for hotbeds for the last 10 or more years. It is one of the cleanest and most convenient methods of heating and when a thermostat is installed in the circuit, the temperature can be maintained and regulated automatically to the needs of any particular kind of plant.

Because the temperature can be maintained and regulated automatically at any desired point, this method of heating lends itself advantageously to germination and propagation beds within the greenhouse and sash house. These beds can be held at any desired temperature regardless of the temperature of the remainder of the house with the result that a higher percentage of germination and of cuttings is obtained. Furthermore this makes it possible to maintain the greenhouse at a lower temperature than would otherwise be necessary, resulting in saving fuel. Electric heat is also used as a safeguard against freezing of plants in a coldframe in case of a sudden drop in temperature. The thermostat is set to turn on the heat should the temperature drop to the danger point but no electricity is used until this point is reached. The use of electric heat in the starting beds and in the coldframes is becoming increasingly popular each year.

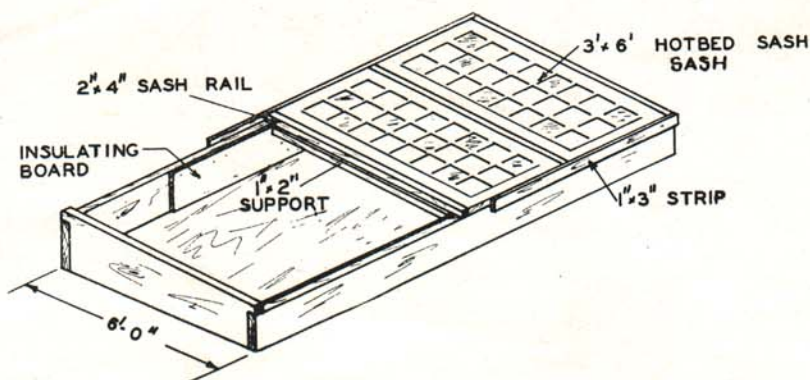
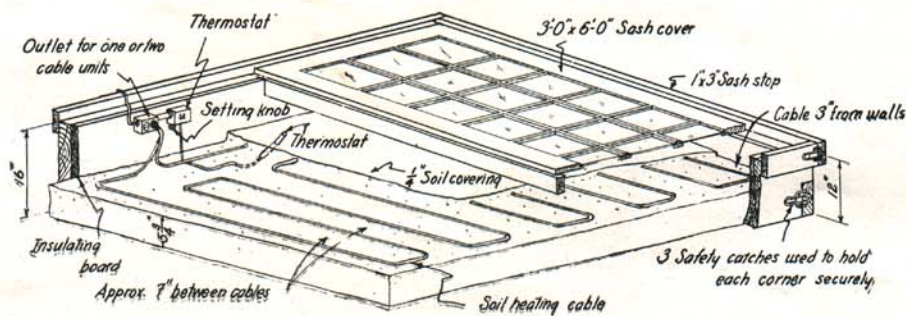


Fig. 1. The electric hotbed should be protected against heat losses.

Electric heat should be used efficiently in order to be economical. This necessitates insulation of the hotbed frame and while the construction of the hotbed frame can be very similar to that shown in Fig. 9, the frame should be insulated, and particular attention should be given to the elimination of cracks between the sash and hotbed frame and at the corners. Figures 1 and 2 both show the methods used to obtain good insulation. A layer of insulating board first treated with asphalt paint can be used on the inside of the frame. Pieces of insulating board, mats and canvas can be used to cover the sash on cold nights and cold dark days. The frame should be banked around the outside with cinders or earth.

The electric hotbed should be located near a convenient outlet if possible, in order to eliminate the use of long wires. If long wires are necessary to carry electricity to the hotbed, it is important to have them of ample size in order to prevent voltage drop. If several lengths of soil heating cable are used, wires of the proper size should run directly from the distribution point to the hotbed.

A reliable thermostat, a well-insulated frame located in a protected place, and wires of ample size together with the good management given

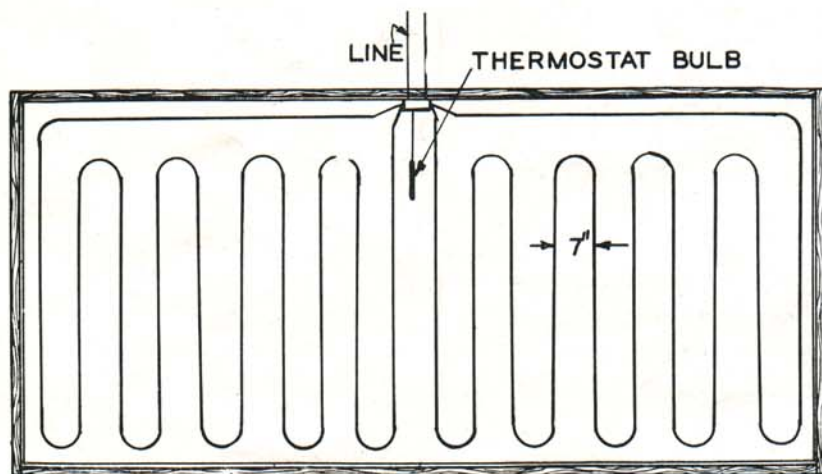


ELECTRICALLY HEATED HOTBED

Fig. 2. If bed is 6 by 12 feet, it is wired as two 6 by 6 foot beds.

any other type of hotbed will insure economical and satisfactory results from an electric hotbed. Good management consists in heating only to the desired temperature, reducing ventilation of the beds except during warm days when the current is off, and watering plants no more than needed.

Methods of Heating with Electricity—Soil heating cable especially developed for this purpose is universally used for soil heating. This cable is a flexible, lead-sheathed cable and is manufactured in 60-foot lengths. A 60-foot length is designed to furnish heat for a two-sash 6' x 6' hotbed when 110-volt current is used. A 6' x 12' hotbed would require two 60-foot cables. The cable can be arranged as illustrated in Fig. 2. One end of the cable is connected directly to the source of power and the other end to the thermostat and thence to the other live wire. A 6' x 12' bed is wired as if it were two 6' x 6' beds. Only one thermostat is necessary (see Fig. 3).



WIRING DIAGRAM

SUB-SURFACE HEATING

Fig. 3. Diagram showing method of connecting cable to current supply line.

Formerly, it was thought best to place the soil heating cable on a bed of cinders and cover it with approximately 6 inches of soil, but according to work recently completed, a lower energy consumption can be obtained without appreciably lowering efficiency in other respects by pressing the cable down until it is buried under one-fourth inch of soil.* This eliminates the necessity of heating large quantities of soil and the possibility of the plants freezing. It also eliminates the necessity for insulation in the bottom of the bed. This method of heating is especially recommended for peppers, tomatoes and eggplant.

*U.S.D.A. Report on the Agricultural Experiment Station, 1938.

The disadvantage of placing the cable near the surface is that it may interfere with working the beds.

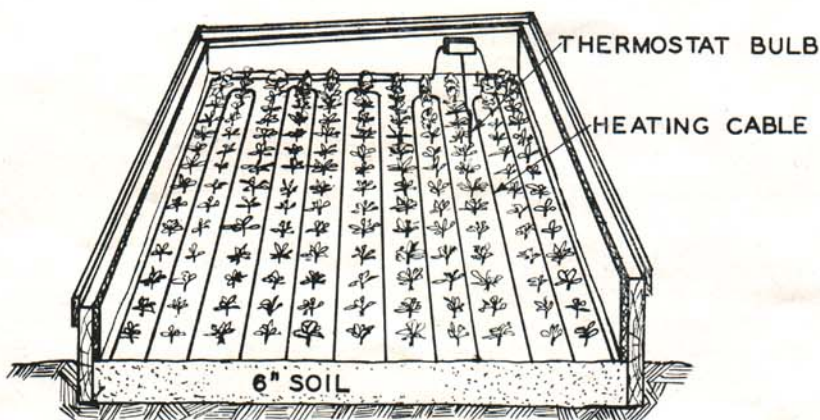
Various makes of thermostats are available and may be installed in several different ways. Some are placed above the ground, some in the ground, and some are partially buried in the soil. In all cases the manufacturer's directions should be followed.

For cool season crops, the heating cable may be attached to the inside of the hotbed frame, as shown in Fig. 5. The cable is usually attached by means of wiring knobs or cleats spaced about 3 feet apart. Since 60 feet of cable is required to heat a 6' x 6' bed, it is necessary to arrange the cable so that the heat will be as evenly distributed as possible. Suggested arrangements for both large and small beds are given in Figs. 6 and 7. This method of heating is suitable for cauliflower, cabbage, lettuce, beets, and broccoli, and, when used in cold-frames, will act as a safeguard against freezing.

Electrical Details—Several beds may be operated by one thermostat with the addition of a relay. When a relay is used, the thermostat handles only sufficient current to operate the coil of the relay. When the thermostat closes the circuit, it energizes the coil of the relay which closes the switch and turns on the heaters in several beds at once.

When heating with lead-sheathed cable, the amount of cable recommended by the manufacturer should be used. To heat a 6' x 6' hotbed, requires 400 watts. Increasing the length of cable increases its resistance and thereby decreases the amount of heat it will furnish. The length of the cable should not be decreased materially, for this will increase the temperature of the cable beyond the point which it will stand.

Cost of Operation—The cost of operating an electric hotbed will depend on its construction, the outside temperature and the cost of the



SURFACE HEATING

Fig. 4. Heating cable may be placed above ground for some plants.

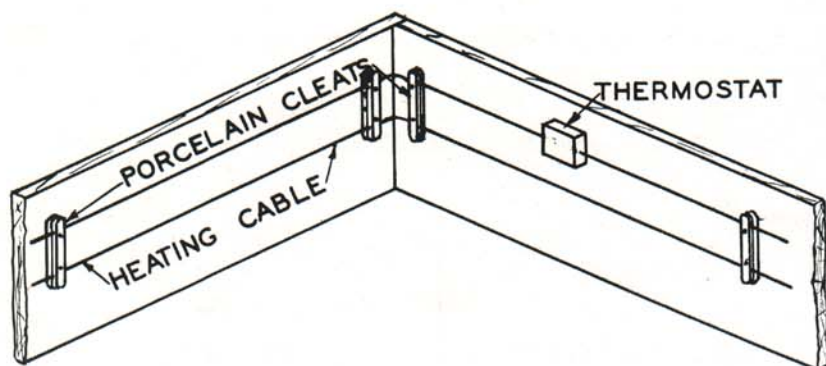


Fig. 5. The heating cable is sometimes placed around the walls of the hotbed.

current. Experiments conducted at the Minnesota Station* indicate that a 6' x 6' hotbed requires about one kilowatt hour of current per week for each degree difference of temperature between inside and outside. Thus, if the inside temperature averages 55° and the outside 20°, the difference would be 35° and would require 35 kilowatt hours per week. As an illustration, one record shows that for a five-week period with an average outside temperature of 19.7°, the cost of current was \$1.50 per week.

Records on a 6' x 6' electric heated hotbed in Macomb County, Michigan reveal an average cost of 9¢ per day over a period of 57 days.

Results of experimental work at the University of Maryland show the following:

Double glazed sash reduced power consumption 20% or more, over single glazed.

Weather stripping, to make sash fit tight, saved 8½% of power.

Straw mats over single glazed sash saved 24 to 42% on power on 13° to 30° nights.

STEAM- AND HOT WATER-HEATED HOTBEDS

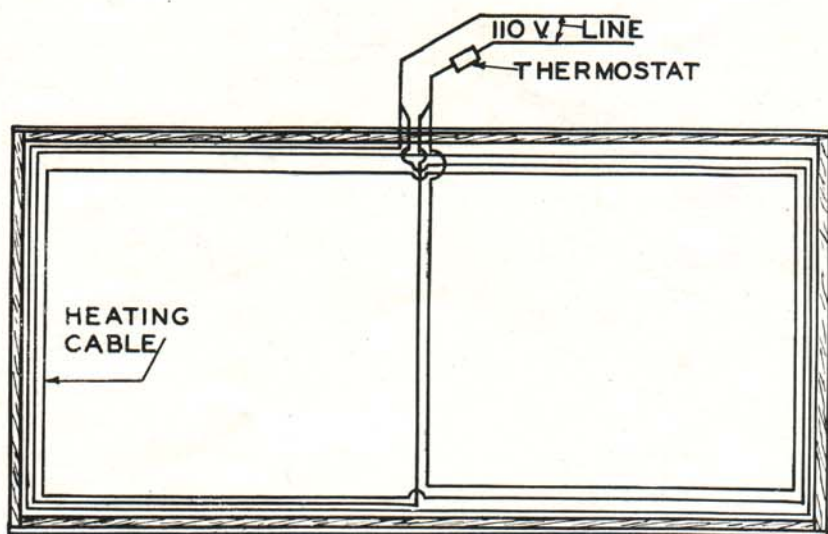
Steam or hot water may be used for heating hotbeds. Where the beds are located adjacent to a sash house heated by steam or hot water, this method of heating is convenient and economical.

The heating pipes are usually run along both-sides of the bed frame as near the top as possible. The feed pipe is placed on the north or high side of the bed and the return on the low side. This arrangement permits a small amount of fall in the lines.

In order to maintain a temperature of 50-55° in sub-zero weather, about 3½ feet of steam radiation is required for each sash; for hot water about 6 feet radiation per sash is required. For steam, a 2-inch feed line should be used and a 1¼-inch return is necessary.

Figure 8 shows a more substantial type of construction for a hotbed. The walls are made of concrete. When concrete construction is used,

*Currence, T. M. Methods of Supplying Electric Heat to Hotbeds, Minn. Agr. Exp. Sta. Bul. 289. 1932.

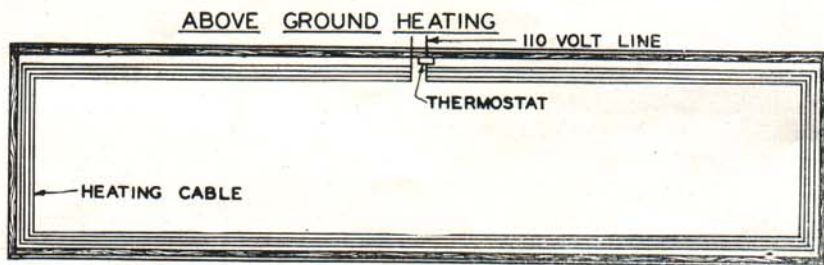


WIRING DIAGRAM - 4 SASH BED

Fig. 6. Wiring diagram for a four-sash bed where the cable is arranged around the frame. The thermostat is shown outside the bed for diagrammatic purposes only.

footings should be provided as shown. Since concrete is a rather poor insulator, either cinders or strawy manure should be banked around the outside.

This type of hotbed is the most practical for the commercial grower having a steam boiler. The bed, 12 feet wide, is wide enough to accommodate two standard sash. Since this is a permanent bed, tile has been laid for steam sterilization, details of which are given in Figs. 8 and 10. This type of bed can also be used for growing to maturity certain crops such as winter parsley, early radishes, green onions, and spinach. Some growers have used this type of bed for growing early head lettuce.



WIRING DIAGRAM - 8 SASH BED

Fig. 7. In wiring an eight-sash bed a thermostat and relay should be used for controlling the current.

When this type of bed is sterilized a temperature of approximately 182 degrees should be maintained for at least one hour, but it will usually require 4 to 10 hours to heat all the soil in the bed to this temperature, depending upon the steam pressure. This temperature according to work done in Ohio* is necessary to kill nematodes and organisms causing Fusarium wilts. A soil thermometer should be used in order to determine the exact soil temperature.

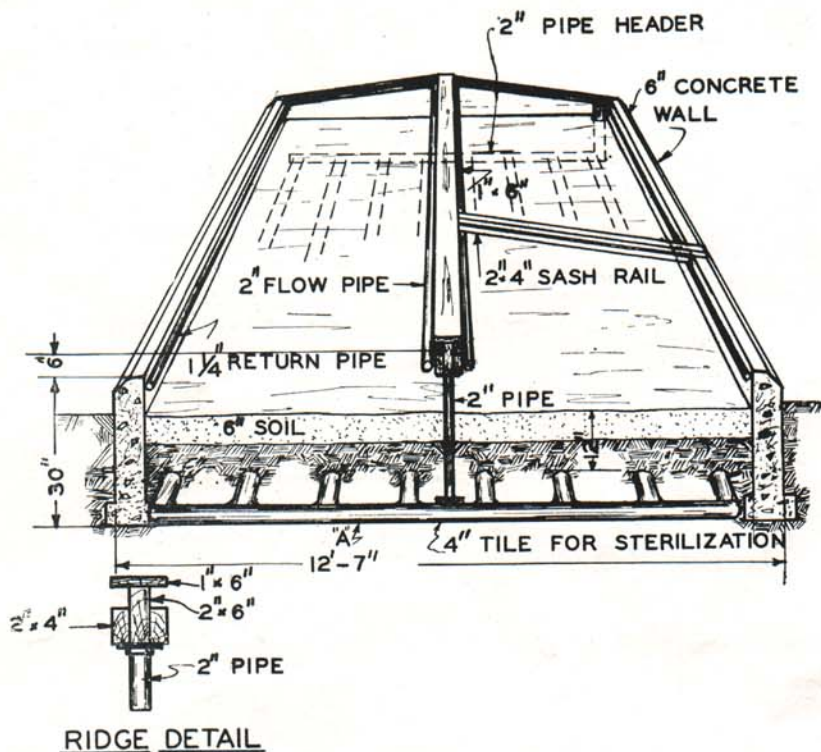


Fig. 8. A permanent type of hotbed built of concrete with steam or hot water heat and with tile for sterilization.

The method of arranging the tile for sterilization purposes is shown in Fig. 8. The tile are usually laid about 18 inches apart and 16 inches deep to the bottom of the tile. Three or four-inch tile are used for this purpose. The steam is allowed to enter the tile through a 2-inch pipe header as shown in Fig. 10. The header is drilled with 9/16-inch holes and tapped for 3/8-inch pipe. Pieces of 3/8-inch pipe about 6 inches long are screwed into the holes. The pipes are inserted in the tile lines and the end of the tile closed with concrete.

The tile lines are tied together with a header made of tile at the other end of the bed from which the steam enters, as shown at A in

*Newhall, A. G. Control of Root-knot Nematode in Greenhouses, Ohio Agr. Exp. Sta. Bul. 451. 1930.

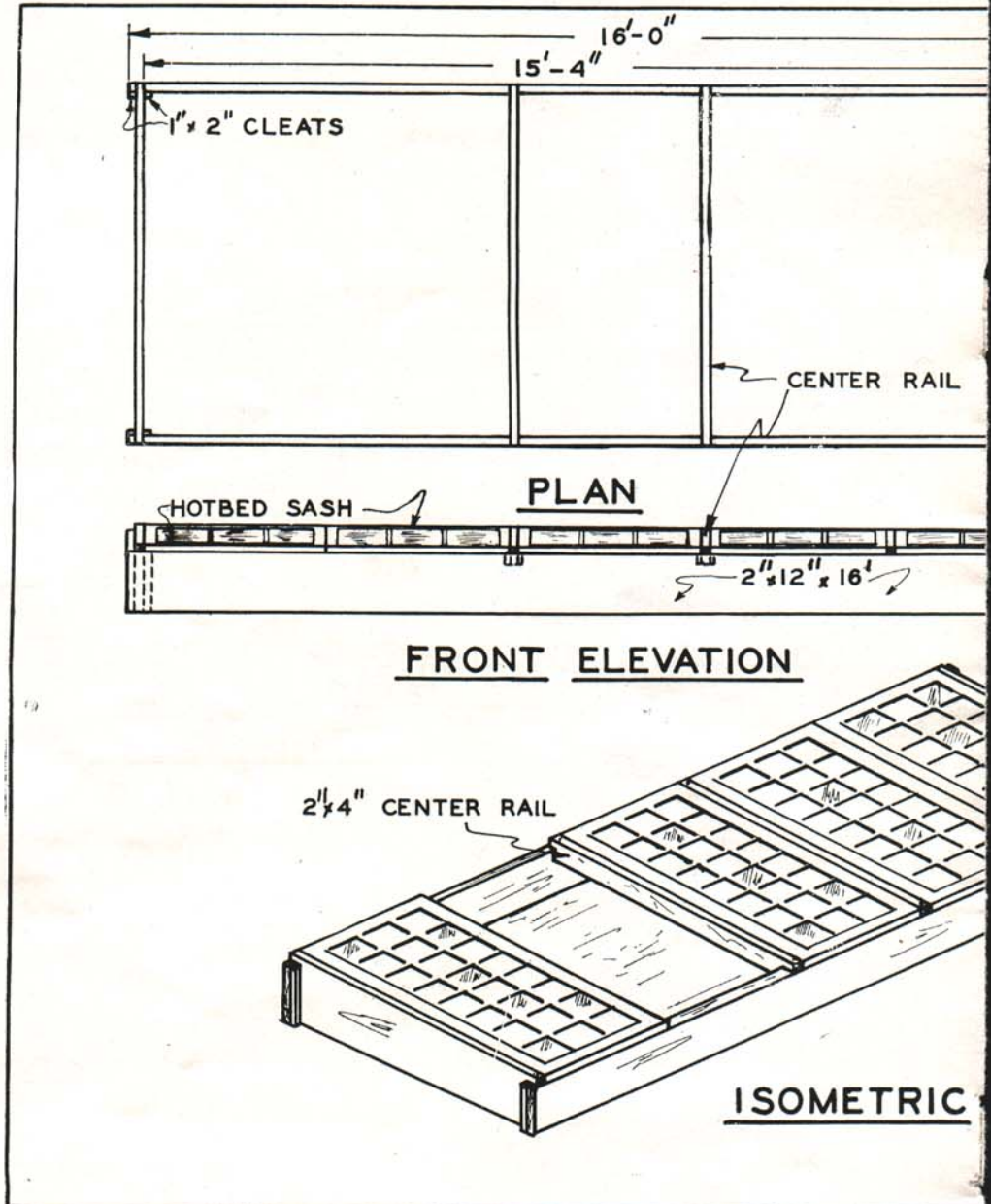
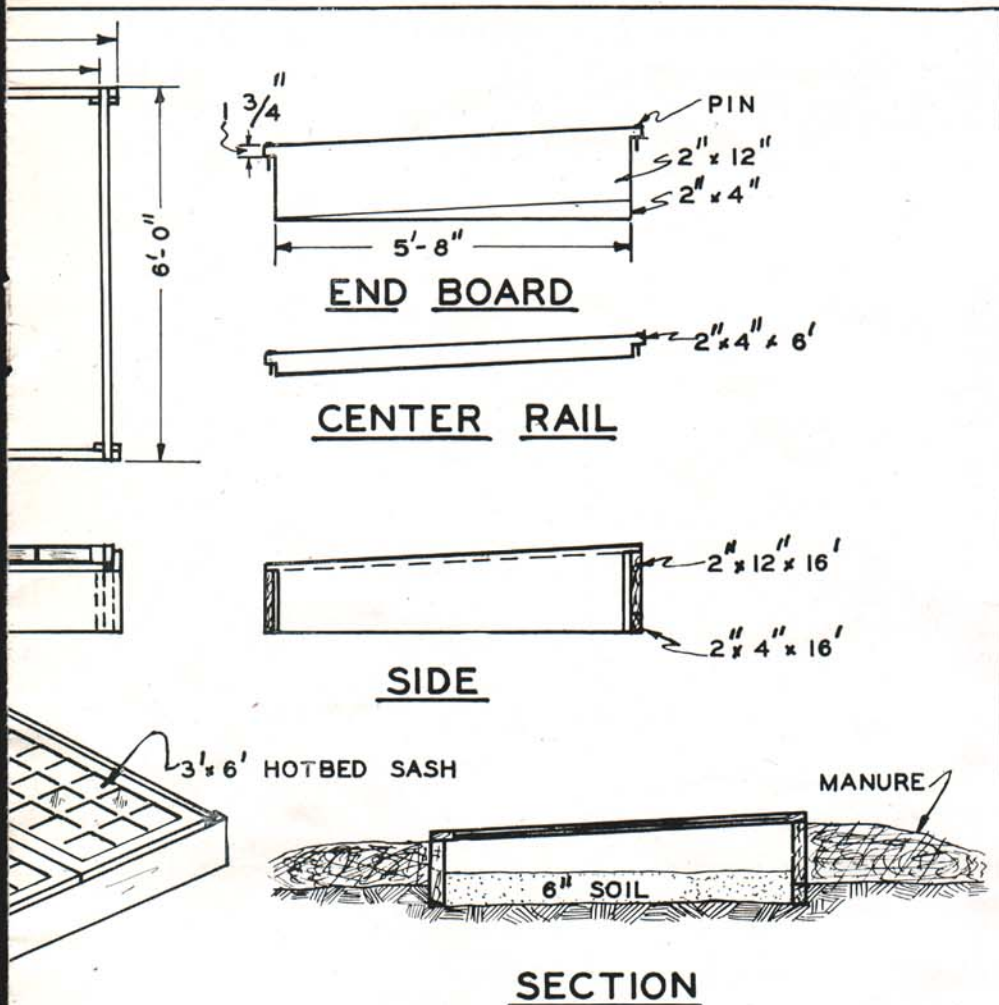


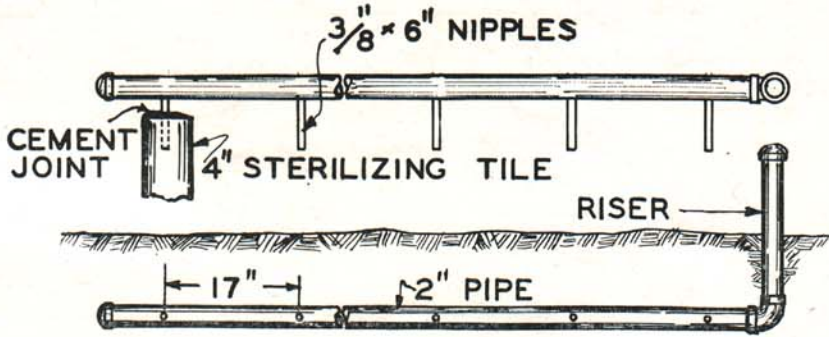
Fig. 9. Construction details



COLDFRAME

AGRL. ENG. DEPT.	P. O. E. R.	L. J. B.
HORT. DEPT.	CH	TR L. J. B.
M. S. C.	SCALE 1/2" = 1'-0"	
E. LANSING, MICH	DATE 2-25-33 No. 795-B-1	

for a five-sash coldframe.



STEAM HEADER DETAIL

Fig. 10. Header pipe used for conducting steam into tile lines.

Fig. 8. The tile lines should be laid with a fall of one inch per 100 feet away from the steam inlet.

Both low and high pressure steam can be used for sterilization, but owing to the fact that low pressure steam does not carry so many heat units, it will be necessary to leave the steam on for a longer time in order to produce the same results. For instance steam of 10 pounds pressure will require about three and one-half times as long to heat up a given amount of soil as steam of 80 pounds pressure. While the boiler used for heating can also be used for sterilizing, it requires a great deal more capacity to sterilize a given area than to heat it. For instance, to sterilize a two-sash bed (6' x 6') requires a 4-horsepower boiler if the work is done in one hour. The same sized boiler would **heat** a bed about 20 times this size, but the boiler used for heating a given bed will be large enough to sterilize one-half of the same bed if the steam is applied for 10 to 12 hours. Tile lines may be as long as 150 feet, but if only a small capacity boiler is available headers must be put in so that an area within the capacity of the boiler can be sterilized at one time. This can be accomplished by putting a header and a temporary partition across the bed and sterilizing these sections one at a time. For example, if a 5-horsepower boiler is used, it will be necessary to sterilize the hotbed in 5-sash sections

Table 2. Showing capacity of boilers for heating and sterilization of hotbeds

Size of boiler in terms of "horse power"	Heating capacity feet radiation	Number sash which can be heated	Area which can be sterilized in 10 hours
1.....	100	28	1 sash
3.....	300	50	3 sash
5.....	500	140	5 sash
10.....	1000	280	10 sash
15.....	1500	420	15 sash
25.....	2500	700	25 sash
50.....	5000	1400	50 sash

(15' x 6'). The bed should be covered over with matting or canvas when sterilizing to prevent loss of heat.

In working with high pressure steam, long tile lines are desirable to prevent blowouts. Also considerable saving in heat can be made if the ground is sterilized when comparatively dry. It requires a great deal of steam to heat up the water in the soil.

The most difficult portion of the bed to sterilize is directly above the header where the steam enters. This portion of the bed can usually be effectively treated by continuing the sterilization for a longer period of time or by providing some means of injecting steam into the soil at this point.

PART II. PRINCIPLES OF PLANT GROWING

The production of early vegetable plants in hotbeds and coldframes involves the use of good seed, the treatment of the seed and soil to prevent disease infections, the proper selection of soils for both the seedlings and transplants and careful attention to the seeding, watering, ventilating, transplanting, hardening and other plant growing operations. The details of these operations are given herewith.

THE SEED SUPPLY

Cheap seed is poor economy, and only the best possible seed of a strain and variety adapted to the locality and which will produce uniformly strong plants should be used. Relatively small quantities of seed are required for starting plants under glass and, in most cases, the cost of the seed is only a minor item in the production costs. The quantity of seed needed to produce sufficient plants for a given area varies greatly with the crop and the field spacings given the plants. This information is given in Table 3. The seed of most all vegetables commonly started under glass retains its viability for at least 4 years. Many growers find it more economical to buy larger quantities and use it for several years. Such a system gives the grower an opportunity to test the performance of the strain under his local conditions.

Table 3. Data on number, longevity, germination and amounts of seed needed for vegetables commonly started under glass

Crop	Approximate No. of seed per ounce	Approximate No. of years good seed will remain viable	Average germination of 1-year-old seed	Approximate amount of seed needed to produce plants for 1 acre
Broccoli.....	10,000	5	85	3-4 oz.
Cabbage.....	7,500	5	85	3-4 oz.
Cauliflower.....	10,000	5	75	3-4 oz.
Celery.....	80,000	4	80	4 oz.
Cucumbers.....	1,000	5	85	2 lb.
Eggplant.....	6,000	6	75	4-5 oz.
Lettuce.....	20,000	5	90	2-3 oz.
Muskmelon.....	1,000	5	85	2 lb.
Pepper.....	4,500	4	75	3-4 oz.
Tomato.....	8,000	4	85	2 oz.

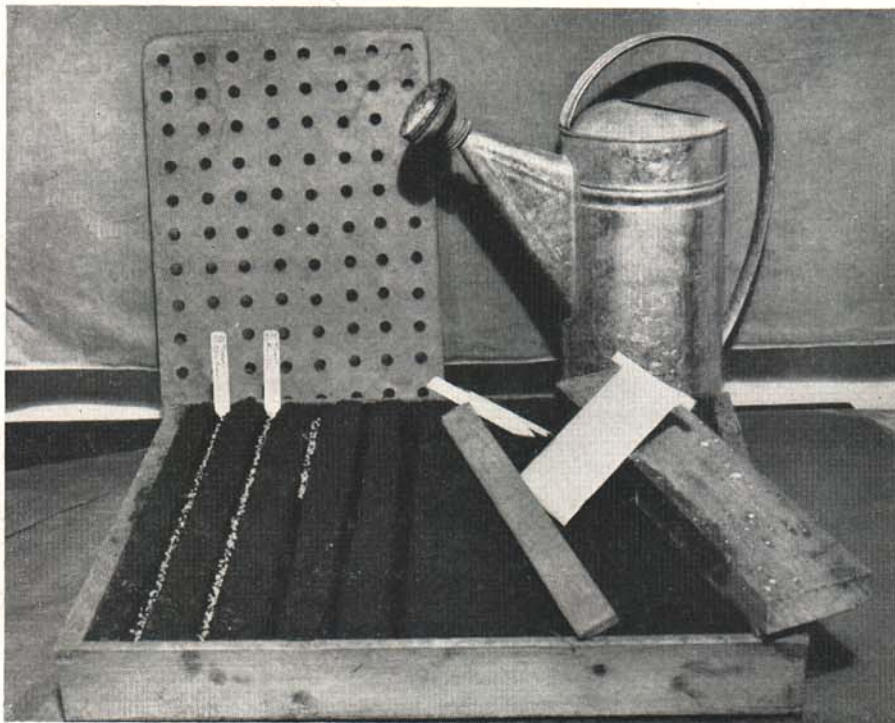


Fig. 11. Sowing tomato seed in flat. Note the equipment shown, including the flat filled with a mixture of compost and soil, the tamper made from a 2 by 4, marker, the labels, seed package, sprinkling can, and spotting board used in transplanting.

SEED TREATMENTS

Treatment of seed before planting is recommended. In general, seed treatments have two definite objectives, (1) to kill the disease-producing organisms on and in the seed, and (2) to protect the seed and young seedlings from disease-producing organisms in the soil. During the past decade numerous treatments have been developed for the control of specific diseases on special crops and no one treatment is effective on all seeds. The recommended seed treatments for all crops commonly started in hotbeds and coldframes are given in Table 4.

SOILS FOR PLANT GROWING

Composts—Even the best of plant growing equipment will not insure good plants if they are grown in soil of poor physical condition. Soils used for growing plants are usually prepared by composting alternate layers of soil and manure. The compost pile should be from 8 to 10 feet wide and as long as desired (Fig. 12). One-foot layers of each of the materials are used, beginning with a layer of soil and finishing the top of the pile with a layer of manure. Sufficient manure should be used in each layer so that after tramping the manure will be at

Table 4. Treatments for vegetable seeds

Crop	Seed Borne Disease	Fungicide or Treatment	Method
2 Cabbage Cauliflower Collards Brussels Sprouts Kale Kohlrabi Radish Turnip	Black Leg Black Rot Alternaria Leaf-spot	Hot water 122° F. (Use Thermometer)	Soak cabbage seed 25 minutes in cheesecloth bags at constant temperature. Test germination after treating. All other seeds soak 15 minutes as above.
	Black Rot	Corrosive Sublimate 1-1000	Dissolve 1 tablet in 1 pint of water or 1 ounce in 7½ gallons of water and soak 30 minutes. Rinse thoroughly and dry.
	Damping-off Wire stem	Semesan Dust or Semesan Jr.	Use according to manufacturers' directions on container. 1 ounce to 3 pounds of seed.
2 Cucumber Squash Muskmelon Pumpkin Watermelon	Scab Angular Leaf-Spot Anthracnose	Corrosive Sublimate 1-1000 solution then dust with	Dissolve 1 tablet in 1 pint of water or 1 ounce in 7½ gallons of water. Soak seed in this solution 5 minutes. Rinse thoroughly and dry.
	Damping-off	Semesan or Red copper oxide	According to directions of manufacturer. 1 teaspoonful to 2-5 pounds seed. Place seed and dust in tight container and mix thoroughly by shaking.
1 Egg Plant Pepper	Wilt Alternaria and Phomopsis Spot	Hot water 122° F. (Use Thermometer) Dry seeds and dust with	Soak seeds in cheesecloth bags for 30 minutes. Test germination after treating.
	Damping-off	Semesan or Red copper oxide	According to directions of manufacturer. 1½ teaspoonfuls to 1 pound of seed. Place seed and dust in tight container and mix thoroughly by shaking.
Beets Lettuce Salsify Spinach	Damping-off	Red copper oxide	½ ounce to 1 pound of seed. Place seed and dust in tight container and mix thoroughly by shaking.
Celery	Leaf Blights	Corrosive Sublimate 1-1000	Place seed in cheesecloth bags and soak seed in lukewarm water 30 min. Dissolve 1 tablet of corrosive sublimate in 1 pint of water. Place bags of pre-soaked seed in corrosive sublimate solution 30 minutes. Wash seed thoroughly after soaking. Dry seed in a warm place. Plant 1/5 more of the treated seed.
	Damping-off	Semesan Solution 1-400	Saturate soil of seedling flat or bed with 1-400 solution (1 ounce of Semesan to 3 gallons of water).
Onions	Smut Damping-off	Formaldehyde Drip	1 pint formaldehyde in 10 gallons of water dripped in furrow when seed is sown. Use 125 gallons of solution to the acre in moist soil. For dry soil use 200 gallons of solution diluted 1 pint to 16 gallons of water.
Peas	Damping-off	Semesan Jr.	Use according to manufacturers' directions on container.
Sweet Corn	Bacterial Wilt	Resistant Varieties	Use according to manufacturers' directions on container.
	Root Rots	Semesan Jr. or Merko or Barbak III	
2 Tomato	Bacterial Spot	Corrosive Sublimate 1-3000	Dissolve 1 tablet in 3 pints of water or 1 ounce in 22 gallons of water. Soak seeds 5 minutes then wash thoroughly in fresh water.
	Damping-off	Red copper oxide	1 teaspoonful to 1 pound of seed. Mix seed and dust by shaking in tight container.
	Bacterial Canker	Use seed from Canker-free plants	(Fermented seed carries less canker than that from ordinary pulped seed.)

least one foot deep. Many growers use soil from woodlots, but such soil is usually heavily infested with *Rhizoctonia*, one of the causal organisms of damping-off, and cannot be recommended. In order to avoid soil-borne diseases, it is not advisable to use soil from lowlands which are subject to drainage and erosion from upland vegetable fields. Soil from a June grass sod field is one of the best types to use. The compost pile should be made so that when it is completed the center will be lower than the sides and will catch and retain water. If the soil and manure are dry it is advisable to water each layer as the pile is being built. Because most Michigan soils, as well as manure, are low in available phosphate, it is advisable to add superphosphate to the compost pile. This may be added to the manure at the rate of 1 to 1½ lb. per cubic yard. The compost pile should be made at least a year in advance of the time needed to allow the organic matter to break down. The decomposed compost should be shredded or passed over a half-inch mesh screen before it is used. The screenings are frequently used in the bottoms of flats or in the coldframe to provide drainage. Compost prepared as outlined is one of the best kinds of soils for growing plants.

Where manure is not available for making the compost pile, synthetic or artificial manure may be used with equally as good results. The synthetic manure is made by treating straw, corn stalks, weeds, or other similar material with a mixture containing nitrogen, phosphorus and lime which hastens the decay of the coarser material. Details for making synthetic manure are given in Michigan Agricultural Experiment Circular Bulletin 157.

When compost is not available, a fairly satisfactory soil for plant growing may be prepared by mixing equal parts of well rotted manure, sand, and top soil or one-fourth manure, one-fourth sand, and one-



Fig. 12. A compost pile such as this one, which has just been completed, will insure an adequate supply of good plant growing soil.



Fig. 13. The sod and manure in this compost pile have broken down after one year into a loose, friable, moisture-retaining mixture.

half top soil. The materials should be thoroughly mixed and shredded or screened before using.

Soil for Seedlings—The soil used in flats or hotbeds where seeds are to be sown need not be so rich as the soil used for growing the transplanted seedlings. A compost or other soil which contains a large quantity of organic matter affords optimum conditions for the development of damping-off organisms. Some growers mix equal parts of coarse sand and compost for this purpose, while others use a layer of coarse compost in the bottom of the flat and cover with coarse sand in which the seed is sown. Still others are reporting excellent results by growing the seedlings in pure sand watered with fertilizer solution. (See page 28.)

SOIL DISINFECTION

Where steam is not available for soil sterilization, fungi which cause damping-off and certain other diseases may be destroyed or inhibited by treatment with chemicals. Formaldehyde either as a liquid or dust is the material most commonly employed.

Liquid Formaldehyde—Where large quantities of soil are to be disinfected, seedbeds may be drenched with formaldehyde solution made up at the rate of 1 gallon of the material in 50 gallons of water. This is applied at the rate of 1 to 1½ gallons to the square yard, or approximately 1 pint to the square foot of soil surface. After treating, cover the soil for 24 to 48 hours with a tarpaulin or sacks, after which the soil should be spaded once or twice to allow the formaldehyde gas to

escape. Allow the treated soil to stand 10 days or 2 weeks before setting seedlings.

For small quantities of soil add 1 level teaspoonful of formaldehyde to 5 teaspoonfuls of water and mix thoroughly with enough soil to fill a 20" x 14" x 3" flat. For 1 bushel of soil, use $2\frac{1}{2}$ teaspoonfuls of formaldehyde and mix as previously described. Allow soil to stand 24 hours before seed is sown. Water thoroughly after sowing seed. Do not set seedlings or cuttings in such soil until after all odor of formaldehyde has disappeared. Seeds sown in disinfected soil need no treatment for damping-off. If damping-off appears on the seedlings, treat as recommended under "Damping-off Control."

Formaldehyde Dust—To prevent puddling of the soil from saturating with formaldehyde solutions, formaldehyde dust may be used. Commercial preparations of this material are much more expensive than liquid formaldehyde and rapidly lose strength even in air-tight containers. A home-made dust may be made by mixing 1 pound of formaldehyde with $5\frac{3}{4}$ pounds of inert carrier. Carriers commonly used are kaolin, sawdust or dried, finely sifted muck. Place the carrier in a drum and add the formaldehyde while stirring with a shovel. Add small stones to the drum, and roll for 2 or 3 minutes. The dust should be used as soon as possible. Add $1\frac{1}{2}$ lb. of home-made dust to each bushel of soil and mix thoroughly by shovelling. For greenhouse benches, the dust is mixed directly with the soil at the rate of 2 ounces to each square foot of soil where the soil is not over 3 inches deep. Water thoroughly after sowing seed.

SOWING THE SEED

Seeding in Flats—Shallow flats or plant boxes afford a convenient method of growing seedlings. The flats are made of redwood or cypress and of a size that fit well in the hotbeds so there is no waste space. A common size is $2\frac{1}{2}$ " x 12" x 18", which may be purchased, sawed and ready to nail together, from the manufacturers of greenhouse and hotbed sash. The bottoms are made in several pieces and at least $\frac{1}{4}$ -inch crack should be left between the bottom slats to provide drainage. These flats may be used in the greenhouse, hotbed, or coldframe and the plants may be moved easily without disturbing their root systems. In filling the flats a layer of coarse material is placed in the bottom to prevent the fine soil from sifting through the openings. The flat is then filled with screened soil, leveled, and tamped slightly.

Seed is usually sown in rows about 2 inches apart. Row seeding allows the sunlight to penetrate to the base of the seedlings and hastens the drying of the surface soil which aids materially in preventing damping-off. The seed is sown in such a manner that from 6 to 8 seedlings will develop to each inch of row. Tomato and cabbage seeds are planted about $\frac{1}{4}$ -inch deep and smaller seed such as celery is just barely covered. After the seeds are covered the surface of the flat should be leveled and covered with a single thickness of burlap. The burlap will prevent the washing out of the seeds and prevent surface evaporation. The burlap covering should be removed as soon as the plants show signs of breaking through the soil.

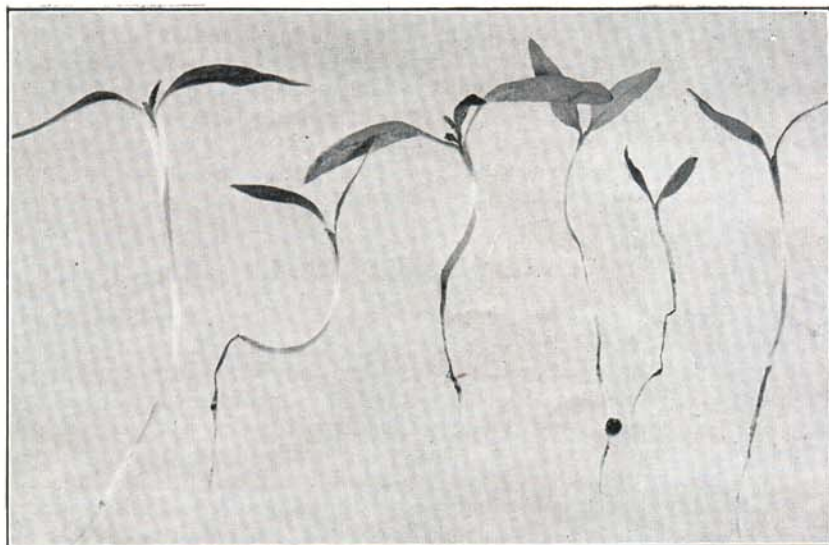


Fig. 14. Damping-off of tomato seedlings. The plant on the left is healthy. Note shriveled stems of the infected seedlings.

Sowing Seed Directly in Hotbed—Seedlings for transplanting are frequently grown by sowing the seed directly in the hotbed or greenhouse bench. The method is essentially the same as outlined for flat seeding. Some growers seed thinly in wider spaced rows in the hotbed and grow the plants without transplanting. The seed is sown about $\frac{3}{4}$ to one inch apart in rows 6 inches apart.

Seeding in Veneer Bands—Cantaloupes, squash, cucumbers, and watermelons do not transplant readily and where early plants are grown they are seeded directly in veneer bands or pots. The veneer bands (Fig. 15) are inexpensive and produce excellent plants. They may be purchased from the manufacturers of berry boxes and are shipped in bundles of 1,000. The bands are flat strips sheared at the joints; after soaking in water, they may be bent and placed in the frame. The bands are prepared for planting by placing a layer of fine soil in the bed, the bands are set side by side, filled with screened compost, tamped slightly, 4 to 6 seeds planted, and covered with sand. Veneer bands are used extensively for growing early tomato plants where the seedlings are transplanted in them. The bands made from wood veneer have consistently given much better plants than any of the various types of paper bands tested.

Time of Sowing Seed—There is a tendency among growers to sow seed too early, which produces plants ready for the field setting long before they can be set in the open with safety. It is then necessary to check their growth which produces hardened plants. Experiments conducted at the Michigan Agricultural Experiment Station have shown that where tomato plants were started early and hardened before field setting, the fruits on the first clusters were small and of

a poor grade. On the other hand where plants were started several weeks later and kept growing continuously, they far exceeded the hardened plants in both total yield and grade of fruit. Tender plants can be produced at much less expense since they are in the beds for a shorter period. In general, it is much easier and safer to force plant growth than it is to retard it. The approximate dates for sowing seed of the crops usually started in hotbeds and coldframes is given in Table 1.

CARE OF SEEDLINGS

Close attention must be given the seed flats and seedbeds if good seedlings are to be obtained. Only by experience can one learn just how to care for the seedlings under the artificial conditions produced in the hotbeds. Over-heating and lack of ventilation will make the plants soft, as will over-watering. Both of these excesses produce favorable conditions for the development and spread of damping-off. The seedlings are equally sensitive to chilling and to wilting as a result of too high or too low temperatures and to too little water.

Watering—The germinating seeds and young seedlings require adequate quantities of water for their proper development but caution should be exercised to avoid over-watering. Immediately after seeding and until the time the young seedlings emerge there is danger of washing out the seeds and packing the surface of the soil. To avoid these conditions it is advisable to water with a fine spray from a sprinkling can. The seedbed should never be allowed to dry out, but one thorough soaking is better than several light sprinklings. The



Fig. 15. A well grown eggplant in a wood veneer band ready for planting in the field.

watering should be given on the mornings of bright clear days so that the foliage and the surface of the soil are dry by night. If the day is cloudy the watering should be delayed until conditions are favorable. The tendency is for over-watering rather than under-watering. The growth of the seedlings may be regulated to a large measure by the amount of water given—for example, if they are growing too rapidly and are long and succulent, growth may be checked materially by giving only enough water to prevent wilting.

Temperature—The temperature to be maintained in the seedbeds depends on the plants being grown. Cabbage, cauliflower, lettuce, and other cool season crops should be grown at 55 to 60° F., while tomatoes, peppers, and eggplants require 70 to 75° F., and cantaloupes and other vine crops do best at 80 to 85° F. The night temperatures for each of the groups should be from 5 to 10 degrees lower than the day temperatures given.

Ventilation—The temperatures within the hotbeds and coldframes is regulated by the amount of ventilation given. Ventilation is also effective in changing and drying the air of the beds. The usual practice in ventilating the frames is to raise the sash on the side away from the prevailing wind. Small blocks are used to hold the sash up and the amount of ventilation given is governed by outside temperatures. In general most growers ventilate too little rather than too much. A good indication of insufficient ventilation is the collection of moisture on the inside of the glass.

DAMPING-OFF CONTROL

Damping-off of seedlings may be caused by one or more of several soil inhabiting fungi. Seed treatment as outlined in Table 4 often gives very satisfactory control of the disease **before** the seedling has pushed its way above ground.

However, after the seedling has emerged above ground, the damping-off fungi may be present just below the soil surface. Here they attack the young seedling, causing it to rot off (Fig. 14). To prevent this post-emergence type of damping-off the seedbed or flat of seedlings may be treated as follows:

Red copper oxide treatment—The red copper oxide is dusted on the surface of the soil at the rate of 1 ounce to each 30 square feet. Another form of red copper oxide known as Cuprocide 54 may be used as a soil sprinkle at the rate of $\frac{1}{2}$ ounce of the material in 1 gallon of water. One pint of this suspension is applied to the square foot of seedbed surface. **Do not use this or other copper materials on cabbage or related plants.**

Semesan treatment—Semesan is usually applied as a sprinkle upon emerging of young seedlings. Follow directions given by the manufacturer which usually call for a solution made up at the rate of 1 part of Semesan in 400 parts of water.

Zinc oxide treatment—This is applied as a dust at the rate of $\frac{1}{2}$ ounce of zinc oxide sifted evenly over each square foot of flat or bed surface. Water lightly to wash material from the seedlings. **Do not use zinc oxide on peppers, lettuce and tomatoes.**

On older seedlings, the foregoing materials may be applied in heavier dosages on areas where damping-off has appeared. However, best control is obtained by treatment before damping-off appears.

GROWING SEEDLINGS IN SAND

The use of sand for starting plants from seed is becoming popular with amateur and professional growers. This method, developed by A. A. Dunlap of the Connecticut Agricultural Experiment Station*, largely eliminates the danger of damping-off and enables the grower to regulate the size of the seedlings. Sand-grown seedlings have large, strong root systems that make transplanting easier. From the experimental work reported, this method seems useful for practically all kinds of plants started from seed.

Sand may be obtained from dunes, a deep pit, or from a dealer in building supplies. Success in the sand culture of seedlings depends to a large extent upon the cleanliness of the sand. Slightly coarse grades are preferable to the finer ones. If the sand is not clean but contains soil particles and organic material it should be treated by one of the following methods:

(a) Wash the sand in several changes of hot water, 160° F. or higher, until the water remains relatively clear after stirring.

(b) Pour boiling water over the sand and allow it to stand for half an hour.

(c) Drench the sand with formaldehyde solution, 1 part commercial formalin to 50 parts of water, and allow it to stand for one day or longer. The formaldehyde must then be thoroughly flushed out of the sand with plain water before planting.

(d) Heat the sand for two or three hours in a hot oven.

(e) Flame the sand with a blowtorch or weed burner.

While the foregoing measures are necessary in some cases, most new sand that is free from loam and organic matter can be used without any special treatment.

The clean or treated sand is placed in fairly tight new or clean flats, a greenhouse bench, or directly in the hotbed or coldframe. If the containers have been used previously for growing seedlings, treat with formaldehyde solution as already described. Where sand is used in the hotbed or coldframe the bottom should be lined with roofing paper before the sand is put in. Six to eight inches of sand is generally needed in these structures but in flats as little as 2½ or 3 inches may be used.

Sand culture is itself a control measure for damping-off and it is usually not desirable to treat the seed with red copper oxide or Semesan before planting in sand. The seed is sown in rows or broadcast and covered to the desired depth with clean dry sand.

Because most sands contain little readily available plant food, it is necessary to supplement the nutrient supply of the seed by watering with a solution of fertilizer chemicals. A solution may be made up of one level teaspoonful each of saltpeter (potassium nitrate), and superphosphate in one gallon of water. Both materials may be pur-

*The Sand Culture of Seedlings and Mature Plants. Conn. Agr. Exp. Sta. Cir. 129. 1939.

chased in commercial grades from dealers in agricultural supplies and it makes little difference whether low or high grade superphosphate is used. Pure grades of saltpeter and sodium phosphate may be purchased at drug stores. Another satisfactory feeding solution for seedlings and older plants may be made by adding 6 level teaspoonfuls of any standard grade of complete commercial fertilizer (5-10-5, 4-12-4, or 4-16-8, or similar analyses) to one gallon of water. These materials contain much insoluble material but after stirring, most of the soluble portions will go into solution and the insoluble portions may be discarded.

Feeding with the fertilizer solution is usually delayed until after the emergence of the seedlings. If flats are used, they may be placed in a shallow pan containing the fertilizer solution and allowed to remain long enough for the solution to wet the sand. Practically as good results may be obtained by sprinkling the surface of the flats or beds with the solution. The fertilizer solutions are weak enough so that little injury to the foliage should be experienced. A light sprinkling with plain water after feeding will wash away nutrients from the leaves. The solutions should be added so that approximately one pint of solution per square foot of surface is given at each feeding. The feedings should be given once or twice a week. Certain kinds of seedlings, especially cabbage and cucumbers, tend to have exceedingly long stems when grown in too dense stands. By withholding the nutrient solution until about 10 days after the seedling emerges normal stocky seedlings may be produced.

Sand-grown seedlings have excellent root development and transplant readily. The usual method is to transfer a group of seedlings with the sand around them into a shallow pan of water. The sand washes away readily and the individual seedlings may be lifted out.

The sand may be used for three or four successive crops of seedlings. If the sand is used over again it is advisable to treat it by one of the methods already outlined. Either new or used sand, when dry, may be stored in a clean place indefinitely without danger of contamination from damping-off fungi.

TRANSPLANTING

When seed is sown in rows 2 inches apart and at the rate of 10 to 12 seed per inch of row, from 800 to 1000 seedlings may be grown in a standard flat. These seedlings must be transplanted as soon as the first true leaves appear or they will be stunted and much of the advantage of starting the plant early will be lost. Transplanting does not benefit the development of the plant but it is not practical to grow early crops without transplanting. It is very poor economy to crowd plants too closely at transplanting time because they must be transplanted again or be stunted owing to crowding. More than one transplanting is not necessary if proper spacing is allowed. The proper transplanting distances are given in Table 1. Some vegetables are never transplanted, such as cantaloupes, squash, and watermelons. The seeds of these crops are planted in veneer bands or pots until they are transferred to the field.

When the seedlings are being lifted for transplanting, it is advisable

to keep as much of the root system intact as possible. Too many seedlings should not be lifted at one time or else they will wilt and be difficult to handle. A small hole is opened with the forefinger or a small dibble and the seedling is inserted down to almost the seed leaves or cotyledons. The soil around the base of the plant is firmed well to establish a direct contact with the roots. After transplanting, the plants should be watered thoroughly in order to settle the soil around the roots. The first day or two after transplanting a light shading is usually desirable.

PLANT GROWING OPERATIONS

Cultivation—If the proper type of compost has been used in the beds, little cultivation is necessary to keep the soil in good tilth. Shallow cultivations between the rows will often help to keep down weeds. All weeds should be removed from the flats or plant beds when they are small because they draw heavily on the limited amount of soil for both nutrients and water.

Fertilizing—Some growers make a practice of working in superphosphate at the rate of two to three pounds per 100 square feet of bed space as the frames are filled with the compost. For flats a four inch pot full is mixed with each wheelbarrow of compost. Where compost is not available for the plant beds, a 4-16-8 or 5-10-5 fertilizer may be applied at the rates given for the superphosphate.

Under certain conditions, the transplanted plants may not make satisfactory growth owing to poor soil conditions. If the plants remain stunted and turn a light yellowish green or purple, which is not traceable to exposure to low temperatures, a shortage of available nutrients is indicated. In such cases it is advisable to feed the plants with one of the fertilizer solutions suggested for the sand culture of seedlings. (See page 29.) However, if the plants are dark green and making satisfactory growth these feedings are not recommended.

Blocking—A method that is commonly followed and which does not require the added expense of pots, bands, or flats is known as blocking. In preparing the coldframe a layer of well rotted manure one and one-half to two inches deep is placed in the bed and this is covered with two to two and one-half inches of compost. The plants are transplanted 4" x 4" or 4½" x 4½" apart. Ten days to two weeks before the plants are to be set in the field, the soil is cut into blocks each containing a plant. This work may be done with a large knife or a wide bladed hoe that has had the shank straightened. The root pruning given in this manner retards the growth and causes the roots to branch. The new roots formed near the edges of the block help to hold the soil together when the plants are moved to the field. This system may also be followed where the plants are grown in flats.

Watering—The plants grown in hotbeds and coldframes should be watered enough to keep them from wilting. As suggested for seedlings, the transplanted plants should be watered only in the mornings of bright clear days so that the foliage and the surface soil will dry off quickly. Enough water should be applied to last for several days.

Temperature—With such crops as celery, beets, cabbage and cauliflower, there is danger of a high percentage of the plant's going to

seed if grown at too low temperatures (40° to 45° F.). The temperatures recommended for starting the seedlings of the various groups of crops should be maintained in the plant beds.

Ventilation—The desired temperature and humidity conditions in the plant beds is controlled by ventilation. During the last two weeks the plants are in the coldframes it is often difficult to keep down the temperature on sunny days. Many times during this period, the sash may be removed from the beds. An effort should be made at all times to prevent water from condensing on the foliage and the under side of the glass.

Spraying—Seed treatment will largely prevent certain seed-borne disease organisms from developing upon the seedlings and transplants. Soil treatments also largely eliminate the spread of diseases from this source. However, neither seed nor soil treatments are entirely effective, and it is necessary to give further protection to the seedlings and transplants. This protection is furnished by spraying the plants with some form of copper compound. The choice of material is determined by its effectiveness as a fungicide and by its effect upon the plant. Certain plants, like those of the cabbage family, may be stunted by copper compounds and those plants should not be sprayed. In certain cases, the presence of excess of lime in bordeaux mixture may react unfavorably upon young plants. Certain compounds of copper seem to be more suitable than others for use as spray materials on certain plants. If bordeaux mixture is employed in the seedbed and the coldframe, a 2-2-50 formula is commonly employed. Usually only one or two applications at weekly intervals are given in seedbed or coldframe. Plants sprayed in the seedbed or coldframe should be allowed about a week between spraying and transplanting.

Some of the newer copper compounds such as Coposil, Basicop, Cuprocide 54Y, Copper Hydro 40, Copper Oxychloride and others have been suggested as substitutes for bordeaux mixture in young plant spraying. The reactions of these materials upon various plants and under different environmental conditions are not definitely known. If such materials are used, they should be tried in an experimental way and according to the manufacturer's recommendations.

Hardening—The purpose of hardening of plants is to produce sturdy and stocky plants that can withstand the hot sun, drying winds, drouths, and cold weather. Hardening will not make tender plants, such as peppers, eggplants, and muskmelons, resistant to frost nor even to cold weather but plants so treated will usually survive field conditions when untreated plants are seriously damaged. Cool season crops, such as cabbage and cauliflower, may be hardened so that they will withstand frosts.

The most efficient method of hardening plants is by withholding moisture or watering only sparingly for a week or 10 days before the plants are transferred to the field. This method is just as efficient as subjecting the plants to lower and lower temperatures, and for crops such as celery and beets, will not cause "bolting" to seed. Increased ventilation along with a decreased water supply is also beneficial, but it is not necessary to subject plants to cold night temperatures and it is often dangerous.

PREPARING THE PLANTS FOR FIELD SETTING

When the plants are being removed from the coldframes for field setting they should be handled so that as many of the small roots and as much of the soil around the roots is retained as is possible. One of the chief advantages of growing plants in pots, veneer bands, and flats is that they may be set in the field with a minimum of disturbance to the roots. Such plants continue to grow and are not checked by having to develop new root systems. Several hours before the plants are to be removed from the frames the soil should be soaked thoroughly. The roots of the plants should never be allowed to become dry from the time they are removed from the frame until they are set in the field. Pruning of the roots or the tops destroys the balance between root and top growth and often results in a retardation of growth.

Where the plants are pulled with no dirt on the roots for setting with transplanting machines, the soil should be loosened with a fork and the plants pulled carefully so as to retain as many roots as possible. The plants should be stodd in pails, baskets or shallow trays with either water or moist soil around the roots. The containers should be covered with moistened burlap and kept in the shade to prevent the plants from drying out.

SANITATION AND CROP ROTATION

One of the cheapest forms of crop insurance is sanitation and rotation. Leaving diseased plant debris on the ground after a crop is removed simply invites further trouble the following year, especially if the same crop is grown in that soil.

Diseased plants left upon the ground are not rotted and when plowed under the following year serve as a source of infection to the next crop. Plowing under plant remains in the fall allows this material to disintegrate, serves as added humus and in the process of decomposition many of the disease-producing organisms are killed.

However, it may require two or more years for the disease organisms to be killed and thus crop rotation should be practiced. In this way the susceptible crop will not be grown upon infested soil until after the disease organisms are largely killed or starved out. Likewise in selecting soil for seedbeds and coldframes care must be exercised to obtain soil as free as possible from undecomposed plant refuse. In certain types of wilt diseases such as those of cabbage, celery and tomato, the causal fungus is known to remain alive in the soil for many years after the crop is grown. In other diseases such as the leaf spots and fruit rots, the causal fungi live only one to a few years in the soil. A three-year crop rotation is considered safe for most diseases.

Many weeds harbor the organisms causing vegetable diseases. For this reason weeds should be kept removed for a considerable distance from hotbeds and coldframes and weed control should be practiced in and around vegetable fields.