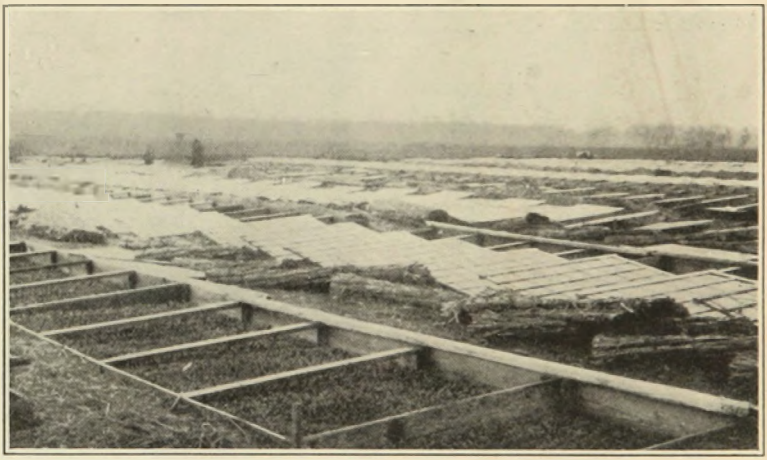
Bulletin 328 Revised August, 1934

HOTBEDS AND COLDFRAMES

By A. M. Binkley and Richard V. Lott



Hotbeds in the Valverde District at Denver, showing the mats removed and sash lifted from one side to allow ventilation.

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HOTBEDS AND COLDFRAMES

By A. M. Binkley and Richard V. Lott*

Due to the short growing season in many parts of Colorado the average vegetable grower should be provided with hotbeds and coldframes to produce his crops most efficiently and to get the greatest possible returns. Certain long-season crops like tomatoes, eggplants, peppers and celery, will not mature in many parts of the state unless the plants are started in the hotbed or coldframe. Crops like early cauliflower, cabbage and cantaloupes in bands may be started under glass and will mature much earlier than they do when planted in the open. This gives the advantage of the high prices of the early market. Such crops as lettuce, radishes, beans, beets and carrots may be grown to maturity in hotbeds or coldframes early in the season before they can be grown out-of-doors. By this means the high prices for out-of-season products can be obtained.

There is a rather extensive area in the Valverde district of Denver devoted to the culture of such plants in hotbeds and coldframes. The picture on the cover of this bulletin shows the typical layout of frames of a grower in the Valverde district. Lettuce, radishes and similar plants can also be grown in them in the fall when it is too cold to grow them successfully outside. The frames can be used for wintering over all sorts of half-hardy plants, including many flowering plants such as pansies and many of the half-hardy perennials.

Hotbeds and coldframes are without doubt good investments for the vegetable grower. They enable him to produce crops out of season, to produce seasonable crops earlier, and to grow crops which could not be matured without their aid. By using hotbeds and coldframes the grower's profits are greatly increased at a relatively small cost.

Hotbeds

The principal functions of the hotbed are: To extend the normal growing season so that crops may be grown which require more time than the average season affords, to force plants to maturity out of season, and to force early plants to be transplanted to coldframes or to the field. A hotbed is a plot of earth enclosed by a frame, covered with glass, and provided with some sort of artificial heat. The most common and most easily constructed type of hotbed is that in which fermenting stable manure is used as a source of heat. Hotbeds are also made which use hot air or hot water as a source of heat. These have the advantage that any desired temperature can be maintained at all times. But, due to the fact that they are rather expensive and

*Mr. Lott has resigned.

Fig. 1.—Growing early cucumbers in hotbeds near Denver.

therefore are not suited to the needs of the average vegetable grower, they will not be considered further in this bulletin, and only manure-heated and electric hotbeds will be discussed.

Location.—If it is possible to choose a location the hotbed should be placed on a well-drained piece of ground, preferably with a southern slope, and close to an abundant supply of water. It is well to place the hotbed on the south side of the farm buildings if possible to obtain the effects of the windbreak afforded by the buildings. If the hotbed must be placed in the open, provide some sort of windbreak. The best sort is a fence of boards 5 or 6 feet high. The slope of the hill also affords some protection.

There are two general types of manure-heated hotbeds: The permanent hotbed and the temporary hotbed. There are several kinds of each, but only the more common types will be described.

Permanent Hotbeds.—The permanent hotbed is usually used by the vegetable grower who has been in the business for a number of years and has a definite idea of his operations from year to year. The permanent hotbed consists of four essential parts: The pit, the frame, the sash and sash covers. The hotbed pit is dug 18 to 24 inches deep, 6 feet wide and as long east and west as is needed. The pit should be dug in the fall before severe freezing weather and filled with straw or litter to keep the walls from

Fig. 2.—Forcing radishes in hotbeds for the early market. Notice that no sash are used but mats are supported by wires.

freezing and crumbling during the winter. If permanent walls are to be used they should be put in at this time. It is often impossible to dig a pit satisfactorily in the spring on account of snow and frozen or wet ground. If the walls of the pit are frozen, much of the early heat generated by the manure is used in thawing them out.

The hotbed frame may be made of brick, hollow tile, reinforced concrete or boards. Reinforced concrete is probably the most lasting and most satisfactory of these materials, but boards are usually more applicable to the conditions of the average farmer. The board frame, if constructed properly, will last for several years and can be made so that it can be taken up and stored each year after the season is over. The frame should be made of boards 1½ to 2 inches thick and may be made of most any sort of good lumber that is available. The frame can be made to extend to the bottom of the pit or down only a few inches, just as the grower prefers.

The easiest to handle and one of the most satisfactory types of frame is that shown in Figure 3. It is made of boards 1½ or 2 inches thick and extends down only a few inches into the pit. It rises 12 inches above the soil level on the north side and 8

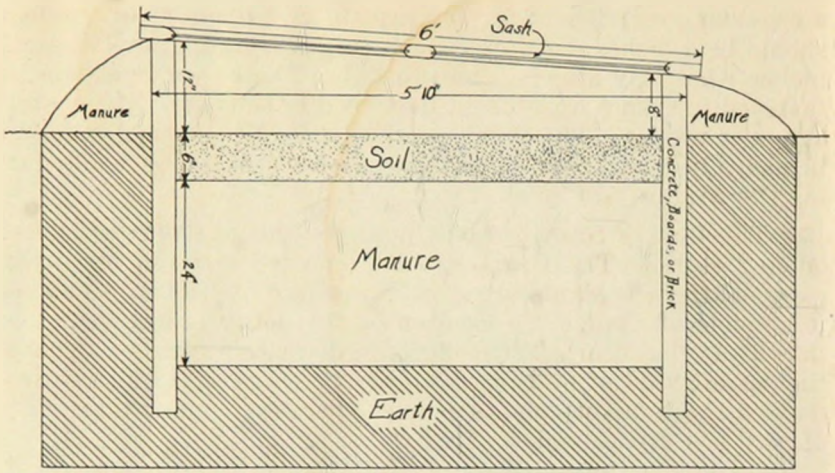

Fig. 3.—Cross-section of a permanent manure-heated hotbed.

inches on the south side. This gives a slope to the south which allows the sun to penetrate easily. This sort of frame can be made in sections of a size to hold any number of sash. The most convenient-sized section is one holding three or four sash which would be 9 or 12 feet long and 6 feet wide. Figure 4 shows a section of such a frame made for four sash. There is, of course,

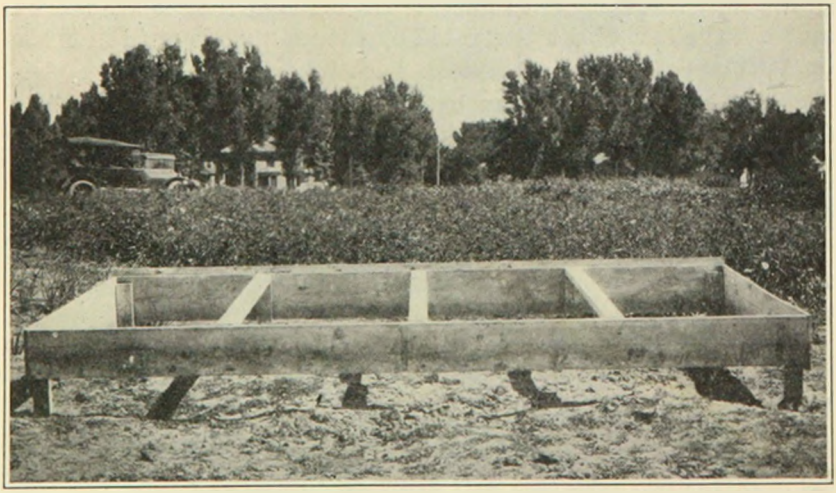

Fig. 4.—Section of frame built to hold four sash. This type of frame can be shifted to a new location each year or used on the same pit for a number of years.

a crossbar every 3 feet for the sash to rest upon. The crossbar should be 4 inches wide and 1 inch thick. A light iron T-beam 2 inches wide may also be used for this. The crossbar should be fastened in such a way that it may readily be taken out for storage over winter. The frame sections may be fastened together in such a way that they can be taken apart and stored inside during the winter.

This kind of frame is easily put upon the pit and easily taken off and stored. The frame can be removed and the pit easily cleaned after the plants are gone. This kind of frame also makes it possible to change the location of the hotbed every year and thus avoid the accumulative effects of diseases in the bed. This is the easiest kind of hotbed frame for the farmer to use. It produces as high-quality plants as any other sort, and, if taken care of, will last for a number of years.

Sash.—The standard sash used on hotbeds is 3 feet wide and 6 feet long, like that shown in Figure 5. It should be made of

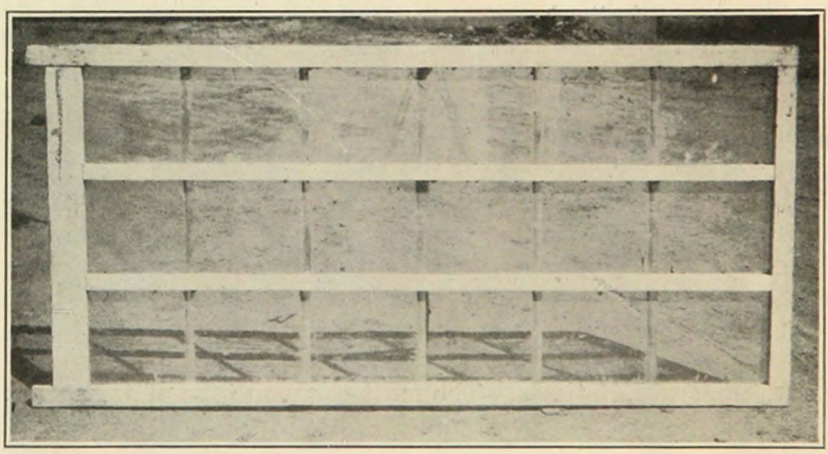

Fig. 5.—The standard single pane sash used on hotbeds and coldframes.

cedar or cypress and may be bought glazed or unglazed. If the grower has the facilities for glazing, it is often cheaper to buy unglazed sash and glaze it himself. Sash vary in thickness but 1½ inches is a good-weight sash to use as it is easily handled and is durable when taken care of.

Double-glass sash are sometimes used. They have these advantages: (1) They are almost as warm as single sash covered with reed mats. (2) There is less labor in managing frames because there are no mats to handle. (3) The plants receive light

all day, since there are no mats to obstruct it. (4) The bed warms up earlier in the day and stays warm longer. The disadvantages of double sash are: (1) They are heavier to handle. (2) They cost about one-third more. (3) Moisture accumulates between the glass and it is therefore doubtful whether they are as durable as single sash. (4) Dirt often accumulates between the panes, thus reducing the amount of light that reaches the plants. This reduction of light is often enough to injure the plants.

It is usually best to buy single-glass sash and cover them with reed mats during periods of cold weather. Mats such as shown in Figure 6 will thoroly cover one sash and can be bought for $1.00 each. They efficiently protect the bed during any unusual weather thru the season.

Glass Substitutes.—During the past few years there have been many glass substitutes on the market to be used for hotbed and coldframe protection. So far glass is probably more satisfactory, since it permits more sunlight to pass thru to the bed and plants. During the early part of the day the glass substitutes do not permit the beds to warm up as quickly. The glass substitute on wire netting is harder to clean by washing, since dust and sediment stick to the surface. It is lighter in weight and must be weighted down to prevent winds from blowing it off or held on the beds by holding attachments.

The glass substitutes seem to be of some value for shading during the germination of small seeds like celery, but after the seedlings are well started, substitutes seem to favor the growing of more spindly plants. More artificial heat, of course, would be necessary when sunlight does not pass thru readily to the bed.

Temporary Hotbeds.—The most common type of temporary hotbed is that shown in Figure 7. The principal advantages of this type are that it is easily constructed and that it can be used in locations where the soil is too poorly drained to permit the use of a permanent hotbed. The temporary hotbed has the disadvantages of requiring more manure and of being harder to protect from winds. Its use is never recommended where a permanent bed can be used

The construction of the temporary hotbed is very simple. The pile of heating manure is leveled off, the hotbed frame placed upon it, manure banked up around the frame, 4 to 6 inches of soil placed in the frame, the sash put on, and the whole managed the same as a permanent hotbed.

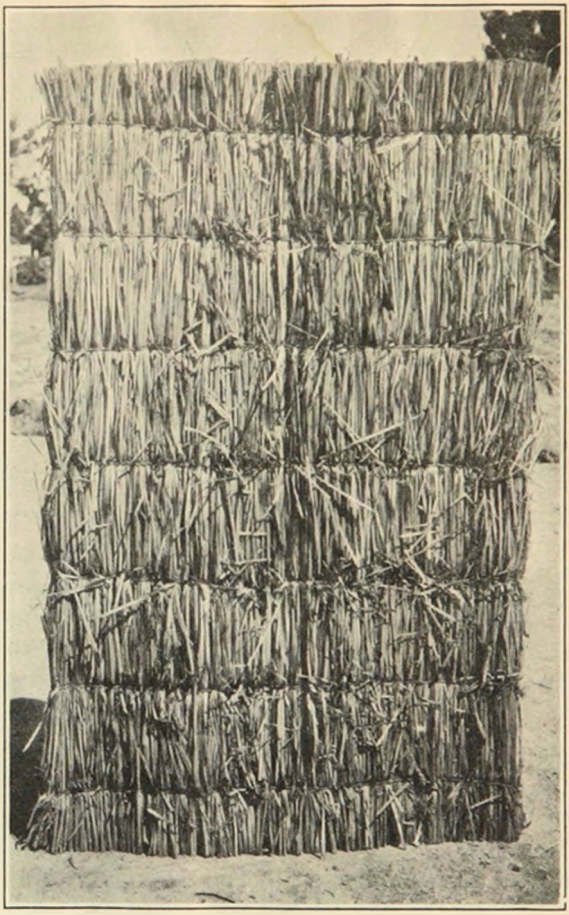

Fig. 6.—Reed mat used for protection on hotbed or coldframe in cold weather.

Preparation of Manure.—The artificial heat of the hotbed is provided by the bacterial fermentation of manure, spent hops or tanbark. Horse manure is used almost entirely for hotbeds.

The best results are secured by using fresh horse manure from grain-fed animals. The manure should contain one-third straw or similar litter which is commonly used in bedding. Manure containing wood shavings is not satisfactory and should not be used. If the manure does not contain litter it often will not ferment and if it does ferment the action is liable to be so violent

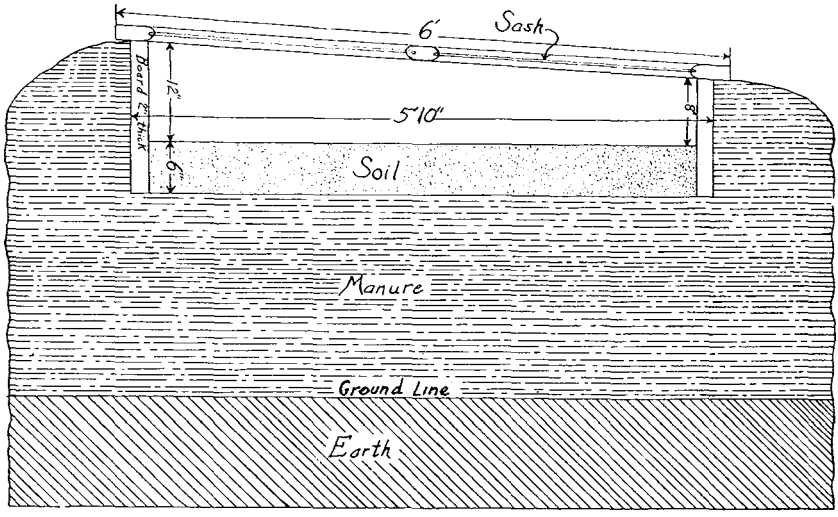

Fig. 7.—Cross-section of a temporary hotbed.

and of such short duration that it is worthless for hotbed use. If there is too much litter in the manure the period of heating is often too short to be of any practical value, due to the fact that the bacteria soon use up all the fermentable part of the manure.

From 10 to 14 days before the manure is to be put into the pit it should be placed in a pile 4 to 5 feet wide and 3 to 4 feet high and the length required for the bed. If it appears dry it should be dampened with warm water but should never be wetted enough to become soggy. In 3 to 5 days, depending on the quality of the manure and the warmth of the weather, the manure will start to heat. When it has heated for a day or two it should be repiled with the outside of the pile in the middle and all lumps well broken up. Any dry spots appearing at this time should be dampened with water, preferably warm but not hot. Repiling the manure insures uniform heating thruout the pile, which is necessary for good results in the hotbed. It will sometimes be necessary to repile the manure two or three times to secure uniform heating, but once is usually enough. If the hotbed is near a shed of any sort it is best to pile the manure under the shed to heat or, if this isn't possible, to construct near the hotbed a cheap shelter under which to pile the manure. This prevents the possible loss of the manure from heavy rains which will usually prevent the manure from fermenting at all. A shelter is, therefore, especially desirable when large hotbeds are made, making necessary the use of large quantities of valuable manure.

When the piled manure is heated uniformly thruout it should be placed in the hotbed pit. The manure should be put into the pit in layers of 5 or 6 inches at a time and tramped thoroly, especially around the edges. This prevents uneven heating in the bed and the manure settles very little. Continue until the pit is full and dampen the manure if it seems to be dry.

Then put the frames in place if portable frames such as were described on page 7 are used. The sash should be put on at this time to guard against rains which would, if very heavy, prevent further heating of the manure. The manure will gradually heat up to a high temperature and then gradually cool down. When it has cooled down to a temperature of about 85 degrees F. the seed can be safely sown. If seeds are sown at a temperature much higher than 85 degrees F. there is danger of the germination being impaired.

The Soil.—The soil may be put in the frame either when the pit is filled with manure or when the temperature is low enough to safely plant the seed. If it is put in when the pit is filled the resulting high temperature may kill most of the weed seed present in the soil. The soil will also be warmed up so that the seed will germinate readily when planted.

Various kinds of soil mixtures are used for hotbeds. A fairly fertile garden loam containing plenty of humus is usually very satisfactory for hotbed use. A too rich soil is not desirable because the plants tend to become succulent and are difficult to harden off and transplant successfully. One soil that is used extensively for hotbeds is made up of one-fourth sand, one-fourth well-rotted manure and one-half good garden loam. Leafmold, rotted sod or rotted straw may be used instead of manure. Some growers use a compost made by piling blue-grass sod and barnyard manure in alternate layers 8 to 10 inches deep. This compost should be made at least 8 months before the soil is to be used. Any coarse material in the compost should be removed and the remainder put in the hotbeds. Whatever sort of soil is used should be moderately fertile, should contain enough organic matter to hold water and be loose and friable, and should contain enough sand to warm up readily and to drain easily.

The soil is placed in a layer 4 to 6 inches deep on top of the manure in the hotbed. The greater depth is used for radishes and root crops with similar growing habits. If the seeds are sown in flats, 2 inches of soil or sand on top of the manure is sufficient. This thin layer allows the heat to reach and warm up the soil in the flats and the plants will grow as well as if they were planted

in the soil in the bed. Plants that have been started in pots in the greenhouse or elsewhere may be successfully grown to transplanting size by plunging the pots to the rim in the hotbed.

The same soil that is used in the hotbed may be used for sowing seed in flats. If the grower prefers a lighter and more porous soil he should add enough sand to make the soil mixture about one-third sand. Well-rotted leafmold mixed with one-third sand is one of the very best soils to use for seeding in flats. It allows the plant roots plenty of room for expansion and is also loose enough that the plants can be pulled for transplanting with very little root injury.

Time to Start the Hotbed.—The time at which the hotbed should be started is governed mainly by the time at which the plants can be set out safely in the field. The date of starting the hotbed also depends upon the type of plant to be grown and upon its treatment before setting in the field. Tender plants like tomatoes, eggplants and peppers cannot be safely planted out until long after the half-hardy plants such as cabbage, lettuce, cauliflower and celery have been set out. Therefore, the hotbed must be started later for tomatoes, etc., than for celery and similar crops. If the plants are to be transplanted from the hotbed to coldframes to grow until set in the field, the seed may be sown earlier than is the case when they are not to be transplanted previous to setting in the field. Briefly, then, the time of starting the hotbed depends upon the type of plant, the treatment the seedlings receive before setting in the field, and the time at which they can be safely transplanted to the field. It is well to allow 8 weeks from the time the seeds are sown until the normal time of setting in the field. This allows plenty of time to grow a healthy, vigorous plant and also plenty of time in which to harden it properly for transplanting. Another 2 weeks should be allowed for preparing the manure and the seedbed for seeding. The great diversity of climatic conditions in Colorado makes it almost impossible to give definite dates for sowing seed.

Electric Hotbeds

During the past few years there has been considerable interest in the use of electricity as a means of heating soil in hotbeds. Previous to 1930 there was not a satisfactory heating element made in this country, altho such material was in use in Norway, Sweden, Holland and other European countries. Dr. E. P. Sandsten, in an unpublished report of his visit to Sweden, Norway and Denmark in 1929, discussed the use of an electric heating cable as a means of heating greenhouses, hotbeds and even

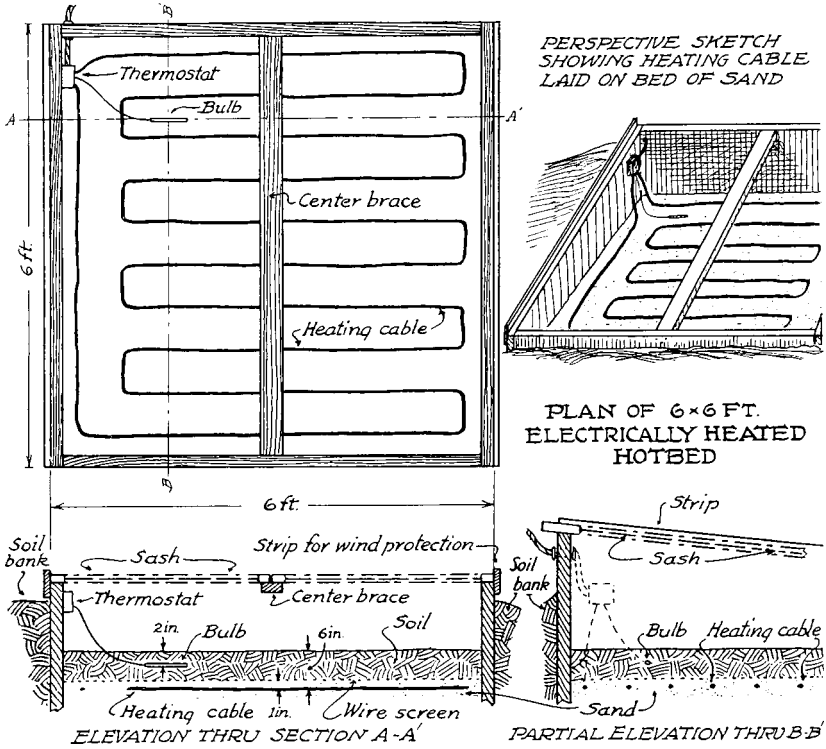

Fig. 8

outdoor soils. At that time there was no manufacturing concern in the United States producing a resistance cable that was satisfactory from a cost and operation standpoint. There are, however, several heating cables manufactured now on a scale of production which makes it possible to sell at a fair price.

The cable is made out of nichochrome resistance wire, wrapped with asbestos paper, jute or other insulating material, and the whole covered with a lead sheath. The diameter varies with the different makes from 3/16 to ½ inch.

With the heating cables available at fair prices, the use of electricity in furnishing heat may now be more generally adopted by growers if electricity can be purchased at a fair rate per kilowatt hour. There are, of course, many economic questions to be answered as far as electric soil heating is concerned.

Advantages of Electricity to Consider.—1. Equipment, when permanently installed and properly taken care of, will last several years.

2. Uniform temperatures can be maintained by thermostatic control. When the temperature reaches a set minimum point, the electricity is turned on automatically.

3. It is always ready to use.

4. Some equipment can be transferred to the greenhouse and used in propagating or cutting beds.

5. Soil moisture can be held more uniform and seedling disease losses reduced.

6. Electrically heated hotbeds can be used for late fall plantings.

7. Good manure is becoming more difficult to secure. It does not maintain a uniform temperature during the plant growing period.

8. The hotbeds can be used as coldframes by turning off the electricity.

Cost of Equipment.—Heat cable can be purchased from many sources at a price of about 5 cents per foot. It is sold generally in definite lengths for a certain number of sash. One company sells 60 feet of cable, sufficient for a 6 x 6-foot hotbed space for a little under $3.00. Thermostats cost from $6 to $10 each.

Installation of Heating Cable for Under-Soil Heating.—The heating cable can be placed at a depth of 6 inches under the soil surface. The spacing between cables should be about 7 inches, which will make it possible to have 5 loops or coils per 3 x 6-foot sash. The longer the cable the more resistance is created, so that increasing the length of the cable lowers the amount of heat produced. It is therefore necessary to use standard lengths and your local power company can advise you on the circuit voltage, ohm resistance of the cable, and the watts of heat for length of cable.

In order to protect the cable from cutting or damage during removal of the soil, a fine wire screen may be placed an inch above the cable. Fine sand is poured around the cable first and then the protecting screen placed over the cable. Two or three inches of straw or strawy manure will be of some protective value, and wooden protecting frames can be used in place of wire screen.

A thermostat can be installed at a convenient location under 2 inches of soil if the bulb type is used. Hand switches may be used in place of a thermostat if the operator desires such an arrangement.

Cost of Operation.—The cost of operation is variable and depends upon the insulation of the hotbeds, the outdoor weather conditions during the period of use, electricity rates, ventilation methods and plants or crop grown. During a period of 6 to 12 weeks, 30 to 120 kilowatt hours per 3 x 6-foot sash have been reported as used.

Heat furnished for hotbeds from fermentation of manure, by hot air, steam or electricity is to supplement the heat furnished by the sun's rays. Therefore, any addition to the hotbeds that will prevent heat losses will cut down operating costs. Protection from cold winds, the use of mat covers for sash, tight-fitting sash, freedom from open cracks in the frames, slope and drainage—all are important factors to consider in reducing heating losses. It is important that hotbeds be checked for heat losses and especially so where electricity is used for heating.

This brief discussion is included to call the attention of growers to the possibilities of electricity as a means of furnishing heat for hotbeds. Many details have not been discussed, and it is recommended that those planning electric installation get in touch with their local power company or electrician for information on electricity rates, proper installation of electrical equipment, electric cable and other necessary supplies.

Care and Management of the Hotbed

Sowing the Seed.—When a temperature of 85 degrees F. has been reached in the hotbed the seed should be sown. Seed may be sown broadcast or in rows. Sowing in rows is preferred, since a better stand is usually obtained and there is better ventilation among the plants. The rows should be 3 inches apart and run across the bed from front to back. The soil should be perfectly level after seeding in order to prevent uneven watering of the bed due to water settling in the lower spots. The bed should be watered with a fine spray immediately after sowing. A hose, unless used very carefully, has too much of a tendency to wash out the seed. After sowing small seeds it is advisable to cover the bed with cheesecloth, burlap or similar material and then water thru the cloth. This minimizes washing and also favors germination by holding the moisture near the seed. The cloth should be removed as soon as germination begins.

Ventilation.—Hotbed ventilation has two main objects: (1) To control temperature and (2) to admit fresh air to the growing plants. Proper temperature conditions are absolutely essential to any degree of success with a hotbed. The amount of heat provided by the manure cannot be regulated, but the temperature surrounding the growing plants can be controlled by ventilation and by shading. The temperature within the frame can be lowered by raising the sash and admitting fresh air, but on severe days the sash cannot be raised without injury to the seedlings from drafts of cold air. On such days the plants may be injured by the bright mid-day sun. This injury can be prevented by partially shading the sash with cloth or by covering

the sash with muddy water which leaves the glass partially shaded. During periods of extremely cold weather the heat can be kept in the bed by keeping the sash down and putting straw mats or other cover over the sash.

Thompson* has shown that celery plants hardened for transplanting at an average temperature under 50 degrees F. for a period of 10 to 14 days will produce a large percentage of premature seed stalks. Therefore, temperature conditions must be regulated properly in the hotbed to reduce the percentage of celery that goes to seed in the field.

Warm-season crops, such as tomatoes, require a day temperature of 75 to 85 degrees F. in the hotbed, while lettuce, radishes and other cool-season crops do best in a temperature of 55 to 60 degrees F. The night temperature in all cases should be 10 to 15 degrees lower than the day temperature. Both warm and cool-season crops can be grown in the same general hotbed by planting on different sides of a partition and by varying the amount of ventilation. It is advisable to keep a thermometer on the inside and one on the outside of the hotbed with the bulbs in the shade. Then the grower can tell accurately whether the bed is getting too cold or too hot, and can vary the amount of ventilation to secure the desired temperature around the plants.

Fresh air is as essential to optimum plant growth as is the correct temperature. Growing plants give off considerable quantities of gases and if these are allowed to accumulate in the bed they soon become toxic to plant growth. Without plenty of fresh air the bed does not dry out well and diseases, especially "damping off," are apt to start. Those plants that do not become diseased usually become weak and tender if they go very long without fresh air. During periods of weather when it is so cold or snowy that the sash must be left down all the time, the amount of watering should be decreased, since the excess water increases the humidity. The plants then become weak and succulent and when the weather warms up it is very difficult to ventilate them properly without injury. Drafts should be avoided at all times, since they always slow up the growth of the plant and in many cases stunt them permanently. Drafts can be avoided by raising the end of the sash away from the wind. The sash may be raised from either end or from either side, depending upon the direction of the wind. Figure 9 shows the method of ventilating a hotbed on a cold day or when plants are still young. As the outside temperature rises, the amount of ventilation should, of

*Thompson, H. C. Premature Seeding of Celery, Bul. 480, New York Agr. Exp. Sta., Cornell University.

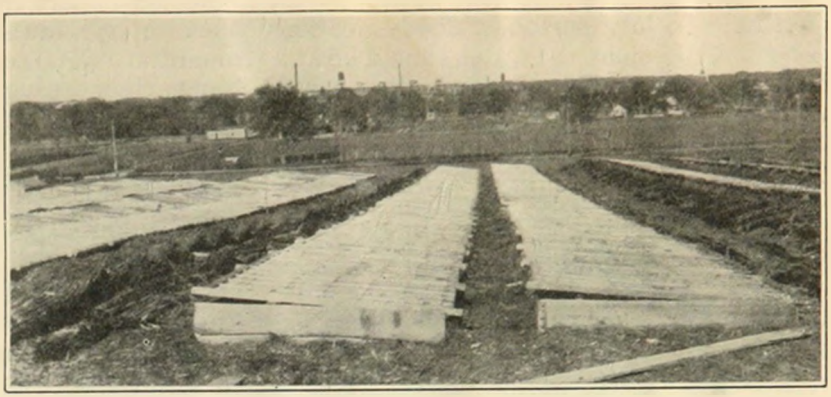

Fig. 9.—Method of ventilating when plants cannot stand much cold air. Sash raised on one side away from wind.

course, be increased. When the weather is very cold the sash should be closed earlier in the afternoon to prevent the heat from escaping from the bed.

Watering.—The growing seedlings in the hotbed must have plenty of water for good growth, but care must be taken to prevent over-watering. The amount of water needed depends upon the temperature, the humidity of the air and the amount of sunshine. Water should be carefully applied, due to the danger of a packed or puddled soil, chilled plants and soaked manure, with a check in fermentation and heat production. Puddling is worse when a hose is used in watering. There is much more water applied to a hotbed soil than to a field soil in the same length of time. Therefore, care must be exercised not to injure the physical condition of the soil. Better results are always secured by watering infrequently and thoroly than by making frequent light waterings. When light watering is practiced every day or oftener, the water seldom penetrates deeply enough to reach the root system of the plants, but wets only the top soil. Under these conditions it is quite possible for the plants to be suffering from lack of water even tho they have been watered recently. It is best to water the bed thoroly, and then let it go until the soil is dried out for a few inches below the surface. Never drench the bed, as there is danger of wetting the manure and checking the fermentation and subsequent heat production. Very little water will be needed during February and March, due to the higher humidity at that time and the greater number of cloudy days. Much more will be needed during April and early May. The water should be put on in the form of a fine spray.

Watering should be done in the morning and only on sunny days unless a long period of cloudy weather makes watering necessary. If possible, the water should be at a temperature of 60 to 65 degrees F. when applied. If water is applied in early morning at this temperature the difference between the temperature of the plant and the water is small and the danger from cold shock is not as great as it would be later in the day when the plants would be warmer than the water. If the plants are watered late in the day when the temperature is falling, the water will cause the temperature of the bed to fall unusually low during the night and there is danger of severely shocking the plants. If watered in the morning when the temperature is rising this danger is eliminated and the plants and top soil are dried off and warm long before night.

Transplanting.—The hotbed plants may be transplanted once before they are set permanently in the field. There are two main purposes of transplanting: (1) To give the plants ample room in which to branch out and form sturdy plants, and (2) to harden off the plants before they are set permanently in the field.

Hotbed-grown plants are grown under artificial conditions and therefore the grower should do all in his power to make their surroundings such that optimum growth is secured. To secure optimum growth the plants can be transplanted from the hotbed into flats or into the earth in a coldframe. The flats may be kept either in the hotbed or in coldframes. When the plants are transplanted into a coldframe either in flats or directly into the soil, the double purpose of allowing more room and of hardening off can be accomplished.

When transplanted into the coldframes or other hotbed the plants are usually placed in rows 3 to 4 inches apart and about 1 inch apart in the rows. This gives the seedlings ample room to develop into strong, healthy plants which are necessary for the production of successful crops. Plants may be set in squares about 2 inches either way instead of in rows. When the plants are transplanted into flats as shown in Figure 10 they are set 1 inch apart either way. The flats are then usually placed in a coldframe and hardened off before setting in the field. This is one of the most satisfactory methods, since the flats can be taken directly to the field when setting out. The plants can be lifted from the flats with a ball of earth. This gives very little chance for the plants to dry out during transplanting.

In many cases the grower feels that he can afford to make but one transplanting, that from the hotbed to the field. In such cases the plants should be thinned as soon as the third leaf is formed. The weak, crooked and diseased plants should be re-

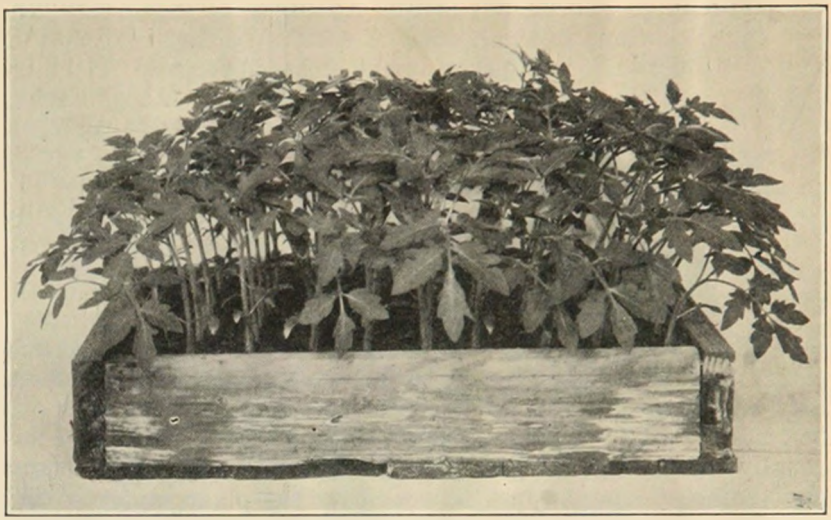

Fig. 10.—Tomato plants growing in a flat. Taken from a coldframe where they are hardened before setting in the field.

moved and only sturdy, vigorous plants left to stand, on the average 1 inch apart in the rows in the hotbed. They should be ventilated and watered carefully until ready for setting out permanently in the field. These plants can be hardened off as successfully as those in the coldframes, since the heat of the manure is gone long before the plants are ready for setting in the field, and the hotbed is then essentially a coldframe.

Transplanting to the Field.—Much care should be taken when the plants are transplanted to the field. If the plants are not properly cared for when transplanted, the resulting crop will be only a partial success and a big disappointment to the grower. Transplanting will always be successful if the following principles are observed:

1. Never let the plants become dry, but keep them moist from the time they are removed from the bed until they are set in the field.

2. Break as few roots as possible when removing plants from the bed. Always loosen the soil about them and remove a ball of earth with each plant.

3. Always pack the soil firmly about the roots of the plants and up to the surface. Leave some loose surface soil about the plants to prevent baking of the soil.

Hardening.—Hardening is the process of so regulating the growing conditions in the hotbed or coldframe that the plant is able to stand outdoor temperatures when set in the field. Hardening prepares the plant to withstand the shock of transplanting from the artificial conditions of the hotbed to the more rigorous environment of the field. Hardening causes the development of an extensive root system and a general toughening of all the tissues of the plant. Figure 11 shows plants being hardened in the hotbed frames at the college garden, after the heat from the manure is spent. Note the frames made in sections as shown in Figure 4.

There are two principal methods of hardening vegetable plants: (1) By gradually increasing the amount of ventilation until a week or 10 days before transplanting, when the sash are left off entirely until transplanting time, except in periods of unusually cold weather, and (2) by withholding water for several days before transplanting. The first method is to be preferred, since it causes the plants to make a sturdy, healthy growth and causes the development of very vigorous plants. Withholding water, if carried to excess, stunts the plants and they are weak

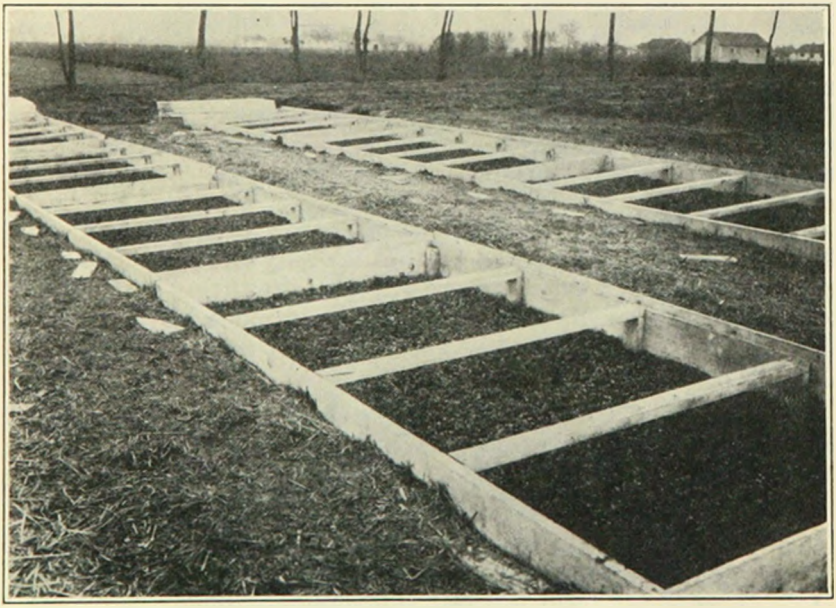

Fig. 11.—Plants being hardened in the hotbed after the heat from the manure is gone. Note the frames made in sections as shown in Fig. 4.

when set in the field. A stunted plant never fully recovers even under the very best of growing conditons. However, decreasing the water supply for 2 weeks before transplanting to that normally available in the field, is a very valuable aid in hardening.

Not all plants are capable of the same degree of hardening. The cool-season crops, especially cabbage, cauliflower and lettuce, are capable of developing considerable resistance to frost when handled properly. On the other hand, the warm or hot-season crops, such as tomatoes, cucumbers, peppers, eggplant, etc., never, under any conditions, attain much resistance to frost, but hardening practices are valuable in preparing them for the other environmental factors which are met in the field. Hardening is especially valuable in causing the development of a sturdy root system in this class of plants.

Root Maggots in Seedbeds

In some sections of the state cabbage and cauliflower plants are damaged in the hotbed by a small, whitish maggot that burrows into the roots. The maggots develop from a small white egg laid by a small fly. The eggs are usually found at the base of the plant, or between the stem and the soil, and can be observed with the naked eye by a careful observer. The eggs hatch out in a few days, and the young maggot works its way down the stems. The plant will wilt at first and in a day or two will die.

Control.—Satisfactory control has been secured by growers in the state by using mercuric chloride or corrosive sublimate treatments, recommended by the Entomology Department of the Colorado Experiment Station. This is a deadly poison and care must be taken in applying it. One ounce of mercuric chloride is dissolved in 10 gallons of water, and in making the solution be sure to use wooden containers. When the crystals are all dissolved, the solution is ready to apply. It is applied by pouring down the row of the plants in the seedbed until the soil around the plants is well moistened. One gallon will treat about 30 feet of row in the hotbed or coldframe.

The solution should be applied when the eggs are first found on the plants. If maggots are injuring cabbage or cauliflower plants in the field, about ½ cupful to a plant poured down the stem and into the ground will reduce losses caused by the maggot. A second application in the field is necessary in about 10 days after the first treatment. Cauliflower growers in the southeastern part of the San Luis valley have secured satisfactory control by using this method.

Cheesecloth or muslin covers placed over hotbeds to keep out adult flies are of value in preventing the laying of eggs in the beds.

Hotbed Diseases

Under favorable conditions there are a number of diseases which may gain entrance to the hotbed or coldframe and become very destructive. However, with good care few of these ever appear.

Damping Off.—The disease that is most common and most destructive in hotbeds is called "damping off." This is a disease of the young seedlings. The diseased plants wilt and die in spots thruout the bed. It appears as soon as the seedling comes thru the ground. On resistant plants it lasts until there is enough growth of the woody tissues to support the stem. Normally the period of damage lasts but 1 or 2 weeks, but that is sufficient time to destroy an entire seedbed if conditions are favorable for damping off. After the plant is too large for damping off the disease may remain and later attack the growing plant as a wilt, rot, stem canker, etc.

Damping off is usually considered to be caused by the fungus *Pythium debaryanum Hesse,* but it may be caused by any one of a number of fungous diseases, including *Rhizoctonia, Fusarium,* etc., when conditions are right for their development. The optimum temperature for the development of damping off necessarily varies with the causal organism. *Rhizoctonia* is most destructive at 60 to 75 degrees F., while *Pythium* is worse at 70 to 85 degrees F. The amount of water present is a greater determining factor than the temperature. Damping off is nearly always found in seedbeds in which the plants are crowded closely together, heavily watered, in soil that dries slowly, and where poor ventilation permits a high air humidity to be maintained.

Control of Damping Off.—Some of the damping-off organisms are carried on the seed, some are in the soil and all are favored by the presence of an abundance of water. Therefore, the three principal methods of control are seed treatment, soil sterilization and keeping the top soil and plants reasonably dry. If there is any probability of the seeds being diseased they should be treated in corrosive sublimate (1 part corrosive sublimate to 3000 parts water) for 5 minutes, rinsed in clear water and dried, or planted before thoroly dry.

The solution should be used only once and then discarded. It should always be placed in wooden, glass or glazed containers. Metal containers cause it to weaken. The seed should be tied loosely in a cheesecloth bag and suspended in the solution. The bag of seed should be thoroly penetrated by the solution. If the seed is treated in a room temperature of over 70 degrees F. there is danger of injury to the seed, as the action of the disinfectant is increased at higher temperatures.

The soil may be sterilized either with steam or formaldehyde. Since the average grower does not have a sufficient source of steam available, the formaldehyde treatment is usually more applicable. It is not quite as effective as steam, but kills nearly all of the pathogenic soil bacteria and fungi. The usual recommendation is to make a solution of 1 part commercial formaldehyde to 50 gallons of water and use ½ to 1½ gallons of the solution per square foot of soil. The amount of solution needed depends upon the physical character of the soil. The soil should be loosened before the solution is applied in order that it may penetrate thoroly. The bed should then be covered with canvas or boards for about 12 hours. The cover is then removed and the soil stirred several times to allow the formaldehyde fumes to escape. Seed or plants should not be placed in the treated soil for 10 days or 2 weeks after sterilization.

Some growers rely on changing the soil annually for control of diseases. This is better than using the same soil year after year, but very few soils are free from all the organisms that cause damping off of seedlings and therefore there is danger of some infection. In case the temporary bed is used there is the advantage of being able to change the location each year and thus avoid the cumulative effects of infection.

Treating the soil with a copper sulphate solution before the plants are up is beneficial. Use a concentration of 1 pound to 25 gallons of water, and apply at the rate of 1 pint of solution to the square foot. Follow this immediately with the same amount of water in order to wash the copper further into the soil. This method of treating is recommended where steam or formaldehyde are not easily available. However, it is not as effective as either of these methods.

The most important practice in preventing damping off is eliminating surface moisture of the soil. If the soil surface is kept relatively dry there is little probability of the fungus getting a foothold, since all fungous organisms require plenty of moisture for growth and reproduction. It is relatively easy to keep the bed dry enough if the pit is so constructed that it gets the benefit of the sun's rays at all times and if adequate ventilation facilities are provided to insure plenty of comparatively dry air. The plants should be far enough apart in the bed so that they will dry quickly. The top soil in the bed should be light enough in texture that it will dry readily. The watering should be done in the morning and if possible only on bright days. It is always best to wet the soil thoroly at each watering and water at long intervals rather than to sprinkle frequently only the surface. Frequent

sprinkling causes the subsoil to dry out and keeps the surface damp and conditions favorable for the development of fungous organisms. After the bed is thoroly wet down it is well to cultivate between the rows as soon as the surface is fairly dry. This helps to dry the surface thoroly and reduces the chances of infection.

Summarizing, the methods of control of damping off are:

1. Treat the seed if it is not known to come from a disease-free source.

2. Sterilize the soil if possible. If sterilization is not practicable use new soil every year in the hotbed.

3. Keep soil surface dry by:
   (a) Watering only in morning and on bright days.
   (b) Allowing plenty of comparatively dry air to circulate thru the bed.
   (c) Watering thoroly at relatively long intervals.
   (d) Give plants plenty of room.
   (e) Drying surface of the bed at once in case any damping off does start.

If these precautions are taken a good stand of healthy, vigorous plants should result if other factors limiting plant growth are likewise controlled. It is also advisable to spray thoroly, or wash all hotbed equipment annually with a formaldehyde solution, 1 pint of commercial formaldehyde to 30 gallons of water.

The organic mercuric dusts such as Semesan are coming into more general use as seed treatments on cabbage, cauliflower and onion seed. The rate of mixture recommended by the manufacturer is satisfactory on the above seeds. The dust treatment seems to give some protection against decay due to soil organisms, as well as a means of reducing losses where a particular fungus is carried on the outside of the seed.

Copper carbonate, copper sulphate and red oxide of copper have all been used as seed-treatment dusts for tomato, eggplant and pepper seed. Red oxide of copper dust is a new treating compound and has not been tried extensively except on tomato seed. Copper carbonate and copper sulphate dust treatment can be used satisfactorily on tomato seed, since the dust adheres to the seed coat satisfactorily. These dusts may also be used on pepper and eggplant seed.

Variable results have been secured, where a 6 percent formaldehyde dust was mixed with the soil, at the rate of 8 ounces to a bushel of seedbed soil as a means of reducing "damping off" losses.

Coldframes

A coldframe is constructed in the same way as a hotbed except there is no source of bottom heat. The coldframe depends entirely upon the sun for its heat during the day and upon the sash and mats or other covers for the retention of heat at night. The lack of bottom heat makes it practically impossible to get a coldframe very hot in cold weather. For this reason the coldframe cannot always be used for the same purposes as a hotbed, but one must supplement the other for best results.

Uses of the Coldframe.—The principal uses of the coldframe are: To harden off early plants grown in the hotbed, to start medium early and late vegetables and flowering plants, to raise to maturity early spring and late fall crops of lettuce and radishes and to carry half-hardy perennials thru the winter. The coldframe may be used as a storage for celery and root crops if the winter temperature does not go too low.

Most growers should have both hotbeds and coldframes in order to operate most efficiently. They can then start plants very early in the hotbed and harden them off in the coldframe. The coldframe is very handy for hardening plants started in greenhouses. In case the grower does not wish to construct both hotbeds and coldframes he should construct hotbeds rather than coldframes. Plants can be started much sooner in a hotbed than they can in a coldframe and the hotbed may be used as a coldframe for hardening the plants after the heat of the manure is spent. This saves transplanting from the hotbed to the coldframe and is the most practicable method when the grower does not operate on a large enough scale to warrant the use of both hotbeds and coldframes.

The construction of the coldframe is essentially the same as that previously described for the hotbed. The frame may be permanent or temporary. The permanent frame may be made of brick, concrete or heavy boards. Very little pit is needed, as there is no manure put in for heating purposes. However, if the coldframe is to be used as a storage pit for half-hardy flowers or for vegetables, an excavation of 2 to 3 feet is needed and should be lined on the sides and bottom. A few inches of sand or cinders should then be put in and flower pots plunged to the rim.

The temporary coldframe does not require a pit and may be set on the ground. A soil such as described for hotbeds should be supplied for the plants. The frame should be thoroly banked around to shut out the cold. For convenience in fitting sash the frame should be of the same width as the hotbed frame. The length is, of course, governed by the amount of plants to be grown.

Management.—The general management of the coldframe is the same as is that for the hotbed. The soil, seeding, watering and transplanting requirements are the same. The coldframe does not require as much ventilation as the hotbed, due to the fact that it seldom reaches as high a temperature as the hotbed, and therefore gas accumulation from the respiratory activities of the plants is slower. However, the seedlings should be given as much air as possible without danger of drafts or frosts. A temperature of 55 to 65 degrees should be maintained, if possible, while the seedlings are small. The plants should be thoroly hardened by giving more and more air until a week or 10 days before setting in the field. The sash should be removed entirely during the day and also left off at night for the last few days before transplanting.

Amount of Sash Needed.—The size of hotbed or coldframe to build will depend upon the amount of crop to be raised, upon the crop under consideration, and upon the method of handling the seedlings before transplanting to the field. If the seedlings are to be hardened in the hotbed, the large plants such as tomatoes, peppers, etc., should be thinned to stand about 1 inch apart when the first few leaves appear. This will give 75 plants per row across the bed and if the rows are 3 inches apart there are 12 rows per sash or 900 plants per sash. For the smaller growing plants, such as celery, cabbage and cauliflower, the grower can raise up to transplanting size about 2,000 healthy plants per sash. In case the seedlings are to be transplanted to a coldframe for hardening there is no advantage in thinning them in the hotbed. Only the more vigorous plants should be transplanted to the coldframes.

It requires more coldframe space than hotbed space for the same number of plants because the plants are always given more room in the coldframe in order to develop sturdy, vigorous plants. The peppers, tomatoes and eggplants should be set in rows 3 inches apart and 2 inches apart in the row. This will give about 475 plants per sash. The cabbage, cauliflower and celery should be set in rows 3 inches apart and 1 inch apart in the row, which will give 900 plants per sash. It is not worth while to transplant onions. The requirements of all other crops will be similar to those of some one of these crops and the amount of space needed by them can be determined by comparison of growth with one of the above crops.

The number of acres of the crop to be grown determines the number of sash needed. To obtain the number of sash needed divide the number of plants required per acre by the number of plants per sash and multiply by the number of acres or fraction

of an acre to be planted. This will give the required number of sash. The following table may be used as a guide in determining the number of plants required. These figures are, of course, for average planting distances and will vary with different planting distances that the grower may prefer.

Crop	Plants Per Acre
Cabbage	12,000 - 13,000
Cauliflower	12,000 - 13,000
Celery	20,000 - 30,000
Eggplant	7,000 - 8,000
Onions	80,000
Peppers	10,000
Tomatoes	4,000 - 6,000

To determine the number of plants required per acre, multiply the width in feet between rows by the distance in feet between plants in the row. This gives the number of square feet required per plant. Divide 43,560 (the number of square feet per acre) by the square feet required per plant to get the number of plants per acre. Then the number of hotbed or coldframe sash can be calculated as explained above.

Growing Plants in Pots and Bands

In the last few years there have been placed on the market a number of different sorts of pots and bands in which to start plants. They are made of paper, wood veneer and similar substances. The latest to appear is a pot made of pure peat. Some of these devices are said to give good results, but they have not been investigated thoroly enough by the Experiment Station to warrant any recommendation concerning their value. Their cost relative to producing plants by other means should be fully investigated by the grower before he invests too heavily.

The bands, either paper or wood veneer, may be preferred to pots because they are easier to handle and are much more economical of space. The advantages of using bands rather than planting directly into the hotbed are:

1. Plants such as melons, cucumbers, etc., which are very difficult to transplant successfully, may be started in bands and an early crop secured.

2. Plants which ordinarily are not started indoors may be grown in bands to get an early crop.

3. Crops can be produced earlier with nearly all plants because there is not the usual shock in transplanting.

4. The labor of shifting and transplanting is greatly reduced and consequently the cost of production is reduced.

5. The plant is transplanted with little shock, since its roots are disturbed very little.

6. Plants can be shipped more easily and more satisfactorily when grown in bands.

7. There is less danger of loss from drying out when set out in the field.

The bands are placed side by side in the hotbed, coldframe or in flats either in the hotbed or coldframe. The flat is very convenient for handling bands, since the labor of shifting plants is greatly reduced and it is much easier to move the plants when transplanting. The size of band to use depends somewhat upon the crop to be grown, but the sizes most used for garden crops are 4 x 4 x 3 inches and 4 x 4 x 4 inches. Smaller sizes can be secured and can be used successfully if the plants are not to be left in them for a very long time.

A thin layer of compost is put in the bottom of the bands and they are then filled with a good grade of garden soil that will not pack. Six to eight seeds should be sown in each band. The seed should be sown 4 to 6 weeks before time for field setting. If sown much before this the plants may become crowded and tender. In such cases they are always slow to start growth after transplanting.

After sowing the seed the same care must be exercised as when sowing in the hotbed. Maintain as nearly as possible a day temperature of 70 to 75 degrees F. until the seeds germinate. Then keep the day temperature at 60 to 65 degrees F. and the night temperature at 60 degrees F. until about a week before planting, when the temperature should be gradually lowered in order to harden the plants.

When the first true leaves appear, thin to three plants per band and when they are growing good, thin to one or two plants for field setting.

Plants should be removed to the field while still in the bands. A hole is then dug in place for each plant, the band removed and the plant with the attached earth placed in the hole and the earth pressed firmly around it. In case extremely dry weather prevails at transplanting time it is advisable to wet the soil in the band thoroly before transplanting. This will prevent wilting with its consequent setback.

Seed of plants such as tomatoes, cabbage and similar plants that are easily transplanted may be sown in flats, pricked off into other flats when they show a few leaves and later transplanted permanently into bands for growing until time to plant in the field. Transplant about a month before setting in the field. By using this method rather than sowing the seed directly in the

bands a great deal of space is saved during the early life of the plants. With plants such as melons, cucumbers, beans, squash and similar plants that will not stand any transplanting, the seed should be sown directly into the bands.

Plant Protectors.—Often the grower is anxious to mature a crop at the earliest possible time. Under such conditions plants must be set out at the first warm period after winter is over. Since these warm periods are quite often followed by cold weather for a few days the grower must provide some means of protection for the early plants in the field or take the chance of getting them killed by frost. To protect plants in the field various sorts of plant protectors are used. The sort of protector to use depends somewhat upon the individual preferences of the grower, since the protectors are all very similar. They can be purchased from a number of firms and full directions for their use are always included. The results secured from their use varies with the climatic conditions of the various seasons. They are of most benefit during cold, late springs which have alternate cold and warm periods of weather. They require considerable labor and attention and are fairly expensive. Therefore, their use is not generally recommended except in those cases in which the grower wishes to produce an especially early crop for a special market and for those small growers who do not raise enough plants to make a hotbed practicable but wish to start their plants fairly early in the season.