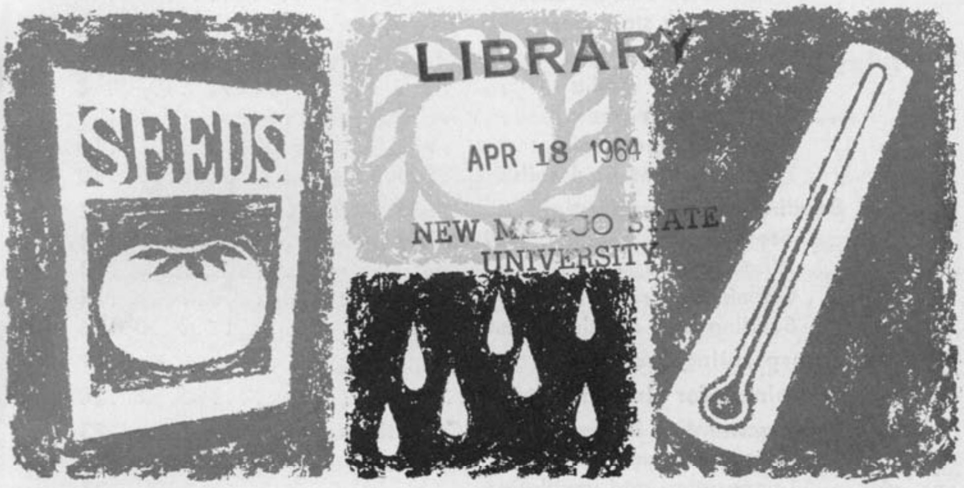
CIRCULAR 884

UNIVERSITY OF ILLINOIS COLLEGE OF AGRICULTURE · COOPERATIVE EXTENSION SERVICE



GROWING VEGETABLE TRANSPLANTS

CONTENTS

This circular was prepared by J. W. COURTER, Assistant Professor of Horticulture, and J. S. VANDEMARK, Professor of Horticulture.

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Growing Vegetable Transplants

THE USE OF PROPERLY GROWN TRANSPLANTS offers a number of benefits, in more economic production and convenience, to both commercial vegetable growers and home gardeners. To produce and market profitable crops, growers often depend on earliness which can only be achieved by setting out well-grown and properly aged transplants. By using transplants, experienced producers of processing crops reduce the time, effort, and expenses of establishing a crop in the field.

Home gardeners as well as commercial growers can realize several advantages by producing their own vegetable transplants, including (a) conditions can be controlled so that suitable plants will be ready when needed, (b) plants may be held in good condition if weather delays planting, (c) it is possible to use container-grown plants that otherwise might not be available because of shipping difficulties, (d) maximum numbers of plants can be obtained from costly seed, (e) the grower is able to start special varieties, or vegetable plants that may not be readily available (such as cucumbers, melons, cole crops, and lettuce), and (f) the hazard of importing diseases with purchased transplants is eliminated.

With a modest investment and effective merchandising methods, you can grow transplants as a profitable seasonal business, especially in commercial vegetable-producing regions and many urban areas. Plant growing also makes a good project activity for vocational agriculture classes and 4-H clubs.

Growing good plants requires skill, proper care, and knowledge of the fundamentals of plant science. The purpose of this circular is to provide information on structures, soils, seeding and transplanting techniques, plant management, and pest control for growing healthy vegetable transplants. Well-grown, good-quality plants are essential for success, whether one grows them for home gardens, commercial production, or for sale.

PLANT-GROWING STRUCTURES

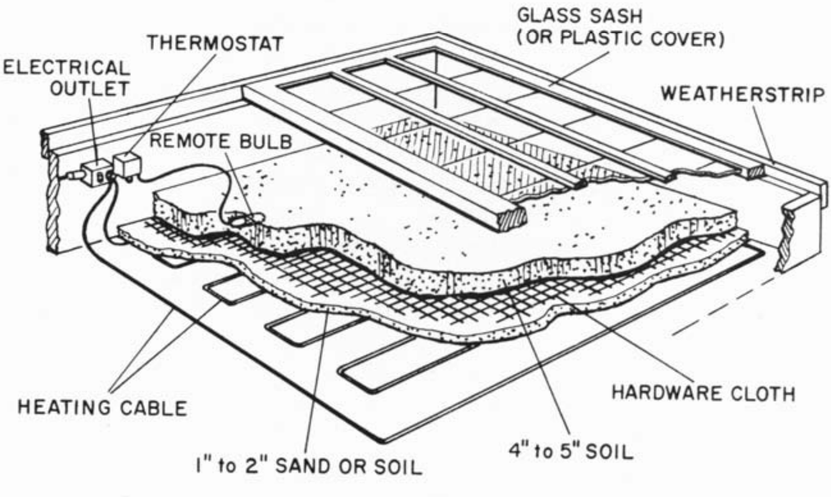
Vegetable plants can be grown in various kinds of structures such as coldframes, hotbeds, and plastic or glass greenhouses. Your choice will depend on the volume of plants to be grown, other uses for the structure, and the costs involved.

Coldframes and Hotbeds

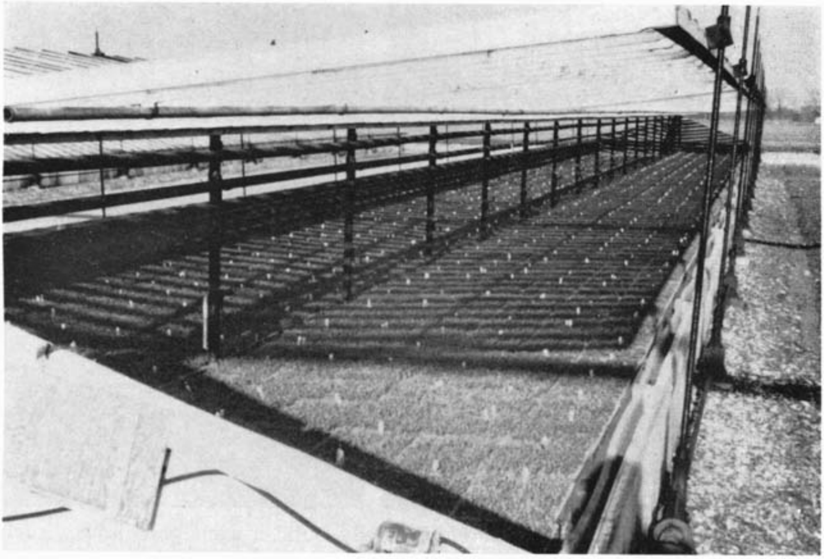
Coldframes are generally simple, inexpensive structures which depend on the sun for heat. In most areas in Illinois, soil temperatures are usually too low in coldframes for successfully starting early transplants. Coldframes may be used effectively later in the season to hold or to harden plants, when it is undesirable to maintain a cool greenhouse for this purpose.

Hotbeds are similar to coldframes, but they are heated. The heat is usually provided by hot air flues, steam or hot water pipes, electric soil cables, or fermenting horse manure. In each case the hotbed is warmed to promote favorable growing temperatures.

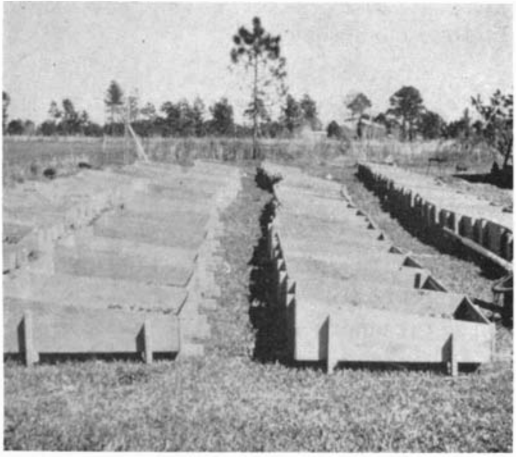
You can grow quality transplants in hotbeds if constant attention is given to maintain proper air temperatures and adequate ventilation.



This diagram illustrates basic construction details of an electrically heated hotbed. If needed for proper drainage, layers of gravel or cinders and vermiculite (not shown) may be used beneath the cable. Detailed instructions are given in U. S. Dept. of Agr. Leaflet 445, "Electric Heating of Hotbeds."



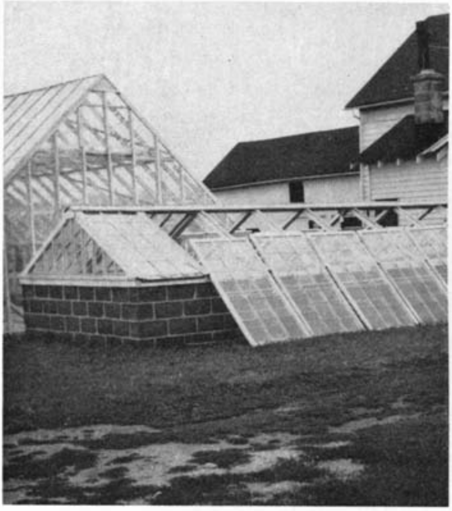
In this Richardson motorized hotbed (above), ventilation is controlled by a powered lifting apparatus which can quickly raise or close the glass sash.

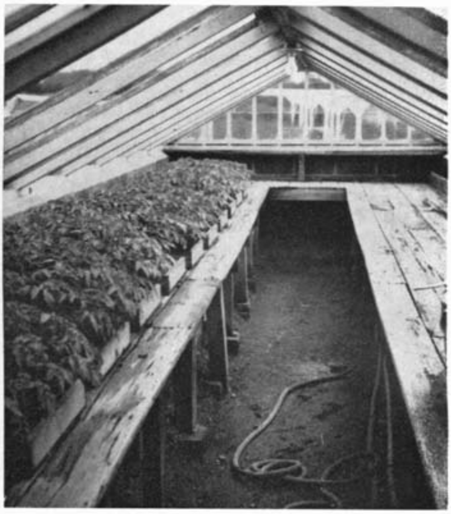


These portable coldframes (right) can be carried with a fork lift tractor. They can be moved, with plants inside, into a heated greenhouse or barn during cold weather.

Electrically heated hotbeds are convenient for small operations, as they are easy to construct, the cost is relatively low, and the soil temperatures are easily controlled.

For further information on construction of coldframes and heating of hotbeds, refer to "Electric Heating of Hotbeds," U. S. Dept. of Agr. Leaflet 445, and "Hotbeds and Coldframes," U. S. Dept. of Agr. Farmers' Bulletin 1743.





Growers with glass sash on hand can easily build a sash greenhouse, such as this, to realize the advantages of walk-in structures.

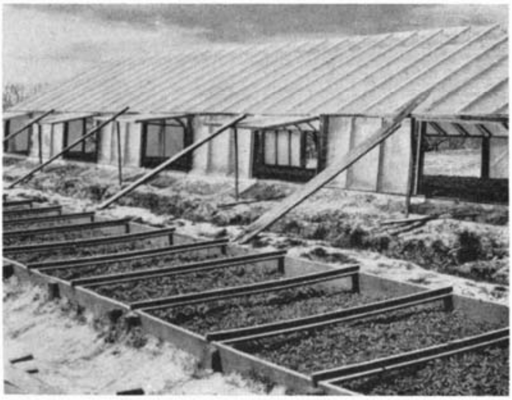
Greenhouse Structures

Greenhouse structures — conventional, sash, or plastic — offer several advantages over both coldframes and hotbeds for growing vegetable transplants. Workers are protected during inclement weather, plant handling is easier and more convenient, and working hours may be extended if the greenhouse is lighted. Walk-in structures facilitate better inspection of plants and materials, and any needed spacing, disease control, or other operation can be more easily accomplished. Also, it is usually easier to control temperatures, moisture and ventilation in greenhouses.

Although greenhouses are generally more expensive to build and operate than hotbeds or coldframes, the higher costs may well be justified. Temporary plastic greenhouses, which are relatively inexpensive, are well suited for seasonal use such as plant growing. One might consider building a more permanent plastic or glass structure if it can also be used for other purposes. Growers with hotbed sash on hand can use them to advantage to build a sash greenhouse.

Greenhouse environment for healthy plant growth is provided by proper ventilation and heating. The most convenient method of ventilating plastic greenhouses is with exhaust fans. Sash and panel greenhouses are manually ventilated by sliding or removing the panels.

Well-grown tomato plants (above), produced in a plastic greenhouse, ready for the field.



A conventional flue-heated hotbed, with sash removed, and a polyethylene-covered greenhouse (right) for growing vegetable transplants.

Plant-growing structures may be designed with removable sidewalls for maximum ventilation in late spring.

Conventional plastic or glass greenhouses may be heated in several ways. Unit heaters, convection heaters, vented space heaters, or forced air furnaces are frequently used in plastic greenhouses. Hot water or steam boiler systems are economical for large greenhouses, or for permanent installations.[1]

[1] For further information on construction and heating of greenhouses for plant growing, refer to the following publications:

"Plastic Greenhouses," Illinois Extension Circular 857.

"Sash Greenhouses," U. S. Dept. of Agr. Leaflet 124.

SOILS AND FERTILITY

Growers generally prefer to use two soil mixes or media for growing plants — one to produce seedlings (seed-sowing medium), and another into which the seedlings are transplanted in flats or individual plant containers (plant-growing medium).

Composted soil and mixes with soil are the most commonly used media for producing vegetable plants. Artificial media (materials other than soil) have also been used successfully, but they are costly and must be used with care.[1] Several advantages are claimed for artificial media. They are light in weight and easy to store, sterilization is usually unnecessary, and fertility can be closely controlled.

Materials used as artificial media include vermiculite, perlite, peat, and sand. These same materials are commonly used as conditioning agents in soil mixes. Vermiculite is light-weight, expanded mica which contains a considerable amount of available magnesium and potassium. Perlite is light-weight, expanded volcanic rock which has no fertility value but has excellent water-holding properties. Horticultural grade perlite should be used. Melons, cucumbers, cabbage and tomatoes can be grown successfully in straight vermiculite when watered with a soluble fertilizer solution.

Growers who have not had experience with artificial media should first experiment on a small scale.

Seed-Sowing Media

A good germinating medium is sterile and uniformly fine. It should be well-aerated, and well-drained, but have good water retention properties. You can use several different media, ranging from a completely artificial material to a soil mixture, for starting vegetable seed.

Vermiculite can be used alone or in combination with soil. Heavily rooted seedlings produced in vermiculite can be easily removed with minimum breakage of roots. Some growers prefer to sow seed in a ½-inch layer of vermiculite placed on a soil mix in a flat.

Soil or soil mixes must have the desired physical characteristics to be used successfully for germinating seeds. Mixtures of equal parts of soil, sand, and peat, or of soil, perlite, and peat, are good media.

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[1] Plant growers interested in artificial mixes can find additional information on preparing and using several types of mixes in the following publications:

"Artificial Soils for Commercial Plant Growing," Cornell Extension Bulletin 1104, Cornell University, Ithaca, New York.

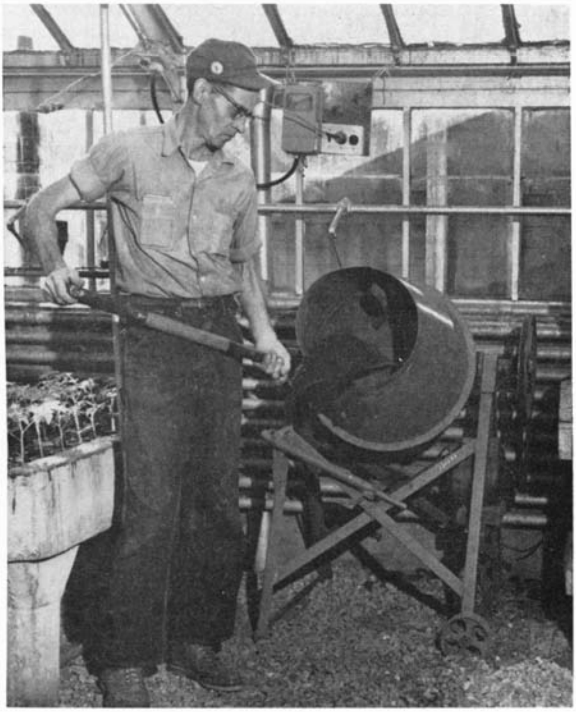
"U. C.-Type Soil Mixes for Container-Grown Plants," California Leaflet 89, University of California, Davis, California.

Straight sand is not recommended, as it has low moisture-holding capacity. Many growers sow the seeds on a soil mix and then cover them with a light layer of sand, vermiculite, or finely shredded peat.

As purchased, vermiculite and perlite are sterile and free of organic matter, and thus you do not need to use any additional treatment for disease control.

Plant-Growing Media

Many different soil mixtures are used in growing vegetable seedlings to the age and size needed for transplanting in the garden or field. Any one mixture cannot be recommended as ideal for all situations, because there is a wide variation in available soils, selection of a medium may be influenced by the crop to be grown, and individual growers have different personal preferences. Good soil mixtures are commonly made up of about one part soil and one or two parts conditioner. The conditioning material, used to improve the physical prop-



Soil and conditioning materials can be thoroughly mixed in a small concrete mixer.

erties of the mixture, may be sand, peat, perlite, vermiculite, or combinations of these materials.

A popular plant-growing medium is a mixture of two parts soil with one part peat and one part sand. If the soil is of light texture, the medium should contain more peat and less sand. If heavy soil must be used, a mixture of one part soil to two parts conditioning material is recommended. The conditioner might be made up of equal volumes of peat and sand, vermiculite and sand, or perlite and sand.

Media to be used for plant growing should be tested for soluble salt content and fertility level. Correct the pH to 6.0 to 6.8, if necessary. To make such tests, you can take samples to your local farm adviser or send them to the Soil Testing Laboratory, Floriculture Building, University of Illinois, Urbana. Indicate the intended use for the soil, and enclose $1.00 for service charge per sample.

Beware of greenhouse soils that are frequently high in soluble salts which may kill or severely stunt seedlings.

A good soil for plant growing may be obtained by composting, or from field sources, as discussed in the following sections.

See page 24 for information on supplemental feeding.

How to Compost Soil

Composted soil, which is very popular for growing vegetable plants, may be used alone or as the soil ingredient in soil mixes as previously discussed.

You can prepare composted soil by building up alternate layers of sod from sandy loam soils and organic materials such as strawy manure, alfalfa, hay, peat, or muck. The usual proportion is two parts sod to one part organic material, but the proportion of organic material should be higher when heavy silt or clay loam soil must be used. Make the pile 4 to 5 feet high, with vertical sides, and a concave top to catch rain water. Turn and mix the pile at least once a year to hasten decomposition of the organic matter in a uniform manner. Good results can be obtained by composting the pile two years.

Put the composted soil through a soil shredder and screen it before use to blend the organic portion and assure desired physical condition.

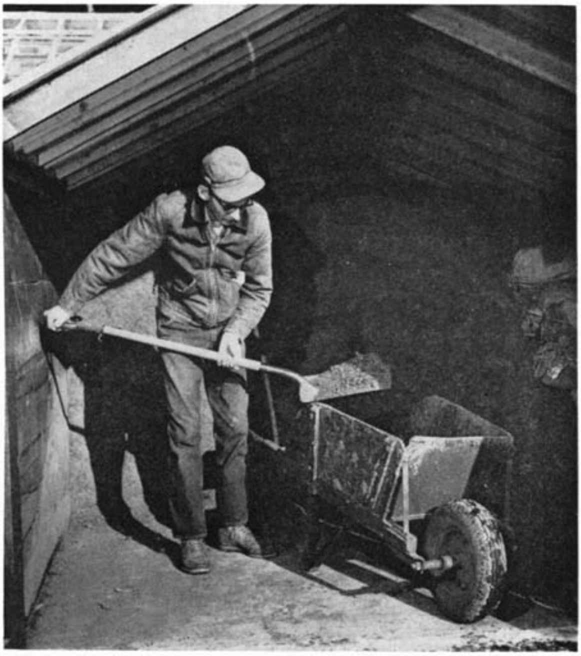
Preparation of Field Soils

The practice of preconditioning field soils for use in soil mixes is preferred by many growers. While it is possible to add fertilizers and organic matter to soil in a matter of minutes, a soil-conditioning program builds good soil by also improving soil structure and allowing sufficient time for certain desirable physical and chemical changes to occur. Soil fertility is increased to a high level to compensate for the later dilution resulting from the use of conditioning materials in soil mixes.

If you plan to use field soil, it should be tested to determine the pH and fertility levels, which will influence the fertility program to be used. Add lime to adjust the soil pH to 6.0 to 6.8.

Here is an example of a conditioning program one might use: Select a field site of clover, alfalfa, or grass sod. Apply 1,200 to 1,500 pounds of 5-25-25 fertilizer per acre (or other application as needed, depending on the soil) plus required lime. Plow down and plant soybeans. Plow down the soybeans before they set pods. Broadcast corn at a rate of two to three bushels per acre and apply 100 pounds of nitrogen per acre. Plow down the corn when it is about 2 feet high and plant spring oats. Disk the oats under before heads appear. During such a program you may need to irrigate the plantings to provide adequate moisture for germination and plant development.

The soil from the top 6 inches then may be taken up and stored inside a building or covered with black polyethylene film.



Field soil, or a prepared soil mixture, can be conveniently stored in a small waterproof building for use when needed.

The time required to condition a soil in such a program should be two years or less. If a good sod is not available at the start, it may take three years.

SEEDING AND GERMINATION

Seed Quality, Quantity, and Variety

Your success will depend on the quality of the seed you plant. Good seed is of current stock, and has a high germination rate. Old seed often has a poor germination rate as well as reduced vigor. Buy the best obtainable seed, certified and treated whenever possible, from reputable seed firms.[1]

Select varieties adapted to your area and, if you are raising plants for sale, learn the particular variety preferences of your potential buyers.[2] Many growers prefer to use seed produced in arid western locations, to reduce the danger of introducing seed-transmitted diseases.

Table 1 shows seed germination standards, longevity, number of seeds per ounce, and seed requirements per acre.

When to Sow Seeds

The date to sow the seeds is determined by the date when the transplants are to be set in the field, and the desired transplant age. How early you can set the plants out depends on the hardiness of the vegetable and the climate in your area. Certain vegetable plants can withstand frost while others cannot.[3]

Refer to Table 2 for the recommended growing periods and frost tolerance information for the various plants. Plants started during the winter in a greenhouse, or in hotbeds or coldframes under less than favorable conditions, will require the longer growing times in the ranges indicated.

Some growers believe that older transplants (grown for longer than the recommended periods) will yield earlier than younger transplants, reasoning that less time is required in the field. In general this

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[1] For a list of seed firms, refer to Horticulture Report "Vegetable Growing No. 10, Vegetable Seed Companies," available from the Department of Horticulture, University of Illinois, Urbana.

[2] For a list of recommended varieties refer to Horticulture Report, "Vegetable Growing No. 11, Vegetable Varieties for Commercial Plant Growers," available from the Department of Horticulture, University of Illinois, Urbana.

[3] Suggested dates for planting specific vegetables in the home garden are given in the "Illinois Vegetable Garden Guide," Illinois Extension Circular 882.

Table 1. — Amount of Seed Needed in Plant Growing

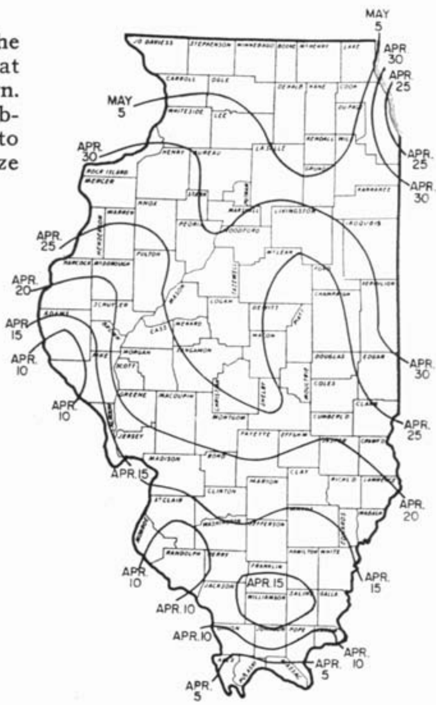
Crop	Expected seed life[a]	Minimum germination	Seeds per ounce	Usable plants per ounce of seed[b]	Quantity of seed to produce plants for 1 acre
	years	*percent*	*number*	*number*	*ounces*
Broccoli	3–4	75	9,000	4,000	3
Brussels sprouts	3–4	70	8,000	4,000	3
Cabbage	3–4	75	8,000	4,000	3
Cauliflower	3–4	80	9,000	4,000	3
Cucumber	4–5	60	1,000	400	8
Eggplant	3–4	80	6,000	2,000	2–3
Lettuce	5–6	75	20,000	10,000	5–15
Muskmelon	4–5	70	1,000	400	4–5
Onion	1	70	9,000	5,000	8–12
Pepper	2–3	55	4,000	2,000	4
Tomato	3–4	75	10,000	5,000	1–2
Watermelon					
Regular	3–4	70	300	100–200	2–3
Seedless	2		400	100	4

[a] Under good storage conditions.
[b] Reduced by half if the plants are to be pulled.

Table 2. — Transplanting Tolerance and Time Required to Grow Plants

Crop	Transplanting tolerance	Time to grow	Frost susceptibility
		weeks	
Broccoli	Survive well	5–7	Tolerant
Brussels sprouts	Survive well	5–7	Tolerant
Cabbage	Survive well	5–7	Tolerant
Cauliflower	Survive well	5–7	Tolerant
Cucumber	Seeded in container[a]	3–4	Very susceptible
Eggplant	Require care	6–8	Very susceptible
Lettuce	Survive well	5–7	Moderately tolerant
Muskmelon	Seeded in container[a]	3–4	Very susceptible
Onion	Survive well	8–10	Very tolerant
Pepper	Require care	6–8	Susceptible
Tomato	Survive well	4–7	Susceptible
Watermelon			
Regular	Seeded in container[a]	4–6	Susceptible
Seedless	Seeded in container[a]	6–8	Susceptible

[a] These crops are generally not successfully transplanted (unless started in containers) as any root disturbance checks growth.



Average dates of last 32° freeze in the spring. There is a 50-percent chance that a freeze will occur after the dates shown. For similar information on freeze probabilities other than 50 percent, refer to Illinois Station Bulletin 650, "Freeze Probabilities in Illinois."

is not true. Actually the use of older transplants is likely to result in tall and spindly plants, delayed harvest, and rough fruit, in addition to lengthening the growing period and increasing costs. In the case of several varieties of tomatoes, for example, the age of the transplants when set in the field will affect earliness, fruit size and grade, and yields (refer to the section on Techniques for Specific Vegetable Crops).

Germination Requirements

There are specific temperature ranges for best germination of the different vegetable seeds. Temperatures below or above the optimum ranges will increase the time required for germination, or decrease the percentage of healthy seedlings produced, or both. Soil temperatures vary considerably, and for this reason should be checked occasionally with an accurate soil thermometer. During early spring, the soil temperatures in unheated germinating flats are often well below air temperatures, but during the summer they may be as high as 95°-100° F. The optimum temperature ranges for germination of different vegetable seeds, and days required for germination, are given in Table 3, which also shows the recommended temperatures to be used after germination.

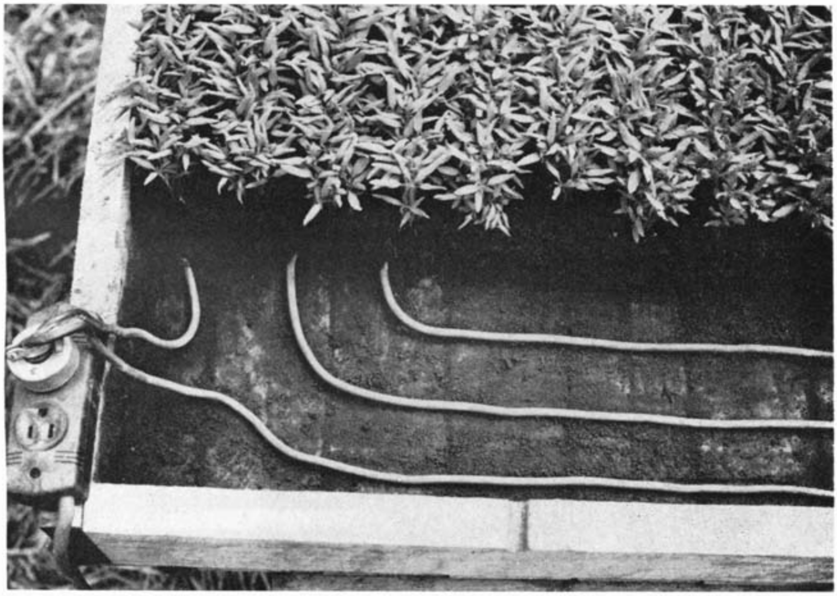
Supplemental light is not required for germination of most seeds, and the flats may be covered with plastic or paper to help prevent the soil surface from drying. Full sunlight conditions are needed after the seedlings emerge.

It is important to water seedling flats with care, using a fine water breaker sprinkler or mist nozzle.

Table 3. — Recommended Seed-Germination and Plant-Growing Temperatures

Crop	Optimum soil temperature range for germination	Days to emerge[a]	Plant-growing temperature[b] Day	Plant-growing temperature[b] Night
	°F.		°F.	
Broccoli	70–80	5	60–70	50–60
Brussels sprouts	70–80	5	60–70	50–60
Cabbage	70–80	4–5	60–70	50–60
Cauliflower	70–80	5–6	60–70	55–60
Cucumber	70–95	2–5	70–80	60–70
Eggplant	75–85	6–8	70–80	65–70
Lettuce	60–75	2–3	55–75	45–55
Muskmelon	75–95	3–4	70–80	60–70
Onion	65–80	4–5	60–70	45–55
Pepper	75–85	7–8	65–80	60–70
Tomato	75–80	6	60–75	60–65
Watermelon				
Regular	70–95	4–5	70–80	60–70
Seedless	85–95	5–6	70–80	60–70

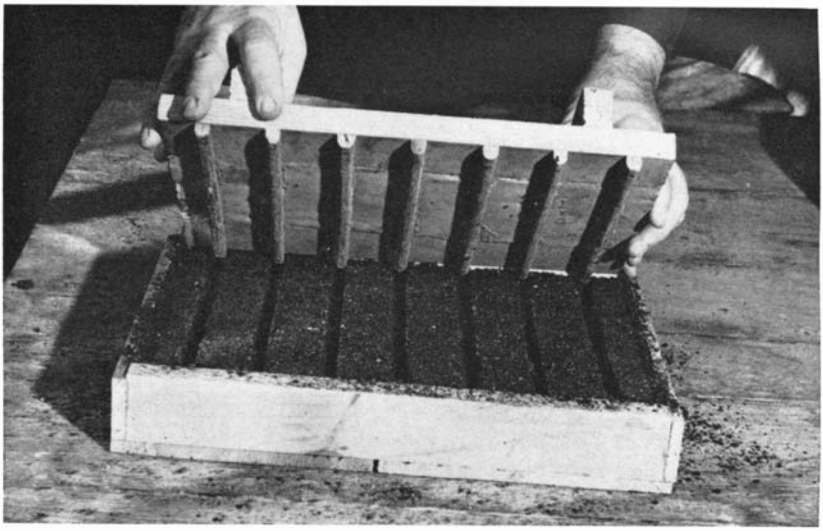
[a] At optimum soil temperature range.
[b] The lower temperatures are recommended during cloudy weather.

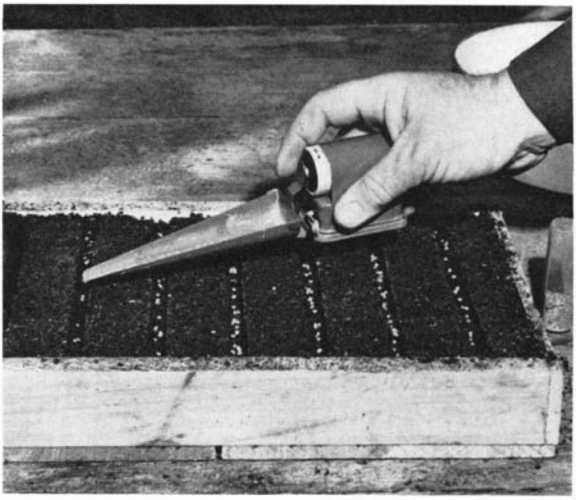


An electric soil-heating cable installed in a flat (as shown) or bench warms the soil to promote optimum seed germination. Part of the soil has been removed to show the cable.

Seeding and Spacing Pointers

Suggested seed and plant spacings are given in Table 4. It is generally recommended that the seed be sown in rows, covered with soil, sand, or vermiculite, and thoroughly moistened. (Additional information on the spacing of plants is included in the section on environmental conditions.)





Rows of uniform depth and spacing (above) can be quickly made with a row marker.

Sowing seeds with a battery-operated vibrator (left) provides even distribution of seeds. The seeds are then covered with soil, sand, vermiculite, or shredded peat.

Table 4. — Seed and Plant Spacing Chart

Crop	Planting depth	Seeds per inch of row	Row width	Minimum space for transplants
	inches	*number*	*inches*	*inches*
Broccoli	¼–½	10	2–3	3 x 3
Brussels sprouts	¼–½	10	2–3	3 x 3
Cabbage				
For containers	½	10	2	3 x 3
To be pulled	½	3–6	4–6	. . .
Cauliflower	¼–½	10	2–3	3 x 3
Cucumber[a]	¾–1	. . .	. . .	3 x 3
Eggplant	¼–½	10	2–3	4 x 4
Lettuce (leaf, Bibb, head)	¼–½	10–15	2–3	2 x 2
Muskmelon[a]	¾–1	. . .	. . .	3 x 3
Onion (pulled)	½	10	3–4	. . .
Pepper				
For containers	¼–½	10	2–3	3 x 3[b]
To be pulled	½	3–6	4–6	. . .
Tomato				
For containers	¼–½	10	2–3	3 x 3[b]
To be pulled	¼–½	3–6	4–8	. . .
Watermelon[a]				
Regular	¾–1	. . .	. . .	3 x 3
Seedless	½–1	. . .	. . .	3 x 3

[a] These crops should be seeded directly in individual containers. Refer to section on Techniques for Specific Vegetable Crops for seeding rates (page 29).
[b] For growing in flats, plants may be spaced 2 x 2 inches.

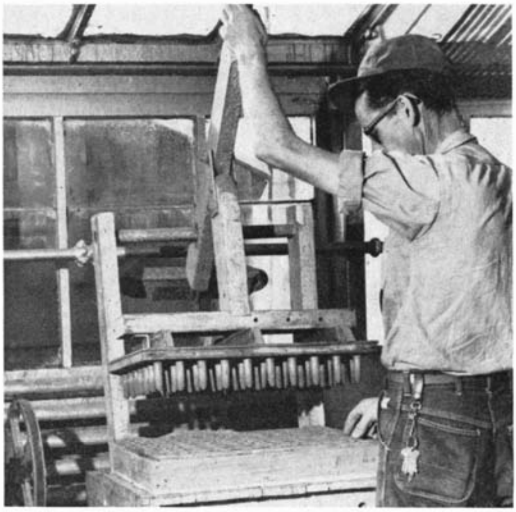
TRANSPLANTING SEEDLINGS

Starting plants in limited areas in hotbeds or greenhouses conserves space and reduces the cost of production in plant growing. As the plants become crowded, they are transplanted from the seed flats to containers or to other flats at the desired spacings, as recommended in Table 4. If put into containers, they may later be spaced further apart to improve plant quality.

Transplanting is not beneficial, and may be harmful, to the plants. The degree to which transplanting checks growth depends on the amount of injury to the root system, the age and size of the seedling, environmental conditions following transplanting, and the kind of vegetable seedling involved.

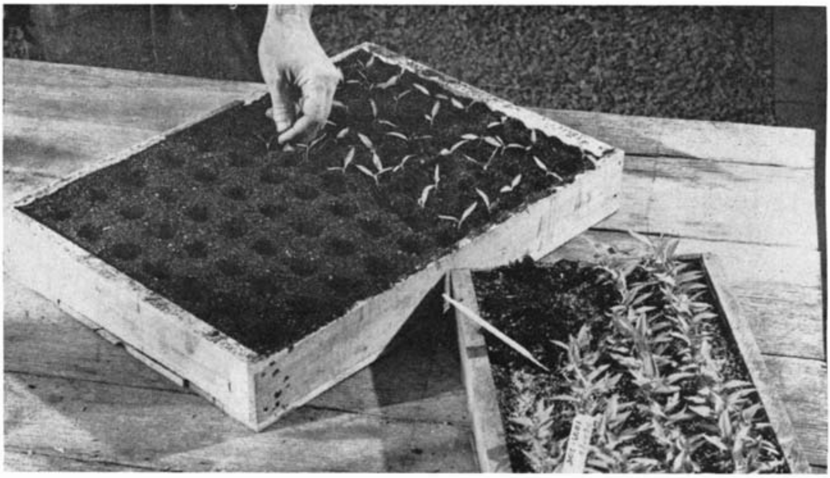
The seedlings of some vegetables, such as the cucurbits, are difficult to transplant successfully and should be seeded directly in individual containers (Table 2).

Handle seedlings with care when transplanting them from the seed flat. Hold the seedling by a leaf, not by the stem. The slightest injury to the stem can result in permanent damage. The best stage to transplant most vegetable seedlings is when the first true leaf appears between the cotyledon leaves. Do not transplant weak, damaged or malformed seedlings. Following transplanting, the seedlings will become established faster if they are kept shaded and moist for one or two days.

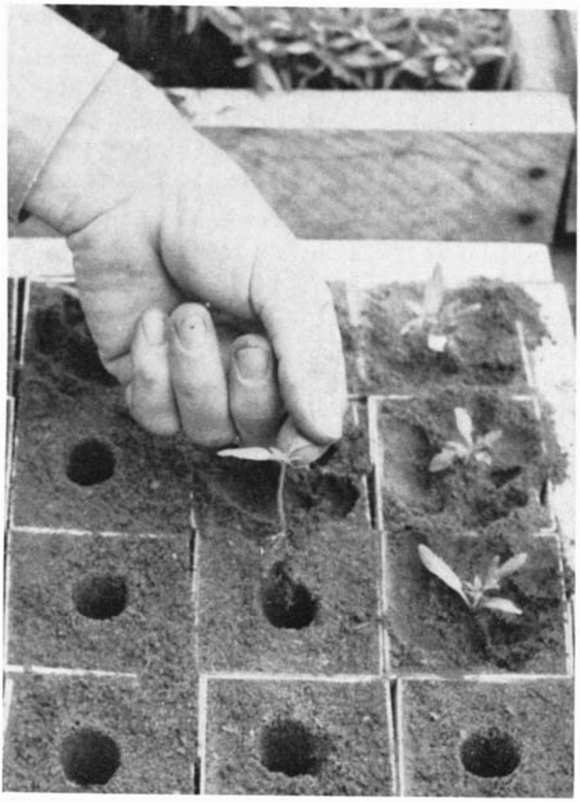


Pegboards, or "spotting boards," such as the one shown at left, are used to quickly make uniformly spaced holes for transplanting.

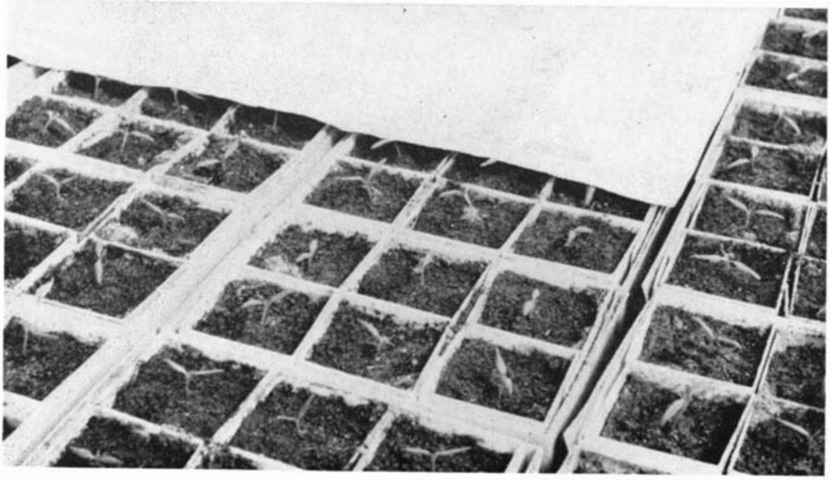
Seedlings being lifted from a seed-germinating flat and planted in a standard wood flat (below). Damaged or malformed seedlings should be discarded.



Seedlings should be handled carefully by a leaf, not by the stem. The slightest injury to the stem can result in permanent damage.



Newly transplanted tomato seedlings growing in 3″ x 3″ wood veneer bands (below). If transplanting must be done on a bright sunny day, they can be shaded temporarily with newspaper.



CONTAINERS FOR PLANT GROWING

Container-grown plants are easy to handle, present an attractive appearance for merchandising, and allow the grower to move plants with intact roots to the field. Plants grown in individual containers will suffer minimum disturbance or damage to the root systems and will continue rapid growth after they are set out. Certain vegetable plants, such as those of the vine crops, which otherwise would present serious transplanting difficulties are easily handled with individual containers.

Many kinds of containers are used for plant growing. Each offers certain advantages or disadvantages in such things as cost, durability, availability, storage convenience, ease of transport, and range of sizes and shapes. Equally good plants can be grown in individual containers (such as wood veneer or paper bands, soil blocks, and pots made of peat, clay, or plastic), in large containers such as flats, or in various market packs. The size of the container is more important than the kind of container. For best results the size should be equivalent to the minimum space suggested for transplants in Table 4.

Reusable containers (for example, clay pots used for greenhouse plants) must be sterilized after each use. For that reason many growers prefer disposable containers. Plant bands, although inexpensive, generally are not as durable as some of the market packs for retail selling. Organic-composition pots, such as those made of peat, are gaining favor because they minimize root disturbance when the plants are set in the field. However, since the pots are not removed, they must be completely

Many kinds of containers can be used with good results to grow vegetable plants. Shown are wood flats, wood veneer bands, composition fiber pots, paper bands, clay and plastic pots, and berry boxes.

covered with soil and watered thoroughly so the plant roots can grow through them. Blocks of soil, compressed from a soil mixture in such a manner that they retain their shape, can serve as containers. A cavity may be formed in the top of the block for planting seeds or seedlings. Special machines are required to make soil blocks, and they are used only to a limited extent in this country.

Pepper plants (above) growing in composition pots, connected in a 12-pot unit.

Soil blocks (right), with planting holes formed, in 12-plant trays.

For retail selling, various multiple-unit containers are available. These containers are made of molded fiber, metal, plastic, or wood. Commonly used containers of this type are generally made to hold 6 or 12 plants. Such packs or trays are convenient for pricing and merchandising, and also for use by home gardeners.

Flats can be used as master containers to hold individual plant containers or market packs, or seedlings may be transplanted directly to flats at the recommended plant spacings. In the latter case the seedlings are later separated for field setting by "blocking out" with a knife. It is a good idea to cut the soil into blocks 5 to 7 days before the plants are to be set out. This encourages secondary branching of the severed roots.

Although flats may be made of metal or other material, they are usually constructed of durable wood such as cedar, cypress, or redwood. If the flats are made of other woods they should be treated with a suitable wood preservative such as copper naphthenate. Do not use pentachlorophenol or creosote on plant-growing containers or benches, or anywhere in greenhouses used for growing vegetable plants.

Special machines are available for setting container-grown plants in the field. Mechanical fingers carry the plants forward from a platform and set them in the ground.

MANAGEMENT OF ENVIRONMENTAL CONDITIONS

Plant growth and development can be largely controlled through careful regulation of the environment. Skillful management of temperature, ventilation, water, fertility, and to some extent humidity, are necessary to produce stocky, healthy transplants.

Light Conditions

Light is the energy source for photosynthesis and plant growth. Except for shading, it is generally not practical to control light conditions. There are no economical methods of providing adequate artificial lighting to grow a volume of good plants. During certain periods of the year, lack of sufficient light may be the factor that limits plant growth. In these situations the best possible management of temperatures, watering, and fertility is necessary for success.

Temperature and Ventilation

Optimum day and night temperature ranges for growing plants are given in Table 3. During periods of low light intensity, use the lower temperatures indicated.

High temperatures (above recommended range) at any time, and especially during conditions of low light, will cause plants to become spindly and weak. Temperatures lower than recommended will reduce growth and delay plant development, and may also cause rough fruit in tomatoes and premature seeding of cabbage and cauliflower.

Use accurate thermometers to frequently check temperatures throughout the plant-growing structure. The thermometers should be located at the level of the plants being grown. Uniform temperatures are essential for adequate control of plant development and production of uniformly sized transplants.

Daytime temperatures and humidity are primarily controlled by ventilation. This air exchange supplies carbon dioxide, which is used in photosynthesis, and helps to minimize disease problems. Ventilation at night, except during excessively windy or cold periods, insures adequate air circulation and reduced humidity. Avoid direct cold drafts, which may be harmful to the plants.

Watering Practices

You can regulate plant growth to a large extent by careful watering. Water the plants only when moisture is needed, and then wet the soil thoroughly. Over-watering, a common error in plant growing, results in soft, succulent plants and restricted root growth. It may also promote certain diseases such as damping-off.

Water the plants in the morning, to permit foliage and soil surfaces to dry before night. Water sparingly on cloudy or rainy days.

Spacing Recommendations

Avoid close spacings which cause plants to compete with each other for light, nutrients, and moisture. Crowded seedlings tend to become weak and spindly and are more susceptible to disease. Recommended minimum plant spacings are given in Table 4. Wider spacings or larger containers generally give superior results. If you want to produce the highest quality plants, space them so the leaves of one plant do not touch those of another plant. However, it may not be economical to provide the space required for growing a volume of plants in this manner.

Plants are frequently overcrowded when seeded directly into hotbeds where they remain undisturbed until ready for transplanting into the field or garden. Such vegetable plants (cabbage, onion, pepper, and tomato) seeded at the recommended rates should be thinned to stand ½ inch or more apart in the row.

Supplemental Feeding

Fertilizers can be easily supplied as the plants are watered. This system affords a practical means of adjusting nutrient levels according to the stages of plant development and existing environmental conditions. You can control plant growth by the amount and strength of the fertilizer solution used and the frequency of application.

Many soluble fertilizers are available for supplemental feeding. Starter fertilizers of various analyses, such as 10-52-17, 10-50-10, 20-20-20, 5-25-15, or 16-32-16 have been used with good results. These are high-analysis, water-soluble fertilizers which are primarily mixtures of di-ammonium phosphate and mono-potassium phosphate. Potassium nitrate (14-0-46 analysis) and ammonium nitrate (33-0-0 analysis) have also been used successfully.

Some growers prefer to fertilize with each watering, using a weak solution. A rate of one teaspoonful of the above soluble fertilizers per gallon of water is suggested. For less frequent feeding, use about ½ ounce per gallon for watering young seedlings. After the plants are 3 weeks of age, the strength can be increased to 1 ounce of the fertilizer per gallon of water. To remove any fertilizer that might burn the foliage, give the plants a light watering with clear water.

Soluble salts can be a problem in plant-growing beds as a result of using too much fertilizer or improper fertilizer. Because it is easy to over-fertilize a small area, be careful not to use rates higher than those suggested. Also, avoid the use of muriate fertilizers which contain large amounts of chlorides. Symptoms of soluble salt injuries are poor seed germination, stunted plant growth, small dark leaves, and wilting. Wilting may occur even when the soil is sufficiently moist.

Plant Hardening

Hardening is a physiological process whereby plants accumulate carbohydrate reserves which enable them to recover rapidly after the disturbance of being set in the field and when subjected to different conditions. Hardened plants can better withstand such adverse field conditions as winds, harmful temperatures, and in some cases frosts.

Plants can be hardened by any treatment that checks growth, such as lowering temperature, withholding water, or limiting fertility. A combination of these factors usually occurs in the marketing process.

It should be emphasized, however, that intentional hardening is not recommended for most kinds of vegetable transplants, as *hardening is not necessarily beneficial and may be detrimental.* Overly hardened plants may survive rigorous conditions in the field, but they begin growth slowly and may never fully recover. Thus they will mature later and may have reduced yields. Low temperatures can harm warm-season crops, or induce premature seed stalk formation in biennial crops.

Additional recommendations, on whether or not to harden specific vegetable plants, are given in the section beginning on page 29.

INSECTS, DISEASES, AND RELATED PROBLEMS

Success in growing vegetable plants depends on control of insects, nematodes, weeds, and numerous disease organisms. Three important preventive measures are to (a) disinfest (by heat treatment or chemical fumigants) plant containers, potting soils, and tools, (b) treat the seed to kill disease-producing organisms that may be carried with the seed, and (c) maintain good soil aeration and drainage, careful management of temperature, ventilation, watering, and fertility to lessen the dangers of loss from diseases.

Soil Treatment

Various heat or chemical treatments can be used to rid the soil of disease-causing organisms, nematodes, insects, and active weed seeds.

For details on how to perform heat and chemical soil treatments, write to the Department of Plant Pathology, 218 Mumford Hall, University of Illinois, Urbana.

Some growers use boilers, steam generators, or specially made soil-heating ovens, treating the soil by heating to 180° F. for 30 minutes. Steam is preferable to chemicals.

Methyl bromide, chloropicrin, Vapam, V.P.M. Soil Fumigant, Vorlex, formaldehyde, and other chemicals are available for soil fumigation. Some chemicals are rather specific in controlling certain organisms. *Always select such materials with care, and follow the manufacturers instructions.*

Soil temperatures must be at least 55° F. for effective control with most chemical treatments. Hotbeds and coldframes can be treated in the fall and kept covered until the following spring. If you wait until spring the combination of low soil temperature and inadequate airing time may result in injury to the seeds or seedlings.

Seed Treatment

Most vegetable seed sold by reliable firms is grown under careful supervision to make sure that it is as disease free as possible. Many companies sell seed already treated as outlined in Table 5, and this seed should not be re-treated. If the seed has not been treated, or if you suspect that it is not disease free, use the eradicative treatments (hot water or mercuric chloride) as shown in the table for the different vegetable seeds. Then apply the indicated dust treatments, according to the manufacturer's recommendations, to protect the germinating seeds from decay and damping-off disease organisms.

Postemergence Disease Control

Even with preventive disease control measures (such as soil and seed treatment, skillful management practices, etc.), damping-off can be a problem in the seedbed. This is especially true during cloudy, humid conditions.

To treat for damping-off, water the seedlings at 5- to 10-day intervals with a solution of captan, thiram, or zineb (1 tablespoonful per gallon of water); or ferbam or ziram (2 tablespoonfuls per gallon of water). Spray or sprinkle at rates of 1 pint per 16 square feet of seedbed for vine crops, 1 pint per 12 square feet of seedbed for tomatoes, and ½ to 1 pint per square foot of seedbed for other seedlings.

Refer to Plant Disease Report No. 916 (see page 28) for more complete information than is presented here, including details of pre-

Table 5. — Vegetable Seed Treatments for Disease Control[a]

Crop	Treatment	Diseases controlled
Broccoli, Cauliflower	Soak 20 minutes in hot water at 122° F. Dry and dust with thiram, captan, chloranil, or Semesan.	Seed rot, damping-off, blackleg, black rot, downy mildew, leaf spot, scab, yellows.
Cabbage, Brussels sprouts	Soak 25 minutes in hot water at 122° F. Dry and dust with thiram, captan, chloranil, or Semesan.	Seed rot, damping-off, blackleg, black rot, downy mildew, leaf spot, scab, yellows.
Cucumber, Muskmelon, Watermelon, Summer squash	Soak 5 minutes in 1 to 1,000 solution of mercuric chloride. Dry and dust with thiram, captan, chloranil, or Semesan.	Seed rot, damping-off, angular leaf spot, anthracnose, Fusarium wilt, scab, leaf blight.
Lettuce	Dust with thiram, captan, chloranil, or Semesan.	Seed rot, damping-off, leaf spots, blights.
Onion	Dust with thiram or captan.	Seed rot, damping-off, smut, purple blotch.
Pepper	Soak 5 minutes in 1 to 1,500 solution of mercuric chloride *or* soak 30 minutes in hot water at 125° F. Dry and dust with thiram or captan.	Seed rot, damping-off, anthracnose, bacterial spot, Cercospora leaf spot, Phytophthora blight, Alternaria blight.
Tomato, Eggplant	Soak 25 minutes in hot water at 122° F. Dry and dust with thiram or captan.	Bacterial spot, canker, and speck; seed rot, damping-off, anthracnose, Fusarium wilt, Septoria leaf spot, Phytophthora blight, Alternaria blight, Phomopsis blight, Verticillium wilt, Didymella stem rot.

[a] Adapted from University of Illinois Report on Plant Diseases No. 915, Vegetable Seed Treatment, available from the Department of Plant Pathology, University of Illinois, Urbana. This report gives details of seed treatment methods, sources of treating materials, timing of treatments, and amounts to use.

planting and postplanting methods and materials for control of damping-off, crown and root rots, and stem cankers.

Observe these three important precautions: (1) Do not use fungicides at rates greater than recommended. (2) Do not apply these treatments when air temperatures are above 75° F. (3) *Do not use maneb,* which is commonly used as a fungicide on tomato plants in the field, *on tomato seedlings.*

For diagnosis and control of other diseases that may affect seedlings, refer to the publications listed on the next page, which can be obtained by writing to the Department of Plant Pathology, 218 Mumford Hall, University of Illinois, Urbana.

Plant Disease	*Disease Description and Control*
Report No. 902	Wirestem of Cabbage and Related Crops
908	Early Blight, Septoria Leaf Spot, and Anthracnose of Tomato
910	Bacterial Spot of Pepper and Tomato
916	Damping-Off and Seedling Blights of Vegetables
917	Virus Diseases of Tomato in Illinois
941	Leaf Mold of Greenhouse Tomatoes
Circular 802	Vegetable Diseases

Sanitation Practices

Soil fumigation, seed treatment, and similar practices will be of little or no value unless they are part of an overall sanitation program.

Consider all areas, objects, tools, water hoses, and workers as sources of disease organisms. Fumigate flats, pots, and other containers before each use, and tools at any time they may be contaminated. You can do this with the same techniques used for fumigating soils. In addition, flats, tools, sashes, and benches can be sterilized by drenching with a solution of 1 part formaldehyde in 30 parts water. Dry and air for 48 hours after drenching. *Warning:* Don't use formaldehyde or other soil fumigants in structures where plants are growing.

Any plants such as flowers, ornamentals, or weeds should also be considered as disease sources. Do not permit them in the plant-growing house. Keep down all weeds around the building by maintaining a 10-foot border of soil, cinders, crushed rock, or gravel around the structure.

The use of tobacco in any form cannot be tolerated in the plant house. Users of tobacco should wash their hands carefully with soap and water and wear a protective apron when handling plants susceptible to tobacco mosaic (such as tomato, pepper, or eggplant).

It is also important to maintain a thorough program to reduce the possibilities of trouble with insect-transmitted diseases.[1] Use appropriate screening (such as cheesecloth with 22 threads per inch or wire screening with 18 strands per inch) on all openings, including ventilators.

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[1] For specific insect-control recommendations refer to:

NHE Series of "Condensed Insecticide Recommendations for Vegetable Crops," available from the State Natural History Survey, Urbana, Illinois.

"Insecticide Recommendations . . . for Control of Insects Attacking Crops and Livestock," U. S. Dept. of Agr. Agriculture Handbook 120.

"Control of Insect Pests of Greenhouse Vegetables," U. S. Dept. of Agr. Agriculture Handbook 142.

TECHNIQUES FOR SPECIFIC VEGETABLE CROPS

COLE CROPS

Seed of the cole crops will germinate in about 5 days at soil temperatures of 70°-80° F. Temperature requirements for growing plants are also similar, as shown in Table 3. It takes 5 to 7 weeks from the time the seed is sown to produce good plants to set out in the field.

Cabbage and Broccoli

If you sow these seeds in a hotbed it may be necessary to transplant the seedlings to a coldframe, because it is sometimes impractical to lower the hotbed temperature enough to grow good, stocky cabbage or broccoli plants (see Table 3). Although cabbage and broccoli thrive on relatively low temperatures, repeated chilling or exposure of the plants to low temperature (45° F.) for a period of 2 weeks or more may cause them to prematurely form seedstalks after they are set in the field.

In southern Illinois, where the weather is fairly warm in early spring, coldframes can be used for growing cabbage and broccoli plants.

Cauliflower and Brussels Sprouts

Cauliflower and brussels sprouts require growing conditions similar to those for the other cole crops. However, *cauliflower plants are more delicate* and require more careful handling. Keep the seedlings growing without interruption, to prevent checking or stunting during the time they are in the plant bed. Crowding, inadequate watering, and low temperatures can check growth of the plants. If the stems become tough or woody from checked growth, the plants may form small and inferior heads ("buttoning") of cauliflower in the field. Cauliflower plants require slightly higher night temperatures than the other cole crops.

When you move cauliflower plants, do not pull them (as is generally done, without serious effects, in the case of cabbage and broccoli). Lift the plants out, with as much soil as possible adhering to the roots.

EGGPLANT

Eggplant seeds require 6 to 8 days to germinate at soil temperatures of 75°-85° F. Seedlings should be ready to transplant to other containers 15 to 20 days after the seed is sown. Take extreme care to keep the seedlings growing uniformly from the start, for if their growth is checked and the stems become hardened or woody, they are of little value for planting in the field or garden. Plants, 6 to 8 weeks old, for field setting should have 4 or 5 true leaves. Eggplant should not be hardened or exposed to low temperatures, as it is less tolerant in this respect than tomatoes and peppers. Do not set transplants into the field until all danger of frost is past and the soil is warm.

LETTUCE

Lettuce seed will germinate in 2 to 3 days, and the seedlings should be ready for transplanting into other containers in 7 to 10 days. Maintain the higher temperatures given in Table 3 for Bibb lettuce, as it has a higher optimum growing temperature than leaf or head lettuce. You can put the lettuce seedlings in individual containers, but generally they are transplanted to a flat or bench and spaced a minimum of 2 inches in each direction. This spacing enables the plants to develop properly, and allows for the transfer of a fair-sized block of soil with the roots when the plants are set in the greenhouse or field.

ONIONS

The Spanish type of onion is usually grown from transplants and should be started in February. Soil temperatures for optimum seed germination are in the 65°-80° F. range. Following germination, maintain growing temperatures of 60°-70° F. during the day and 45°-55° F. at night. Unlike most other vegetable transplants, these onions will do better with moderate hardening. To harden the seedlings, water them less frequently and expose them to night temperatures of 40°-45° F. for 7 to 10 days before transplanting. The tops of the plants may be clipped for ease of field setting, but excessive trimming may delay plant growth and decrease ultimate yields.

PEPPERS

Pepper seed germinates rather slowly, requiring 8 days at a soil temperature of 75°-80° F. Following germination, lower the soil temperature to 65°-68° F. to produce stocky plants. Pepper seedlings should be ready for transplanting (when the first true leaf is visible) to other containers 15 to 20 days after the seed is sown. Peppers require growing conditions similar to those for tomatoes.

TOMATOES

The time it takes for tomato seeds to germinate may be influenced by the viability of the seed, but temperature is the most important factor. Tomato seeds germinate readily at a soil temperature of about 75° F. After the seedlings appear above ground, maintain soil temperatures, as closely as possible, to a range of 62°-65° F., with adequate light and moderate watering, to produce stocky plants. The seedlings will be ready for removal from the seed flats 10 to 14 days after the seed is sown, and should be transplanted to other flats, hotbeds, or containers. Regulate air temperatures according to Table 3.

To assure maximum early production of tomato plants, maintain favorable growing conditions at all times. The practice of withholding water, lowering temperatures, or reducing fertility (hardening) is likely to result in delayed plant establishment in the field as well as delaying the harvest. Such hardening will also increase the possibility of rough fruit on the first and second clusters.

In recent years much attention and publicity have been given to increasing the numbers of flowers in the first cluster. Two methods, a cold temperature treatment and a chemical treatment, have been effective for certain varieties. However, while a few more flowers may be produced, there is no assurance that more fruits will set, especially early in the season.

Tomato plants for the field or greenhouse should have stocky, thick stems, well-developed root systems, and visible flower buds of the first cluster. The flowers should not be in bloom, and the fruit should not be set. If fruits are set before the plant becomes established in the field, the plant will not develop properly and the early fruit will be small and probably unmarketable.

When grown under favorable conditions, tomato transplants that are 4 to 7 weeks old have the best potential for both earliest and greatest production. However, the transplant age is more critical for certain varieties. Transplants of early-maturing determinate varieties such as Fireball, should be 4 to 5 weeks old, and some greenhouse varieties, such as Ohio WR-7, should be 6 weeks of age. Plants that are properly aged can be held a week in good condition if adverse weather delays planting.

Do not prune or trim tomato plants in the plant bed to hold back their growth. In removing the leaves you destroy vital parts of the plant needed for production of carbohydrates (in photosynthesis) essential for vegetative and reproductive growth. Topping the plants prior to field setting, to promote branching, has not been found to be beneficial and may reduce early production.

In general, container-grown tomato transplants are recommended, and they will produce earlier yields than will pulled plants. For the production of processing tomatoes, bare-root pulled plants, such as southern-grown plants, are satisfactory.

VINE CROPS (Cucurbits)

Seeds of these crops are generally planted directly in the field or garden where the crop is to be grown. When extreme earliness is important, plants may be started in hotbeds or greenhouses. Seedlings of the vine crops are not easily transplanted and thus are best seeded in containers where they may remain until they are set out.

Individual containers that are easily removed (such as bands), or containers that are "planted" with the plants (such as organic-composition pots), are recommended. With such containers you avoid disturbing the root systems when setting out the plants, and delaying their establishment in the field. Three-inch containers are adequate, although some growers prefer the 4-inch size. Plants can also be grown in 2¼-inch bands or pots if they are to be set in the field at a younger age.

Cucumbers and Summer Squash

Cucumber and summer squash seeds should germinate in 3 to 5 days at soil temperatures of 70°-85° F. Four or five seeds are commonly planted in each container. After germination, thin to leave the strongest two seedlings. It is generally best to thin by pinching off or cutting the stems with a knife, as pulling can result in injury to the roots of the remaining seedlings.

Muskmelons and Watermelons

The practical soil temperature for germinating most melon seeds is 80°-90° F., although the acceptable range is from a low of 70° to a high of 95° F. In the case of seedless watermelons, the temperature should never go below 85° F. If possible, use thermostatically controlled electric heating cables to maintain the desired soil temperatures.

Muskmelons and watermelons require plant-growing temperatures similar to those for cucumbers (Table 3).

A general recommendation is to plant three to five seeds in each container, and thin to the two best plants after the seedlings emerge. Considering costs of seedless and hybrid melon seeds, most growers plant only one or two seeds per container.

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Photographs appearing on pages 5 (portable cold frames), 19 (pepper plants in composition pots), and 22 courtesy of the Jiffy-Pot Company of America, West Chicago, Illinois.

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