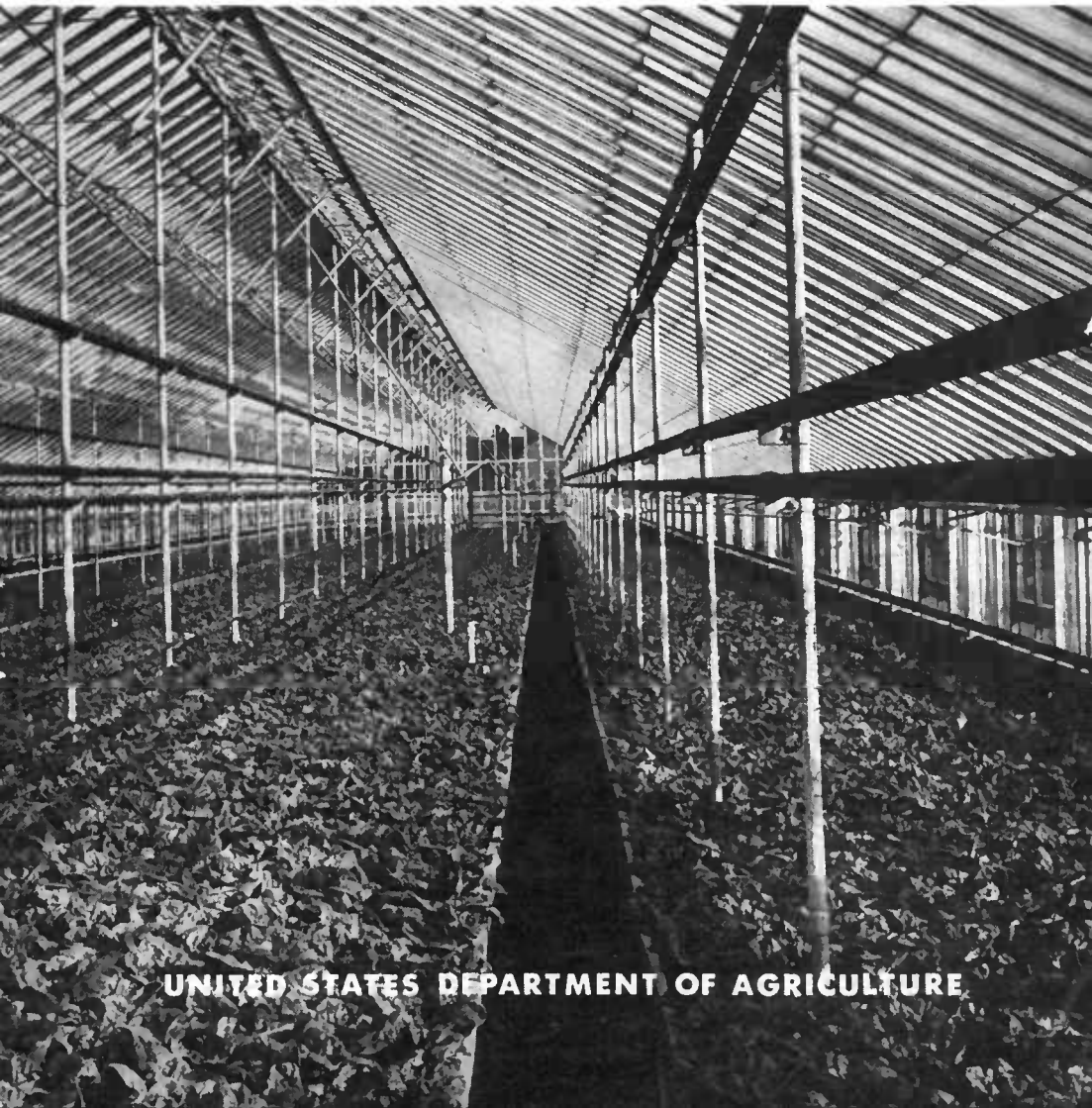
Agriculture Handbook No. 149

Growing Lettuce In Greenhouses



UNITED STATES DEPARTMENT OF AGRICULTURE

CONTENTS

Thompson, Ross Calvin, 1896–

Growing lettuce in greenhouses [by Ross C. Thompson, S. P. Doolittle and T. J. Henneberry. Washington] U. S. Dept. of Agriculture [1958]

22 p. illus. 24 cm. ([U. S. Dept. of Agriculture] Agriculture handbook no. 149)

"Replaces Farmers' bulletin 1418, Lettuce growing in greenhouses."

1. Forcing (Plants) 2. Greenhouse management. [2. Greenhouse cultivation] 3. Lettuce. I. Title. (Series)

SB351.L6T47 1958 635.52 Agr 58–355

U. S. Dept. of Agr. Libr. for Library of Congress 1Ag84Ah no. 149 [*]†

This publication replaces Farmers' Bulletin 1418, Lettuce Growing in Greenhouses.

Washington, D. C. Issued November 1958

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 15 cents

Growing Lettuce In Greenhouses

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Growing lettuce under glass is one of the oldest vegetable-forcing industries. Lettuce is well adapted for forcing during the colder months of the year, when light and temperature are less favorable for other vegetable-forcing crops. Much lettuce was grown in hotbeds and coldframes before greenhouses were generally used for growing vegetables. Some lettuce is still grown in frames in early spring and late fall, when only limited protection from cold is required. However, most of the forced crop is now grown in greenhouses especially designed for growing vegetables, and therefore the market can be supplied with fresh lettuce throughout the winter, when the weather is too cold for growing crops in frames.

With the expansion of the field-grown lettuce industry into regions with mild winters, the demand for greenhouse-grown lettuce has gradually declined. Although field-grown head lettuce can now be obtained in most markets the year round, there is still a demand for high-quality greenhouse-grown lettuce during the winter. Growing lettuce under glass still constitutes a sizable industry in certain districts, where its production has become highly specialized and the winter market has been well organized and maintained. The industry has now become fairly well stabilized. It centers around Grand Rapids, Mich., Rochester, N. Y., Ashtabula, Cleveland, and Toledo, Ohio, and Boston, Mass.

Growing lettuce in greenhouses is an expensive and highly specialized business, and it should not be undertaken commercially without practical knowledge in the growing and marketing of the crop.

LOCATION AND CONSTRUCTION OF GREENHOUSES

Since many growers of greenhouse lettuce also plant other crops, they should consider the requirements of these crops in planning the construction of new greenhouses. Lettuce, tomatoes, and cucumbers are the important vegetable-forcing crops, and many growers plant all three at different seasons. Since lettuce is grown chiefly during the winter, when the days are short and there are many hours of dull, cloudy weather, it is important that greenhouses be constructed so as to afford the maximum of light. It is important that the tempera-

[1] Retired July 31, 1958.

ture be properly controlled and that drafts be reduced to the minimum consistent with good ventilation. Efficient heating equipment is essential.

Some important points to be considered in selecting a location for a vegetable-forcing greenhouse include (1) nearness to market, (2) availability and cost of labor, (3) supply and cost of fuel, (4) soil suitable for the crops to be grown, (5) water supply, and (6) freedom from smoke and fumes from industrial plants.

The type of lettuce grown in greenhouses is not so well adapted for long-distance shipment as the hard-headed type grown in the field. It tends to wilt quickly unless it is kept moist and cool. The delicacy of the product makes it imperative that the crops be grown fairly near the market.

Labor is a major item in the cost of almost all commodities, agricultural as well as industrial. Capable, well-trained help is often difficult to obtain. The available labor supply should be kept in mind in selecting a location for a vegetable greenhouse.

The cost of fuel has always been a large item of expense in greenhouse maintenance, and it has risen sharply in recent years. Soft coal has been the chief source of fuel for greenhouse heating, but oil and gas have replaced it to some extent.

Although the soil used in greenhouses can be made to suit the crop to be grown by adding fertilizer, organic matter, lime, and other soil amendments, it is highly desirable that the range be located where the soil is naturally suitable for the crops to be grown. The lighter types of soil are preferred for greenhouse-vegetable production.

There should be an adequate and constant supply of water free of materials that may be toxic to plants or that may corrode the heating system. Highly chlorinated water is not desirable. Avoid a high concentration of salts.

Smoke from industrial plants reduces light intensity through its presence in the air and forms a film on the glass, which greatly reduces the intensity of the light that reaches the plants. Avoid reducing the light of dull winter days by smoke or fumes. Do not locate greenhouses near industrial plants because of the smoke and also the fumes, which may be toxic to certain plants.

Most of the newer greenhouses built for growing lettuce are even-span structures of steel, aluminum, or steel and aluminum. Wood is used much less than in the past. Although the original cost of wood construction may be low, the upkeep in painting, glazing, and other repairs over a period of years adds greatly to the total cost.

Lettuce can be grown in almost any type of greenhouse in which the lighting is good, except the lean-to type, which is not suitable for commercial lettuce growing.

The ridge-and-furrow type of construction (fig. 1) is widely used to enclose a large area under one roof. This kind of structure permits an almost unlimited area to be enclosed with a minimum of obstruction to interfere with cultural operations and the entrance of light.

Large even-span metal-frame greenhouses (fig. 2) are being widely used for vegetable forcing. The use of steel and aluminum in the framework adds greatly to the strength and life of these greenhouses, and they afford better lighting than the old-style wood-frame buildings.

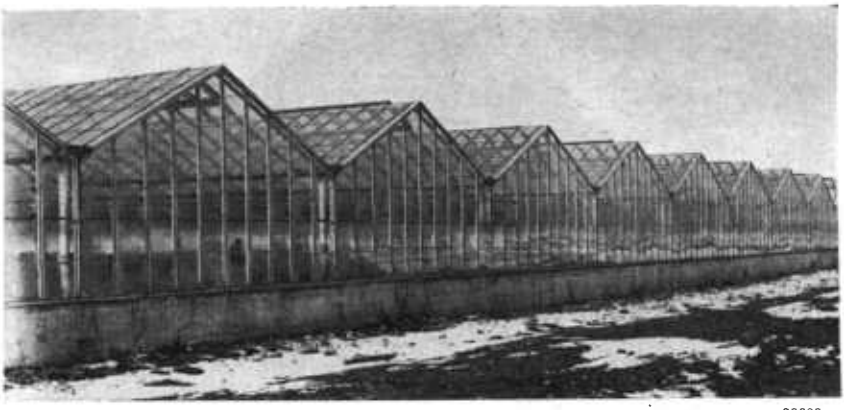

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FIGURE 1.—Ridge-and-furrow type of greenhouse, which permits enclosure of very large areas under one roof.

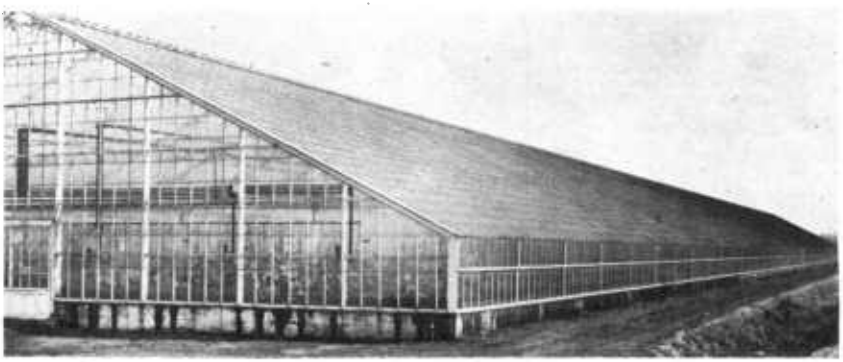

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FIGURE 2.—Steel-frame greenhouse, ideal for vegetable forcing.

Most greenhouse lettuce is grown on ground beds. In large ranges the entire floor of the greenhouse is fertilized, plowed, and tilled in much the same manner as a field.

LETTUCE VARIETIES FOR FORCING

Of the many lettuce varieties, only a few are suitable for forcing. In the past numerous varieties of head, Cos, and leaf lettuce were grown under glass, but now two or three constitute almost the entire commercial crop.

Only in the Boston district is head lettuce forced in quantity. In the past Belmont, May King, Big Boston, and Salamander were grown under glass with varying success.

Bel-May is a small butterhead variety of lettuce (fig. 3, *A*) developed by the Massachusetts Agricultural Experiment Station. It is still the important greenhouse variety in the Boston market-garden district, but it is not grown in other districts.

None of the crisp head varieties of lettuce are well adapted for growing in greenhouses. Paris White, Trianon, Bath, Express, and other

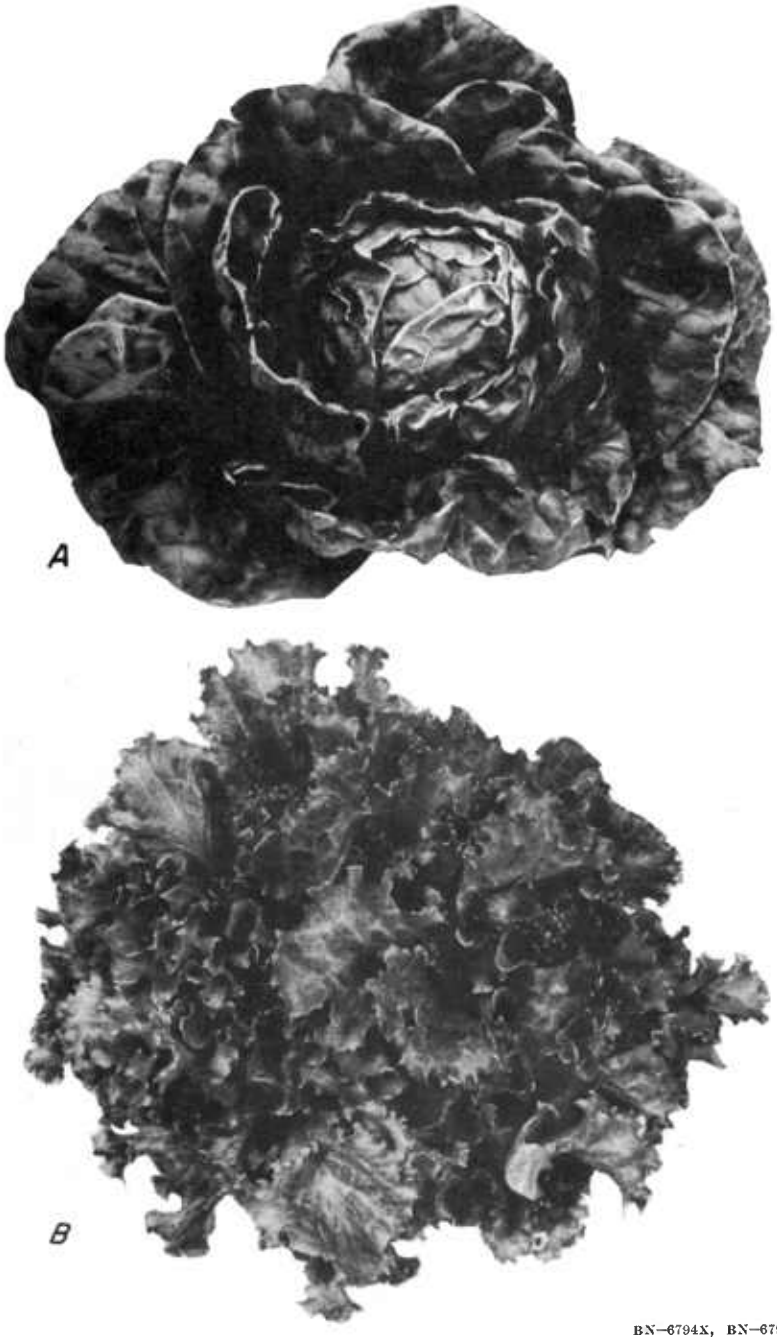

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FIGURE 3.—The two most important varieties of lettuce grown under glass: *A*, Bel-May, a small butterhead variety; *B*, Grand Rapids, a leaf, or nonheading, variety.

varieties of Cos lettuce have at times been grown as forcing crops but with limited success.

Of all the types of lettuce, the leaf variety Grand Rapids (fig. 3, *B*) is the most popular, and it is also the most important greenhouse forcing variety. There are several strains of Grand Rapids, each adapted to particular locations and growing conditions. The Washington strain, sometimes called Grand Rapids Forcing, was developed by the United States Department of Agriculture. It is very popular with the Grand Rapids, Mich., growers. A forcing strain of Grand Rapids that is resistant to tipburn was developed by the Ohio Agricultural Experiment Station. Sometimes known as Resistant Grand Rapids, it appears a few days earlier than the other strains. A third one, Grand Rapids U. S. No. 1, also developed by the Department, is an important strain in New York and other districts where lettuce is forced. It is slower to bolt than the other Grand Rapids strains.

PRODUCTION AND CARE OF SEED

Only those lettuce varieties that are known to be adapted for forcing should be grown under glass. High-quality seed of a good strain is even more important for the forcing industry than for field production. The supply of such seed is often limited, and therefore many large growers have found it profitable to produce their own seed.

By carefully selecting the most desirable plants for seed production, a strain can be developed that is especially adapted to local conditions and resistant to certain diseases. In working for disease resistance, selection should be made under conditions favorable for disease and where disease is present. A pound of seed will be produced from 50 to 75 well-grown lettuce plants. Lettuce averages about 350,000 seeds per pound. The seed of Grand Rapids is small and well below the average in size. A pound of high-quality lettuce seed, if properly handled, will produce enough plants to set an acre.

Plants selected for seed production should be transplanted from the beds to some part of the greenhouse where they can be given special attention (fig. 4). Do not save seed plants that are even slightly off-type lest the strain deteriorate. Unless the greenhouse is screened and all insects are kept out, cover each plant with a light-weight muslin bag just before the first flowers open. Keep the coverings on until all flowers have set seed. If the bags are left on until the seed is mature, the plants can be cut and left in the bags until seed-cleaning time.

After a desirable strain has been isolated, it need not be increased every year. Enough seed for 2 or 3 years can be grown and kept until used if it is stored in a cool, thoroughly dry place. Lettuce seed loses its viability rapidly under humid conditions.

ROTATION AND INTERCROPPING

Growing lettuce in greenhouses should be considered in relation to growing other forcing crops. Very few growers produce a single crop throughout the year. At least part of the year most of them grow other vegetables, such as tomatoes or cucumbers, or some kind of flowering plant.

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FIGURE 4.—A crop of Grand Rapids lettuce seed nearing maturity in a greenhouse.

Since lettuce is the only one of the three important vegetable-forcing crops that thrives during the short, dull days of winter, growers usually plan to have it occupy the greenhouse during this period. A crop of tomatoes is often followed by a crop of lettuce, which is followed by a spring crop of tomatoes or cucumbers. Two or three crops of lettuce sometimes follow a fall crop of tomatoes. If cucumbers are used in the rotation, they are usually grown as a spring crop, when light and temperature are more favorable than during the fall and winter months. Rotation plans in common use in large ranges are given in table 1. If it is desired that lettuce be available for cutting continuously for an indefinite period, plantings should be made on several successive dates, so that only part of the crop will reach cutting size at one time.

TABLE 1.—*Greenhouse crop rotations, with planting and harvesting dates*

Plan and crop	Seed sown	Plants set	Crop harvested
Plan 1:			
Tomatoes	July 1–15	Aug. 15–30	Dec. 15–31
Lettuce	Nov. 15–30	Dec. 15–31	Mar. 15–31
Cucumbers	Feb. 1–15	Apr. 1–15	July 1–31
Plan 2:			
Tomatoes	July 1–15	Aug. 15–31	Dec. 15–31
Lettuce	Nov. 15–30	Dec. 15–31	Mar. 15–31
Do	Feb. 1–28	Mar. 15–31	June 1–15
Plan 3:			
Lettuce	Aug. 1–15	Sept. 1–15	Nov. 15–30
Do	Oct. 15–30	Nov. 15–30	Feb. 1–28
Tomatoes	Jan. 1–15	Mar. 1–15	Before Aug. 1

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FIGURE 5.—Leaf lettuce intercropped with cucumbers. The lettuce is to be harvested before the cucumber vines begin to run.

In plan 1, the time between the removal of the cucumbers and the planting of tomatoes may be used for soil sterilization. In plan 2, it is possible to grow a third crop of lettuce in part of the space. Growers who follow this cropping plan usually count on 2½ crops of lettuce.

Since leaf lettuce can be grown to salable size in about 8 weeks from the transplanting date, it is often planted between rows of tomatoes or cucumbers (fig. 5) and is harvested before the tomatoes or cucumbers reach such size as to interfere too much with its growth.

Intercropping of lettuce presents difficulties, and the product is usually not of the highest quality. Since cucumbers and tomatoes both require temperatures too high for lettuce, either lettuce or the crop it is grown with is likely to suffer from improper temperature. The shading effect of tall-growing tomatoes and cucumbers where the vines are trained on trellises makes growing conditions unfavorable for lettuce. In general, intercropping tomatoes or cucumbers with lettuce is not a good practice.

GREENHOUSE SOIL AND ITS MANAGEMENT

Growing lettuce and other vegetable-forcing crops in greenhouses is an intensive and expensive operation. Maximum production must be reached quickly and maintained continuously. Most ordinary field soils are not suitable and often require large amounts of organic matter, fertilizer, and lime. Sometimes sand or ashes are added to change the texture and physical properties and thus to make the soil better suited for intensive crop production. Few field soils are ideal for greenhouse-vegetable growing. If it is possible to select the soil upon which the greenhouses are to be constructed, choose land that will require as little modification as possible.

For greenhouse-vegetable production the soil should be lighter than is generally considered suitable for growing the same crops in the

field. The lighter soils are favored because (1) they are more easily handled in transplanting, tilling, and sterilizing than heavy soils; (2) their surface dries more quickly, and thus disease is less apt to become established and spread; and (3) they are more easily kept in good physical condition, and since they are less likely to become packed, they afford better aeration.

Where the original soil is too heavy, make it more friable by incorporating sand and well-decomposed organic matter. Muck is ideal for supplying organic matter and making soil more friable. However, muck alone is not suitable for vegetable forcing.

Good drainage is essential. Unless the land selected for the greenhouse site is already well drained, provide proper drainage when the greenhouse is constructed. Tile installed for drainage may also be used for soil sterilization. If underlain by a heavy soil, the tile can be used for subirrigation.

Soil Sterilization

The control of plant pests in the greenhouse is more necessary and sometimes more difficult than in the field. Almost universally greenhouse growers practice soil sterilization to control diseases, insects, nematodes, and other plant pests. Sterilize greenhouse soil at least once a year whenever it can be done with the least interference with crop production. This is usually during the summer, when high temperatures are unfavorable for greenhouse crops.

Most large greenhouse ranges for forcing vegetables are equipped to sterilize with steam, which is the most effective and widely used method of controlling soil-borne plant pests. New greenhouses should be provided with such equipment. The most generally used devices for applying steam in soil sterilization are (1) the inverted pan, (2) perforated iron pipes, and (3) drain tile. The method to be used must be determined largely by the conditions.

The inverted pan is best adapted for porous soils, which offer the least resistance to penetration by steam. The equipment consists of a wooden or metal pan of almost any convenient size. Galvanized sheet iron is more durable and lighter than wood. Convenient-sized pans are 4 to 6 feet by 10 to 12 feet and 6 to 8 inches deep. However, the size and shape of the pans should be determined by the dimensions of the planting beds, the capacity of the boiler, and the means of moving the equipment. Each pan is provided with a pipe connection for attaching the steam hose. The pan is inverted, and the edges are forced into the soil a few inches to prevent the escape of steam. If the steam pressure is high, it may be necessary to add some additional weight to hold the pan in the soil. Some large growers have the pan equipped with wheels and a mechanical device by which the apparatus is lifted and rolled when it is necessary to move the pan (fig. 6).

The perforated-pipe arrangement consists of 4 to 6 perforated iron pipes, 1¼ or 1½ inches in diameter and 20 to 70 feet or more in length, which are fastened to a header pipe, 2 inches in diameter, at spacings of 12 to 18 inches. The header pipe is provided with a connection for attachment to the steam hose. The perforations are usually ⅛ or ¼ inch in diameter and 12 inches apart. The size of the equipment is determined by the size of the greenhouse, boiler capacity, and help

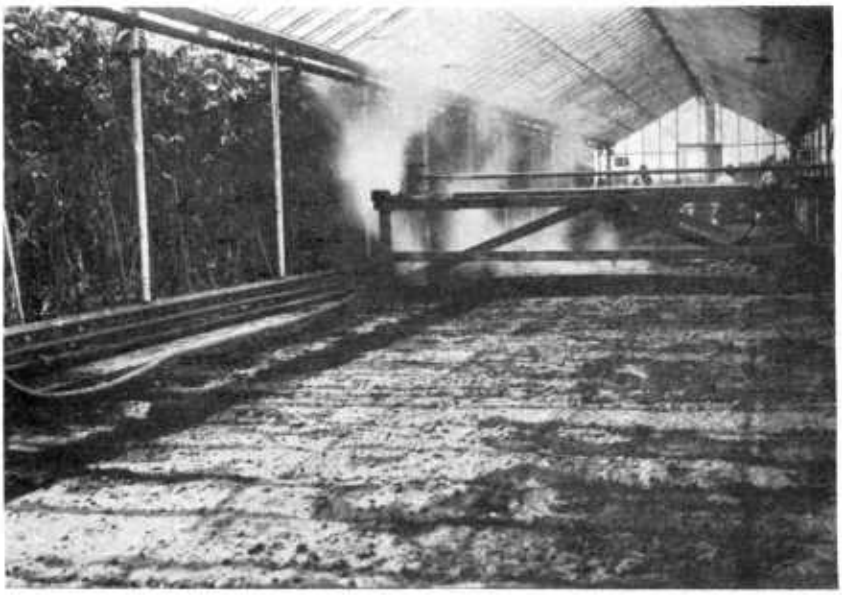

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FIGURE 6.—Mechanically movable steam pan being used for sterilizing greenhouse soil. The equipment is lifted by a special hoist and moved to a new location on wheels, which roll on the concrete walks.

available for moving. This equipment is buried to a depth of 6 to 10 inches in the soil, and the entire surface is covered with plastic or a heavy canvas to confine the steam. If two or more sets of equipment are available, one set can be buried and made ready while sterilization is going on in another section. The chief objection to this method of sterilization is the great amount of labor required to bury the pipes.

A variation of this method is known as the rake, or steam-harrow, system. The equipment consists of a framework of metal pipes with tees at intervals of 6 to 8 inches, to which about 6-inch lengths of small iron pipe, usually ½ inch in diameter, are connected. The lower ends of these small pipes are closed by flattening to form wedges. Holes, ⅛ or 3/16 inch in diameter, which are drilled through each pipe just above the wedge, provide openings for the escape of steam. The header pipe is equipped with a connection for attachment to the steam hose. The perforated pipes, or pegs, of this equipment are forced into the soil, and the surface is covered with plastic or a heavy canvas to confine the heat. Where the boiler capacity is sufficient to supply the steam, several of these rakes can be operated continuously by a group of workmen. The rake is especially well suited for small greenhouses and ranges having raised benches.

A drain tile 4 inches in diameter and set about 1½ feet deep in rows 1½ to 2 feet apart can be used for both steam sterilization and subirrigation. However, tile lines may be a source of trouble, because they provide a shelter and breeding place for crickets, roaches, and other pests.

In order to destroy the most resistant plant pests, heat the soil to a depth of several inches to 212° F. for a half hour or more. The time required for the soil to reach this temperature will depend on the amount of steam, soil texture, and type of equipment used. Excessive heating breaks down organic materials and leaves the soil in a poor condition for the growing of plants. Plant growth is more satisfactory when steam-sterilized soil is permitted to lie idle for 3 to 4 weeks before it is used.

Soil Preparation

The best soil for forcing crops is one naturally deep, well drained, and friable. In large ranges where the crop is grown on ground beds, the soil remains in place from year to year. Its productivity is maintained by the addition of manure, or other organic matter and fertilizer, and by sterilization. Animal manure is the best source of organic matter. Apply it at the rate of 1 ton to each 1,500 square feet of surface, or about 30 tons per acre. Because of the increasing scarcity and cost of animal manure, greenhouse growers have had to find substitutes for part of the organic matter and to supplement manure with chemical fertilizers. Muck is a good source of organic matter and can be used as a substitute for manure if supplemented with chemical fertilizer. Experiments show that good results can be obtained with 15 tons per acre of manure plus half a ton per acre of a 3–12–4 fertilizer or other commercial fertilizer having a similar formula.

Except on highly fertile soils already well supplied with phosphorus, lettuce yield generally increases with an application of phosphorus in an available form. Superphosphate is preferred to the less soluble forms of bonemeal and ground rock phosphate. Foliage crops like lettuce use large amounts of nitrogen. However, avoid overfeeding with available forms of nitrogen such as nitrate of soda and sulfate of ammonia. Excessive stimulation with nitrogen causes a rank, succulent growth that is subject to disease. Lettuce does not have a high potassium requirement. However, best results with lettuce are generally obtained when a complete fertilizer supplying nitrogen, phosphorus, and potassium in the proportion of about 1 part of nitrogen, 2 or 3 parts of phosphorus, and 1 part of potassium is used.

When making a heavy application of chemical fertilizer, spread it uniformly and work it thoroughly into the soil before planting. Side dressing with nitrate of soda or sulfate of ammonia after the crop has become established should not exceed about 200 pounds per acre. Continued use of large amounts of nitrate of soda may in time result in toxic residues.

Lettuce is more sensitive to soil reaction than are tomatoes or cucumbers. When tomatoes or cucumbers are grown in rotation with lettuce on the same soil, note especially the requirement of lettuce, which does best on soils that are only slightly acid. If the soil is moderately or very acid, correct the acidity by applying lime. It is usually unsafe to exceed the amount indicated by lime-requirement tests.

Lime may be applied as ground limestone, ground burned limestone, or hydrated lime. Ground burned limestone gives the quickest results; ground limestone is slow in its reaction. About one-half as

much ground burned limestone or about three-fourths as much hydrated lime is required to give the same change in soil reaction as a given quantity of ground limestone. Once the soil in a greenhouse has been brought to the proper condition of acidity, a moderate application once a year as indicated by lime-requirement tests will generally maintain a satisfactory soil reaction. More lime will be required when acid-forming materials like sulfate of ammonia are used in the fertilizer than when base-forming materials are used.

STARTING THE PLANTS

Greenhouse lettuce is usually grown from transplants rather than by seeding in the beds where the crop is to be grown. Enough seedlings for an entire range can be grown in one greenhouse, where uniform growing conditions can be maintained. A large part of the range is thus available for other crops while the lettuce plants are being started.

The seedlings are grown on solid beds or raised benches with or without the use of flats. Better plants can generally be obtained if flats are used, and the plants are more easily handled.

Soil for Seedlings

Use a good grade of composted soil for starting the plants. Prepare the compost pile several months or preferably a year in advance. This prepared soil should be free of large clods, stones, or trashy organic matter. Two parts of field sod to one part of stable manure, preferably horse or cattle manure, makes a good compost. If the soil is acid, add ground limestone to the compost pile to correct the condition. It is generally desirable to add a few pounds of a complete fertilizer high in phosphorus to each ton of compost. A 5–10–5 fertilizer or one having a similar analysis is suitable. Cut down the compost pile and turn once and preferably twice to incorporate the manure thoroughly. The lime and fertilizer can best be added at the first turning.

Large ranges are equipped with soil shredders, through which the compost is passed before it is used for planting. If the prepared compost contains coarse material, pass it through a screen. It is advisable to sterilize all compost used for starting the plants, although this is not always done. An entire range may be infected with a disease that originates in the plant bed or seed flat.

It is important that the soil used for starting the plants be friable enough to fall apart readily and permit the separation of the seedlings with a minimum of root injury. Small plants start off more rapidly after transplanting and are much less subject to injury by soil-borne organisms if the root system is kept intact than if the roots are broken or otherwise injured.

Planting the Seed

Since greenhouse lettuce does not sell well until local field-grown lettuce is off the market, set the fall crop so as to be ready to harvest it soon after the field-grown crop is no longer available. About a month is required to produce plants for setting. Growth is slower

and more time is required to produce the crop during the short days of winter than when the days are brighter and longer. When lettuce is not grown with other crops, plant the seed from August 1 to 15 for a crop to mature the last part of October or early November. In large ranges where several crops are grown during the fall, winter, and spring, planting and harvesting go on continuously and several plantings are necessary.

Drill planting of lettuce seed is preferable; however, the seed may be planted broadcast. Drop the seed at the rate of 8 to 12 per inch in very shallow furrows spaced about 2 inches apart. A suitable planting furrow can be made with the edge of a thin piece of wood such as a lath. Cover the seed to a depth of not more than one-eighth inch with muck or leaf mold mixed with sand. Muck is not a good covering when used alone, as it is too light and tends to be pushed up in a sheet as the seed germinates, and therefore a weak, elongated seedling may result. Muck mixed with sand to add weight makes an ideal cover for lettuce seed. Sometimes burlap or other cloth is substituted for the soil covering, and it is thoroughly wet after being laid to help hold the moisture until the seed germinates. When cloth is used, it is essential to remove it as soon as the seed starts to germinate.

Seed Treatments To Improve Germination

The seed of many lettuce varieties germinates poorly if planted soon after harvest. Such dormant seed requires a month or two of after-ripening in storage under dry conditions before it will germinate well.

Some lettuce seed germinates poorly at temperatures of 75° F. or above, especially the Grand Rapids variety. When the greenhouse temperature can be controlled, keep it at 65° to 70° until the lettuce seedlings have emerged aboveground. Good, viable, nondormant seed will germinate in less than 24 hours at this temperature. At higher temperatures most lettuce seed will require at least 3 to 5 days for emergence, depending somewhat on the depth of covering.

If dormant lettuce seed is to be planted when the greenhouse temperature cannot be held below 75°, germination can be greatly improved by soaking the seed in a ½-percent solution of thiourea for 8 to 10 hours at 65° to 70°. After removal from the solution, the seed may be planted while damp, or it may be scattered thinly on a dry surface until dry and then stored until planting time. The increase in germination due to the thiourea treatment will remain effective for several months if the seed is stored in a cool, dry place. A similar treatment with water alone will aid in the germination of most lettuce seed.

Dormant lettuce seed can be made to germinate more readily if given a cold treatment just before planting. Germination has improved greatly when dormant lettuce seed is soaked in water for 2 or 3 hours and then held at 39° with good aeration for 4 to 6 days. With the cold treatment the seed cannot be dried and stored. It must be planted while moist to benefit from the treatment.

Transplanting

Greenhouse lettuce is usually transplanted, or pricked off, twice, (1) from the planting bed or seed flats to other flats and (2) from

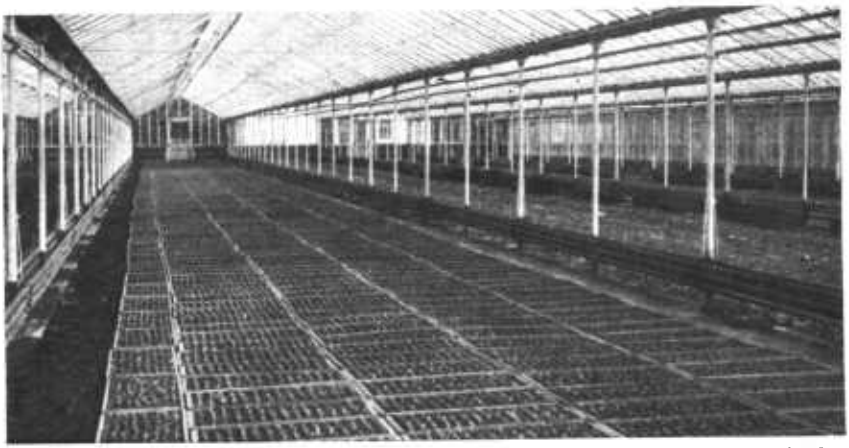

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FIGURE 7.—Plants for a 10-acre range transplanted into flats and placed on a greenhouse bed.

these flats to the beds where the crop will be grown. Transplanting is expensive, but it produces better plants. Do the first transplanting about a week after the seedlings emerge. The interval between emergence and transplanting depends on the growth rate and the thickness of seeding. If the seedlings are close together or the temperature in the greenhouse is high, transplant sooner than if the greenhouse is cool or the plants are not crowded. If vigorous, stocky plants are to be obtained, do not delay transplanting until the seedlings become crowded. The less the roots of the seedlings are broken or injured in lifting from the plant beds or flats, the sooner the plants will recover after transplanting.

The seedlings are sometimes transplanted into small pots or paper bands, but the common practice is to transplant them into standard planting flats (fig. 7). Allow about 2 inches between the plants in the flats. The flats in general use hold 60 to 75 plants at the 2-inch spacing. Experienced workers can transplant as many as 5,000 plants a day. As soon as the plants are set in the flats, water the soil. It is important that the first watering be thorough. Apply enough water to wet the soil to the bottom of the flat. Apply the water as a fine spray so as not to injure the plants by covering the leaves with mud. Be especially careful if the plants are wilted.

ESTABLISHING THE CROP PLANTS

After transplanting the seedlings, leave them in the growing flats or pots until good, sturdy plants have developed but not until they are crowded. Holding too long before the final transplanting results in elongated, bleached plants that are stunted and start off slowly. Planting distances of 7 by 7 inches to 9 by 9 inches are generally used. Some growers plant closer in one direction than in the other to make cultivation easier. Planting in squares allows the plants to develop uniformly. The greater number of plants required for close planting

(table 2) adds to the cost of plants, increases the chances for disease, and may not increase the total yield per unit area enough to justify the practice.

In setting the plants in the greenhouse beds, some kind of marker is essential for spacing the plants accurately. One such device (fig. 8) consists of a broad board with wooden pegs, which are 1½ inches in diameter and about 2 inches long and are attached at the desired planting distances. It speeds the work of setting and assures accurate spacing of the plants. The workers kneel on the board while they are transplanting. As the plants are being set in holes already made by the marker, other holes are being made.

Retain as much soil as possible on the roots in removing the plants from the flats, so that there will be a minimum check in growth. Running a knife through the soil between the plants in both directions

TABLE 2.—*Planting distance and number of lettuce plants required per 1,000 square feet and per acre*

Distance between plants (inches)	Plants for—		Distance between plants (inches)	Plants for—	
	1,000 square feet	1 acre		1,000 square feet	1 acre
	Number	*Number*		*Number*	*Number*
6 by 7	3, 429	149, 368	7 by 8	2, 571	111, 993
6 by 8	3, 000	130, 680	7 by 9	2, 286	99, 579
6 by 9	2, 667	116, 175	8 by 8	2, 250	98, 010
7 by 7	2, 939	128, 023	8 by 9	2, 000	87, 120

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FIGURE 8.—Setting lettuce plants in the greenhouse. The board serves as a support for the workers as well as a marker for spacing the plants.

helps to retain the soil around the roots. Too deep setting of lettuce plants is ruinous. It is better to set them a little shallow than too deep. The soil should come almost to the bottom pair of leaves. Leaf petioles and blades are much more subject to decay by soil organisms than stems.

GENERAL CARE OF THE CROP

Watering

Lettuce, which requires a great deal of water, should never be permitted to suffer from want of moisture. Thorough irrigation is much better than frequent light wettings. Frequent wetting of lettuce leaves tends to spread diseases. Moisture favors drop, bottom rot, gray mold, and mildew. The sooner moisture can be dried from the leaves after wetting the better. There is less danger of foliage diseases getting started in lettuce during the early stages before the plants cover the soil and when ventilation and air movement are good. Subirrigation is ideal for lettuce, because moisture can be kept off the leaves.

Overhead irrigation insures more uniform distribution of water, reduces labor costs, and provides less chance for damage to plants than hand-operated nozzles.

Pipelines equipped with sprinkling nozzles spaced about a foot apart are fastened to the supporting parts of the greenhouse. A single line of pipe will handle a 40- to 50-foot width of greenhouse space. By inserting a swinging joint near the valve end, the entire line can be rotated so as to cover all the space between the lines.

Temperature and Ventilation

Lettuce is a cool-season crop and thrives best at fairly low temperatures. High temperatures favor rapid growth, but they increase the chances for disease and may cause weak, spindling plants. Temperatures may be high with less danger to the plants during the early stages of growth than when the plants are larger and air movement between them is reduced. It is important that temperatures be held low as the crop nears maturity.

There should be a difference of 10° to 15° F., and perhaps more, between day and night temperatures; however, sudden changes in temperature should be avoided. The exact temperatures that should be maintained within a greenhouse for growing lettuce must be determined to some extent by the conditions outside, as they affect the amount of ventilation that can be used. After irrigation, when the humidity within the greenhouse is high, it is best to maintain the temperature a few degrees lower than if the foilage were dry and the humidity low. Night temperatures of 45° to 50° and day temperatures 15° higher are satisfactory for lettuce during the winter. However, in early fall and late spring it may be impossible to maintain these optimum temperatures.

Ventilate the lettuce as much as outside conditions will permit. The top vents should never be closed tightly, except during very cold or stormy weather. Stagnant, humid air contributes to the development of some diseases of greenhouse lettuce.

Cultivation

The removal of weeds, which is one of the chief purposes of cultivating crops grown in the open, is generally not a problem in greenhouses. Once the soil in a greenhouse has been steam sterilized, weeds should not be troublesome unless their seeds are introduced in manure and other materials used in preparing the soil. Shallow cultivation to break up the surface crust may be beneficial while the plants are small, especially if the soil contains considerable clay. However, after the plants have begun to cover the soil, cultivation may do more harm than good. Cultivation is usually done with ordinary hand tools. Long-handle tools can be used on narrow beds, but some kind of trestlework on which workmen can stand is desirable for wide beds. If the spacing is wide, wheel hoes may be used for cultivating small plants.

HARVESTING AND MARKETING

The time required to produce a crop of lettuce, from transplanting in the greenhouse beds until harvesting, ranges from 6 to 12 weeks, depending on the market demand as regards plant size and the season of the year. When prices are good, it may be profitable to harvest before the plants reach maximum size even though this means some loss in total yield. When lettuce is sold by weight, growers like to allow the plants to become as large as possible without reduction in quality. A longer time is required to produce plants of marketable size during the short days of winter than during the sunnier, longer days. If another lettuce crop is to follow the one about ready to harvest, the condition of the seedlings for the next crop may make it necessary to harvest earlier than otherwise to avoid damage from holding the seedlings in a crowded condition.

In harvesting, the plants are cut just above the soil surface with a short-blade knife. Sometimes they are trimmed and packed in the greenhouse as they are harvested. However, most large establishments are equipped with washing and packing sheds, and then only the spoiled, dirty outer leaves are removed in the greenhouse. The plants are placed in containers and taken to the shed where they are trimmed, washed, and packed for market (fig. 9).

The washed plants are packed wet, as some moisture is required to keep them fresh in transit. If the bottom of the packing containers is tight, holes should be made to permit the escape of the water that collects at the bottom.

There is no established standard container for packing and shipping greenhouse lettuce. Various kinds of packages, baskets, hampers, boxes, and barrels have been used. Rectangular splint baskets holding about 10 pounds of lettuce are generally used by Ohio growers. Large containers are usually lined with heavy paper. Paper linings afford some protection from freezing when lettuce is shipped in cold weather. The container covers are of paper to prevent wilting of the lettuce before it is placed on the market.

Grades and marketing standards are subject to periodic changes. Information about legal standards can be obtained from the Agricultural Marketing Service, United States Department of Agriculture.

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FIGURE 9.—Harvesting lettuce in bushel baskets for removal to the packing shed, where it is to be trimmed, washed, and packed.

The profit to be expected from a given unit area of greenhouse lettuce depends on many factors—labor, fuel, fertilizer, and other production costs, market demand, quality of the product, and yield. Any estimate of profit that might be expected could only be a rough approximation. About a pound of lettuce per square foot of greenhouse space is considered a good yield. Yield per unit area depends largely on the stage of development at which the crop is harvested. In order to obtain a yield of a pound per square foot of space, the plants must reach near-maximum size before cutting. Market demand and prices may make it more profitable to harvest smaller plants even though the total yield is reduced.

DISEASES AND THEIR CONTROL

Drop

Drop is possibly the most damaging disease of greenhouse lettuce. It is caused by fungi that persist in the soil. The stem is infected at the soil line, after which the leaves progressively wilt and the entire plant eventually collapses. Affected plants show a soft watery rot of the stems and leaves near the soil. The decayed tissues are soon covered with a cottony-white fungus growth, which produces black sclerotia, or seedlike bodies. These are found in or on the decayed leaves and stems, their size depending on the species of fungus present. Sclerotia are resistant to an unfavorable environment and serve to maintain the fungus in the soil.

Drop is particularly apt to cause trouble during damp, cloudy weather. Too high a temperature, improper ventilation, overwatering, and crowding the plants tend to increase losses from the disease. Proper management of the crop, particularly using water sparingly during the 3 or 4 weeks before harvest, helps to check the spread of drop. When the disease appears, remove and destroy affected plants,

including taproots and surrounding soil. This helps to prevent infection of adjacent plants and also the formation of sclerotia. When drop causes severe loss, the best remedy is to sterilize the soil with steam (see p. 8).

Bottom Rot

Bottom rot is destructive in some sections of the country, especially to head lettuce, whose outer leaves rest on the ground. It most frequently occurs as the plants approach maturity. The disease is caused by a soil-borne fungus. Brown spots develop on the midribs and blades of the leaves. This begins at the bottom of the plant and is followed by a brown soft rot that extends into the head. There is a brown fungus growth over the leaves and formation of brown sclerotia.

Excess moisture favors bottom rot, and losses can often be much reduced by using no more water than is essential for satisfactory growth. When this measure is not effective, sterilize the soil with steam (see p. 8).

Gray Mold

Gray mold is caused by a fungus that is most likely to be damaging when plants are weakened by unfavorable growing conditions or by other diseases. It is characterized by a brown soft rot of the leaves, which become covered with a grayish mass of fungus growth. When plants are severely damaged, black sclerotia may be produced.

Gray mold often follows tipburn, as the fungus readily attacks the dead areas caused by tipburn at the leaf margins. Ample ventilation and soil sterilization with steam (see p. 8) help to prevent or delay the development of gray mold.

Downy Mildew

Downy mildew is characterized by yellowish or brownish spots on the outer leaves. The lower surface of the leaves becomes covered with a white fuzzy growth of the causal fungus.

Insufficient ventilation, overwatering, and fluctuating temperatures favor the development of downy mildew. Careful management of the greenhouses, particularly the avoidance of high humidity, is usually effective in controlling this disease.

Anthracnose

Anthracnose, also known as shot hole or rust, is caused by a fungus that produces reddish-brown roughly circular spots on the leaves. The centers of the older spots often drop out and give a shot-hole appearance. On the midribs the spots are narrow and slightly sunken. The fungus lives on infected plant refuse and its spores are water borne.

Low temperatures and overwatering favor this infection, especially when water is applied as a coarse spray that spatters soil on the plants. Plant losses can be reduced by using water sparingly. Apply it as a fine mist, as a slow stream from a hose, or by subirrigation to avoid spattering soil on the leaves.

Rosette

Rosette causes considerable losses of greenhouse lettuce. This disease and bottom rot are caused by the same fungus, which attacks the plants when they are small. Rosette is characterized by a decay of the roots that stunts the plants, especially when they have been badly set, improperly fertilized, or grown on poor soil.

Good growing practices help to reduce loss, but soil sterilization (see p. 8) may be necessary if the disease persists.

Tipburn

Head lettuce and, to a less extent, leaf lettuce are subject to tipburn. This nonparasitic injury causes the margins of the leaves in the central part of the plant to turn brown and die. The dead areas rarely extend more than one-half inch from the edge of the leaf.

Tipburn is most prevalent when temperatures are high and the plants are making a rapid succulent growth. It often occurs after a few cloudy days when the greenhouses are kept at rather high temperatures with inadequate ventilation. Slightly lower temperatures than normal and adequate ventilation will reduce losses from tipburn during the winter. When outside temperatures are high during the fall and spring, care in the use of nitrogenous fertilizers, watering, and ventilating will help to maintain a firm growth of leaves and hold the disease in check.

Root Knot [2]

Root knot has never been considered particularly destructive to greenhouse lettuce, but it must be controlled to obtain the best lettuce yield. During the winter, lettuce greenhouses are usually kept at such a low temperature that the disease remains dormant and does no damage, but during the warmer weather of fall and spring root knot may cause serious injury. It is very injurious to both cucumbers and tomatoes, and when one or both of these vegetables are rotated in the greenhouse, the disease should be controlled.

Steam sterilization of the soil is an effective control measure if done carefully and thoroughly. The microscopic nematode, or eelworm, causing this disease works down to a depth of a foot or more and penetrates under walks and side walls. Satisfactory control cannot be expected unless the soil is heated to at least 212° F. and to a depth of at least a foot.

INSECT PESTS AND THEIR CONTROL

Greenhouse lettuce is subject to injury by a variety of insects and related pests. Those most commonly encountered are aphids, caterpillars, the greenhouse whitefly, the two-spotted spider mite, slugs, snails, sowbugs, and the garden symphylid. These pests frequently cause serious damage to the lettuce crop. Try to prevent infestations and apply control measures when these pests appear.

[2] Prepared by A. L. Taylor, nematologist, Crops Research Division.

Prevention of Infestations

A good sanitary program is important in preventing infestations. Outside the greenhouse provide a clean strip free from weeds and crops that may harbor pests of lettuce. In the greenhouse eliminate trash and plant debris to prevent breeding and hiding places of these pests. If possible, grow transplants in a separate house free from pests so as to start with clean plants.

After harvesting a crop, apply a 10-percent parathion aerosol at 1 pound of solution per 25,000 cubic feet of greenhouse space to keep the greenhouse free of insect pests for a new crop. After applying the aerosol, keep the greenhouse closed overnight for maximum results. Fumigation with calcium cyanide at 4 ounces per 1,000 cubic feet of greenhouse space is also effective.

Precautions in the Use of Insecticides

Insecticides are poisonous. Handle them with care. Follow the directions and heed all precautions on the container label.

When handling or mixing concentrated insecticides, avoid spilling them on your skin and keep them out of your eyes, nose, and mouth. If you spill any on the skin or clothing, wash it off and change your clothing immediately. Wear a respirator and goggles when you are working with concentrated sprays or dusts.

Many insecticides can be absorbed directly through the skin in hazardous quantities. In applying them, try to keep them off your skin and away from your eyes, nose, and mouth. When you have finished using them, wash all exposed surfaces of the body with soap and water. Change your clothing if you have spilled any insecticide on it.

Parathion, TEPP, and calcium cyanide are extremely poisonous. They should be applied only by a person thoroughly familiar with their hazards and one who will assume full responsibility for safe use and comply with all the precautions on the labels.

Store insecticides in closed containers in a dry place where children, irresponsible persons, and animals cannot reach them.

Aerosols usually contain the poison gas methyl chloride. Regardless of the insecticide in these aerosols, they should be applied only by a trained operator who will enforce the precautions prescribed by the manufacturer and assume full responsibility for safety.

Do not use parathion on lettuce within 21 days or TEPP within 3 days before harvest. Do not use malathion within 10 days or nicotine sulfate within 7 days before harvest. Do not apply DDT to lettuce after the leaves to be marketed or eaten appear.

Aphids

Three species of aphids, or plant lice—foxglove aphid, green peach aphid, and potato aphid—are common pests of greenhouse lettuce. These insects are readily controlled with a parathion or malathion

aerosol, except in plots or benches of dense foliage. TEPP is then the most effective insecticide. Use a 10-percent parathion or malathion aerosol or a 5-percent TEPP aerosol at the rate of 1 pound of solution per 50,000 cubic feet of greenhouse space. One application is usually adequate. Malathion may also be applied to the foliage in wettable-powder or emulsion sprays. Use 1 pound of malathion per 100 gallons of water. Nicotine sulfate is also effective when applied to the foliage in a spray containing 1 quart of the 40-percent solution per 100 gallons of water.

Caterpillars

The caterpillars attacking lettuce include the armyworm, cabbage looper, and cutworms. These insect pests may be controlled with a 10-percent malathion or parathion aerosol applied at the rate of 1 pound of solution per 50,000 cubic feet of greenhouse space. Malathion may also be applied in a spray as for aphids. A 3-percent DDT dust is effective when applied to the foliage, but it should not be used after the leaves to be marketed or eaten appear.

Greenhouse Whitefly

The greenhouse whitefly is a common pest of greenhouse lettuce. It sucks the juices from the leaves. Infested plants become yellowish green and often stunted.

These insects may be controlled with a 10-percent parathion or malathion aerosol at the rate of 1 pound of solution per 50,000 cubic feet of greenhouse space. Repeat this treatment 2 to 3 times at 2-week intervals or until satisfactory control is obtained. Malathion may be used in a spray as for aphid control. A 5-percent TEPP aerosol is effective when applied at the rate of 1 pound of solution per 50,000 cubic feet of greenhouse space. Repeat this treatment every 5 days for 4 to 5 weeks.

Two-Spotted Spider Mite

The two-spotted spider mite is often troublesome. It feeds on the undersurface of the leaf and produces a chlorotic condition. In extreme cases the plants may be stunted or even killed.

Apply a 10-percent parathion or a 5-percent TEPP aerosol at the rate of 1 pound of solution per 50,000 cubic feet of greenhouse space. Two or three applications of the parathion aerosol at 7- to 10-day intervals are necessary to destroy an infestation. Repeat the TEPP treatment at 5-day intervals until the infestation is controlled.

Slugs, Snails, and Sowbugs

The presence of slugs and snails is revealed by their trail of slime, as well as feeding injury. They feed at night and hide by day under pots, benchboards, flats, or dense foliage.

Effective baits on the market usually contain metaldehyde with 2 percent of calcium arsenate or 5 percent of chlordane. Sprinkle the bait between the plants, or place about a teaspoonful in a pile at in-

tervals. Two or more applications may be required, as the slugs and snails may not feed every night but rest for several days between feedings. Use extreme care in applying these baits. Do not apply them to the foliage or excess residues may be left on the marketed crop.

Sowbugs feed at night or on cloudy days and hide by day under pots, boards, or trash. Apply a 3-percent DDT dust to the soil for effective control.

Garden Symphylid

Garden symphylids are present in the loose soil high in organic matter that is found in most greenhouses. They feed on the roots and do the most damage to young plants.

Soil sterilization (see p. 8) is the recommended method of control. First moisten the soil so that the symphylids will congregate near the surface, heat to 180° F., and hold at this temperature for 4 hours. The method most used in vegetable greenhouses makes use of buried lines of drain tiles spaced about 18 inches apart and connected by headers. Steam at 15 pounds' pressure is introduced into the headers. Suitable covers of plastic or special paper over the soil help retain the steam and insure sterilization of the soil surface. They also aid in getting heat penetration to the maximum depth. Sterilization by the inverted-pan method will destroy garden symphylids in raised benches.

LIST OF SCIENTIFIC NAMES

Fungi That Cause Diseases of Greenhouse Lettuce and Insects That Attack It

DISEASES

Common name	*Causal organism*
Anthracnose	*Marssonina panattoniana* (Berl.) Magn.
Bottom rot	*Rhizoctonia solani* Kuehn
Downy mildew	*Bremia lactucae* Regel
Drop	*Sclerotinia sclerotiorum* (Lib.) DBy. and *S. minor* Jagger
Gray mold	*Botrytis cinerea* Pers.
Rosette	*Rhizoctonia solani* Kuehn

INSECTS

Common name	*Scientific name*
Armyworm	*Pseudaletia unipuncta* (Haw.)
Cabbage looper	*Trichoplusia ni* (Hbn.)
Foxglove aphid	*Myzus solani* (Kltb.)
Garden symphylid	*Scutigerella immaculata* (Newp.)
Green peach aphid	*Myzus persicae* (Sulz.)
Greenhouse whitefly	*Trialeurodes vaporariorum* (Westw.)
Potato aphid	*Macrosiphum solanifolii* (Ashm.)
Two-spotted spider mite	*Tetranychus telarius* (L.)

U. S. GOVERNMENT PRINTING OFFICE: 1958