VEGETABLE FORCING

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BY

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TO MY MOTHER

MY FIRST TEACHER
IN VEGETABLE GARDENING

PREFACE

Vegetable forcing occupies an important place in American horticulture. The subject is taught to large numbers of students, and it has enlisted the interest of thousands of gardeners who are attracted by the idea of growing vegetables under artificial conditions. To meet the needs of these two groups of people has been the constant aim of the author.

The treatise is necessarily condensed. It has not seemed expedient to enter into a lengthy discussion of subjects naturally belonging to the entomologist, plant pathologist, botanist or chemist. This would necessarily result in the overlapping of college courses and in trying the patience of practical growers who want merely a working knowledge of the principles and practices involved in the production of the various forcing crops.

Frequent visits have been made to the most important vegetable forcing centers of the United States. Many bulletins of the agricultural experiment stations and of the United States Department of Agriculture have proved to be of great value as sources of information. Special mention should be made in this connection of the *Market Growers' Journal*, and of courtesies extended by its manager and editor, Sam W. Severance.

The preparation of the manuscript would not have been possible without the assistance of scores of friends. Extensive correspondence was conducted with numerous growers, teachers and investigators, and I desire to thank all of these friends for their most valuable co-operation.

The author is particularly indebted to Prof. J. R. Bechtel of The Pennsylvania State College, and to Prof. C. W.

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Most of the illustrations were made by the author upon visits to commercial establishments, and we gratefully acknowledge the courtesies extended in this connection by a large number of growers, including M. L. Ruetenik, Cleveland, Ohio; Searles Brothers, Toledo, Ohio; Chauncey West, Irondequoit, N. Y.; Dunbar and Hopkins, Ashtabula, Ohio; J. H. Rice, Ashtabula, Ohio; R. Hittinger, Belmont, Mass.; Wyman Brothers, Arlington, Mass.; F. J. Zuck, Erie, Pa.; W. H. Weinschenk, New Castle, Pa.; H. H. Mishler, Johnstown, Pa.; and others.

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CHAPTER I

A GENERAL VIEW

Vegetable forcing is an important branch of vegetable gardening or olericulture. It relates to the growing of vegetables to maturity or to edible size in greenhouses, hotbeds, coldframes, or other special structures. The cultural conditions are usually artificial throughout the growing period, although there are exceptions, as when lettuce is planted in frames during the spring season and the glass dispensed with for a few weeks previous to the harvesting of the crop. Of the various branches of olericulture, vegetable forcing is the most intensive and the most highly specialized. The cultural conditions must be created and kept under absolute control, in order that the best results may be realized. Because of this possibility, vegetable forcing is often regarded as the most certain or most reliable branch of vegetable gardening.

The history of vegetable forcing in the United States began with the use of hotbeds by the pioneer gardeners. Hotbeds were employed mainly for the starting of the early plants, although growers found it profitable to mature some crops, especially lettuce and radishes, in hotbeds heated by manure. Previous to 1880 very few greenhouses were devoted to vegetable forcing, and their use for that purpose at all was very infrequent until 1888. The first houses were low and narrow—mere toyhouses as compared with our modern structures covering acres of ground. Houses 11 feet wide and about 100 feet long were common, and later some were built that measured 20 or 22 feet in width and more than 100 feet in length.

Vegetable forcing, however, was not of great commercial importance until after 1890, and the industry has made its greatest and most rapid development since 1900. In 1894, Taft called attention to a house near Arlington, Mass., which up to that time was probably the largest ever erected for the forcing of vegetables. It was 33 feet wide, 370 feet long, and covered nearly one-third of an acre. In 1912 a range of the ridge and furrow type that covered 10 acres was completed at Toledo, Ohio.

Three men were particularly prominent in connection with the early history of vegetable forcing. No one did so much to encourage the growing of crops in frames and in inexpensive greenhouses as Peter Henderson. He taught both by example and by writing, and his books are so practical that they are still greatly prized by vegetable growers. In New England, W. W. Rawson exerted a great influence on greenhouse production. He was one of the first to construct greenhouses for the forcing of vegetables, and he was especially prominent because he built and advocated the building of greenhouses of larger proportions than were known previous to 1894. His writings were also valuable in promoting the industry.

In the West, Eugene Davis has been one of the most prominent figures in this industry. He has been the leader at Grand Rapids; his first houses were built in 1876 and others were added to his range as market demands increased. These were probably the first vegetable forcing houses built in the Middle West. For many years, Grand Rapids supplied practically all the greenhouse produce that was consumed by the large cities of the Middle West. Mr. Davis is best known as the originator of the famous Grand Rapids lettuce and the Davis Perfect cucumber.

Prominent sections.—Boston occupies first place in the commercial importance of its vegetable-forcing interests. Most of the houses are located in suburban towns, Arlington and Belmont being the most important. In 1912, there were 16 establishments of two acres or more, and some of the ranges covered four acres of land. This district then had about 60 acres of glass devoted exclusively to vegetable forcing.

There are more acres of glass devoted to this industry in Ohio than in any other state. In 1912 Toledo had about 40 acres under glass, one of the ranges covering 10 acres; Cleveland had about 25 acres and Ashtabula probably an equal area. There are large houses at Newark, Columbus, Cincinnati, Lancaster and many other smaller cities and towns. It is estimated that, in 1912, about 140 acres of glass were used in Ohio for the forcing of vegetables. Greenhouse building has been active in some of these sections since the 1912 estimates were made.

Although there are some spacious houses at various places in Michigan, Grand Rapids is the most important center. This district had from 35 to 40 acres of vegetable-forcing houses in 1912, and one establishment covered over four acres of land.

Irondequoit, New York, is well known for its large number of houses of medium size. No establishment in this district contains more than four acres, and most of the ranges cover less than one acre. There were 65 houses in 1912 within a radius of three miles, and they included a total area of about 25 acres, so that the average is less than one-half of an acre. They are almost invariably operated in connection with market gardens, and are of great value in the starting of early plants.

There are many vegetable-forcing establishments in Pennsylvania, although less progress has been made there than in several other states. The industry is most prominent at New Castle, Erie, Altoona and Kennett Square.

In Illinois there are large ranges at Chicago, Aurora, Streator, Morrison and other points. There are many extensive establishments in Indiana, Iowa, Minnesota, New Jersey and other states. There are also large vegetable-forcing establishments in Canada.

The hotbed and frame industries of the country should also be considered in this connection. All along the Atlantic Coast, and in many trucking sections of the South, hundreds of acres are covered with sash or protecting cloth, and used in forcing vegetables for market.

Importance of vegetable forcing.—The value of frame and greenhouse-grown vegetables in the United States amounts to millions of dollars annually. The importance of the industry from the commercial standpoint can scarcely be overestimated. There are other considerations, too, which should not be overlooked. Among them are: (1) Better facilities with which to start early vegetable plants for outdoor culture; probably 90 per cent of our greenhouse vegetable growers are also market gardeners or truckers. (2) The possibility of keeping in touch with one's patrons between the summer seasons. (3) The ability to give employment during the winter to the most satisfactory employees. (4) The increased pleasures of rural life during the winter by creating summer conditions on a small part of the farm.

Types of vegetable forcing.—There are five rather distinct types of vegetable forcing, namely: (1) By the use of manure-heated hotbeds. This is the oldest type used in the United States, and it is still practiced to some extent by commercial growers. Its chief value, however, is for the farmer and village gardener who desire a continuous supply of fresh vegetables for their own tables.

(2) By the growing of crops on a large commercial scale in frames heated by steam or hot water, or merely covered with glass or protecting cloth. This type of forcing is especially important in southern gardening districts.

(3) By the growing of vegetables for the home table by people who can afford to operate greenhouses solely

for this purpose. This phase of vegetable forcing will become more and more important as the wealthier classes become acquainted with the superiority of greenhouse products.

(4) By erecting small greenhouses, primarily for starting early vegetables for outdoor planting, which are large enough to yield a profit in the forcing of vegetables when the space is not otherwise in demand.

(5) By the construction of very large ranges for the sole purpose of growing and maturing vegetables out of season. The owners of many of the largest establishments are also market gardeners, who utilize a small percentage of the greenhouse space for the starting of early plants.

Organization.—The vegetable-forcing interests of the United States are fairly well organized. In 1908 the Greenhouse Vegetable Growers' and Market Gardeners' Association of America was organized at Cleveland, Ohio. A few years later the name was changed to the Vegetable Growers' Association of America. While the society has for its object the promotion of all types of vegetable gardening, the forcing interests have received much attention because many of the members have been prominent growers of vegetables under glass. This organization is one of the strongest horticultural societies in America, and it is exerting a strong influence upon the development of vegetable forcing.

The widest field for organization, however, is in the development of co-operative associations. These have been formed in many of the most important forcing centers, and it is hoped that the movement will continue until every district is organized.

The following are some of the advantages or benefits of co-operation: (1) Educational. The strongest associations hold regular meetings, in which methods are discussed and the entire industry considered. (2) One of the marked advantages is in the selling of produce. A shrewd business man can attend to all sales. To obtain the best prices he must be constantly informed of crop conditions in competing sections, and he must have a thorough knowledge of the problems relating to distribution. If all greenhouse sections were properly organized and affiliated with a general organization, market slumps would rarely occur. (3) Supplies, such as greenhouse-building materials, pipe, tools and fertilizers, may be purchased at lower cost because of larger orders. (4) Each community might work to advantage through its organization in the production of well-bred seed. This would be especially valuable in obtaining greater uniformity of the products offered for sale. (5) Organization promotes uniformity in the packages used, and also more thorough and skillful grading and packing. (6) If the produce is sold through a general manager, the grower is relieved of the worry, trouble and responsibility of finding a market, and is thus permitted to devote all his energy to production. (7) Fraternal advantages. Growers are brought closer together and the community enjoys a more delightful fellowship than is possible when neighbors are constantly competing with one another in business matters.

Southern competition is unquestionably the most serious obstacle to the development of vegetable forcing in the North. There are times when southern-grown lettuce, cucumbers and tomatoes are rushed to the great markets in such enormous quantities that northern greenhouse growers are forced to sell their products at very low prices. These periods of depression occur almost every year and are barriers to the extension of the forcing industry; the result is to make greenhouse building in the various sections rather spasmodic. For example, Boston, in 1910, built no houses for vegetable forcing because of the two discouraging previous seasons, when

Florida sent immense quantities of head lettuce to Boston and other markets of the Boston growers. Mishaps in the Florida fields since 1909 have improved market conditions for head lettuce in the East, so that greenhouse building about Boston was a few years later more active. The western growers have also felt the keen competition of southern gardeners; notwithstanding this fact, there has been a very large increase of the glass area in most of the Middle States in recent years.

The superior quality of greenhouse vegetables is becoming more generally recognized every year, and this is the factor that assures the successful grower of at least reasonable profits. The southern field-grown vegetables sometimes find their way to the garbage disposal plants, while the better products of the greenhouses are sold, though the prices may be very low. There can be no discounting the fact that tomatoes, fully ripened on the plants in the greenhouse, are far superior in quality to the field-grown specimens picked green or only partially ripe, and held for days in transportation and by a long line of middlemen before arriving at the consumer's table. Similar statements might be made regarding other important forcing crops.

Above all, it behooves the greenhouse grower of vegetables to bear in mind that high quality is the first consideration if he is to make a financial success of his enterprise, and no effort should be spared which will contribute to that end. The choice of good varieties, seed selection, proper cultural methods, rigid grading, skillful packing and prompt marketing, all count for high quality, and high quality counts for high prices.

Economic production.—Greenhouse growers of vegetables usually meet with competition from two sources: First, from those who are forcing crops under artificial conditions; and, second, from cultivators who are producing under the natural conditions of the field, but are handicapped by transportation charges and other difficulties. In order to meet the competition of both classes it is necessary to use every possible means to maintain a low cost of production. Greenhouse growers have succeeded remarkably well in this respect, and nothing has contributed so much to the advancement and extension of the industry.

Various factors enter into this problem, the following being the most important: (1) Durable and substantial greenhouses of semi-iron frame construction at moderate cost. (2) The elimination of benches, concrete beds or other fixtures, which increase the cost of construction and maintenance, interfere with tillage, handling of manures and the general management of the house. (3) Improved systems of heating and ventilating. (4) Overhead watering, which reduces the cost of labor for this operation to a minimum. (5) Better facilities for harvesting and marketing greenhouse crops. (6) Larger greenhouses. The cost of growing 100 pounds of lettuce in a house covering one-tenth of an acre is necessarily greater than in an acre or a five-acre range. (7) Soil sterilization and better sanitation have made possible the use of the same soil indefinitely, the heavy expense of making frequent changes of the soil being thus eliminated. (8) Improved varieties adapted to greenhouse culture have done much for the industry. (9) Proximity to market, railroad, and supplies of manure and coal. (10) A trained and regular force of employees.

Capital required.—The capital required to engage in the vegetable-forcing industry depends upon conditions which are so variable that it is difficult to give estimates of definite value. The cost of a good semi-iron form of greenhouse construction for an acre is approximately $20,000, although such houses have been constructed for several thousand dollars less than that sum; two acres of land in the suburbs of a good market would probably cost

$1,000; horse, harness and wagon, $300; tools and equipment, $100; manure, $100; operating capital, $800; total, $22,300.

Starting on a smaller scale, say 10,000 square feet of house space, the requirements might be estimated as follows: Cost of house, $5,000; one acre of land, $500; horse, harness and wagon, $300; tools and equipment, $75; manure, $25; operating capital, $200; total, $6,100. Men have started in the greenhouse business with much less capital, especially when extra land was available for market gardening. It is not desirable, however, for any man to start in the business seriously handicapped by insufficient capital.

Profits.—Definite statements regarding the profits of any industry, especially along horticultural lines, are usually more misleading than helpful. Some growers have succeeded in paying for their greenhouses in a remarkably short time, from the profits of their crops, while others have absolutely failed to realize satisfactory profits. In this respect vegetable forcing is not unlike other branches of olericulture—the man being the most important factor in the achievement of success. The enterprise, however, certainly compares favorably with other lines of horticulture, floriculture not excepted. Greenhouse vegetable growers, as a class, are prosperous, and the rapid expansion of their ranges speaks well for the profits of the industry.

Location.—Most men now engaged in this industry did not deliberately seek the best conditions for the growing of crops under glass, but they simply concluded that the land which they already owned was sufficiently well located to enable them to realize a profit. The result is that some establishments are advantageously located, while others are producing under the most unfavorable circumstances.

When it is possible to select a location for the express purpose of vegetable forcing, the following considerations should receive attention:

(1) Cost of fuel. The coal bill is usually the heaviest item of expense, although the labor sometimes costs more. Growers in the bituminous regions sometimes obtain coal at the mines for a dollar or less a ton. This is remarkably cheap fuel and materially lowers the cost of production when compared with establishments that must pay from $3 to $6 a ton. It is sometimes claimed that our great commercial greenhouse plants should be located at the mines, so that there would be no drayage or transportation charges of any kind, so far as fuel is concerned, and this view of the problem is worth considering. It is largely a question, however, whether the freight charges on a ton of coal from the mines to the greenhouse, the latter located presumably at the market, will exceed the express charges on the vegetables produced by a ton of coal, in conveying them from the mines to the market. In most instances, however, the advantage of being near a good local market much more than offsets the disadvantage of transporting coal long distances.

(2) Transportation facilities. Unless located within driving distance of the market, the greenhouse should be easily accessible by railroad. Many of the largest establishments are located near railroad centers, where competition secures more reasonable freight rates and several large markets are easily reached. Electric lines often afford cheap and satisfactory transportation.

(3) A large, nearby market is always a great advantage. Growers who sell from the wagon obtain higher average prices than those who must make consignments to city dealers.

(4) Although many successful greenhouses are located on heavy soils, the sandy types are preferred.

(5) There must be an ample supply of water. The evaporation of moisture from soil in a greenhouse, during

the spring and early summer months, is enormous. It is then necessary to apply water every day, and sometimes twice a day. If the greenhouse covers an acre of ground, 26,963 gallons of water will be required to equal the quantity that would be applied by an inch of rainfall.

(6) It is impossible to grow greenhouse crops successfully without a liberal supply of manure. Some vegetable forcers use 30 to 40 tons annually to the acre. The supply should be within easy reach, and the cost reasonable.

(7) Labor should be easily obtainable. Vegetable forcing is an all-year proposition, a fact which simplifies the problem of securing and keeping the necessary help.

(8) A clear atmosphere, free from the smoke of factories and railroad trains, is essential to success.

Climatic influences.—Although the grower of greenhouse vegetables is able to create proper conditions for plant growth, yet he is at the mercy of climatic influences to a great extent, and these should also be considered in the selection of a location. An abundance of sunshine is of prime importance because it reduces the amount of fuel required, accelerates growth, increases yields, shortens the time required to mature a crop, and decreases the ravages of disease. Sunshine is particularly important in furnishing favorable conditions for pollenizing the flowers of fruit-bearing plants, such as the tomato, pepper, eggplant and cucumber.

Southern sections have a greater percentage of sunny days during the winter season than has the North. Furthermore, fuel consumption depends upon the duration of the firing period and the severity of the weather. Here, the South again has the advantage over the North. Other disadvantages, however, have seemed to give northern locations the preference in the production of greenhouse vegetables for their own markets. As previously stated, the frame industry in the South is very important, owing to a milder climate, and there is now some evidence that greenhouses will be used more extensively in the Middle South in growing products for northern markets.

Relative importance of forcing crops.—Lettuce undoubtedly occupies first place in commercial importance. It is grown extensively as a frame crop, and is the leader in nearly all large forcing establishments. The cucumber ranks second and the tomato third, although the tomato is more important in some sections. The radish ranks fourth and cauliflower fifth. Rhubarb, asparagus, beet, pepper and eggplant are grown to some extent and the bean, pea, onion, muskmelon, asparagus, witloof chicory, carrot, cress, mints, parsley, spinach, celery, and a few other vegetables are of minor importance.

The outlook.—The outlook for vegetable forcing was probably never better than at present. The demand for high-grade vegetables is on the increase, and consumers want them the year round. People are asking for the best, and the best grows in forcing structures. While prices are low at times, they average just as high as they did several years ago.

Growers are better able to meet southern competition. Modern methods of greenhouse construction are favorable. Vegetable forcing appeals to many people because the returns are so prompt. A house completed the middle of October, and planted at once with strong, frame-grown lettuce plants, will yield a crop for Thanksgiving and two more lettuce crops before cucumbers or tomatoes are planted for spring and summer market. With successful management and good prices, the cost of construction is soon covered, but a certain amount of conservatism on the part of greenhouse vegetable growers is highly desirable. It is better not to make large extensions in the ranges unless the results assure a satisfactory outlet for the increased production.

CHAPTER II.

GREENHOUSE CONSTRUCTION AND HEATING

The purpose of this chapter is to discuss the principles of greenhouse construction and heating. The details may be found in special books, and in catalogs of manufacturers.

Greenhouses vs. frames.—Frames are admirably adapted to vegetable forcing in the South, but for the conditions of northern latitudes, greenhouses are vastly superior for most purposes to frames. Their advantages are numerous: (1) Heat for forcing purposes can be generated cheaper by the burning of coal than by the fermentation of manure. (2) All cultural conditions may be better controlled or regulated in greenhouses than in frames. (3) The labor expenditure on a given area is usually much less in greenhouses than in frames. (4) Shelter during inclement weather enables the employer of labor to follow a prearranged plan, and to utilize the time of his workmen fully and economically. (5) In the North it is not possible to grow in frames at midwinter such crops as tomatoes and cucumbers. In the vicinity of all northern cities greenhouses are rapidly taking the place of hotbeds and coldframes, not only for the forcing of vegetables, but also for the starting of early vegetable plants. Hotbeds and coldframes, however, have an important place in the vegetable forcing industry, and their uses are discussed on page 387.

Site and position of house.—Any protection that can be afforded by trees, hills, buildings or special windbreaks, without shading the house, will reduce the consumption of fuel and aid in saving the structure from damage by hard windstorms. It is advantageous to build on level land, although gentle slopes are not objectionable.

The position of the house with reference to the points of the compass has long been a question of argument. Many experienced growers positively claim that it makes no difference whether the house runs east and west or north and south. Houses running east and west admit more sunlight during the short days of the winter, while light distribution is more uniform in those running north and south. The majority of vegetable forcers, especially growers operating three-quarter-span houses, probably prefer buildings running east and west. Many growers

Fig. 1.—A modern range of houses at Toledo, Ohio.

in the West prefer north and south houses because of the greater comfort in working in them in hot weather.

Grading the land generally reduces the cost of construction, and always makes the work in the daily care of crops more convenient. Water is more evenly applied when the land is comparatively level, and uniform temperatures in all parts of the range are more easily maintained.

Size and proportions.—Large houses have many advantages. They are heated more economically, and the cost of operation is less than in a series of small houses of equal area. As previously stated, it is not uncommon to find single houses covering an acre or more of land, and there are a few ranges (Fig. 1) that cover from 4 to 10 acres of land.

Houses vary greatly in width. The majority of the oldest houses range from 9 to 12 feet wide. The even, connected ridge and furrow type, so common in the West, varies from 15 to 18 feet wide. Numerous commercial houses are from 20 to 24 feet wide. The 27-foot standard house of the West has many advocates, and its width is considered by some of the experienced growers the maximum for best results.

In New York, New Jersey and Pennsylvania 30 to 34-foot houses are common, while Boston inclines toward the 40-foot three-quarter span. (Fig. 2.) Much wider

Fig. 2.—Typical three-quarter-span houses of the Boston district.

houses than these have been built and used for vegetable forcing. There is, at New Castle, Pa., a hillside three-quarter-span house (Fig. 3) that is 120 feet wide; and a house of similar form, built on level ground, at North Wales, Pa., that measures 172 feet in width. These are very unusual structures.

Wide houses should be considered with special reference to economy of heating. In actual practice the air in a wide house with greater height cannot be changed as often in a given period as that in two or more narrow houses covering the same area; furthermore, there is not so much air to be re-heated. The large house, therefore, requires less radiating surface and less fuel.

The length of the house is not of great consequence, although unusual length should be avoided. Most of the largest houses vary from 200 to 600 feet in length. Two hundred feet is probably the maximum which can be heated satisfactorily with the gravity system of hot water, but with forced circulation the largest ranges may be heated economically with hot water.

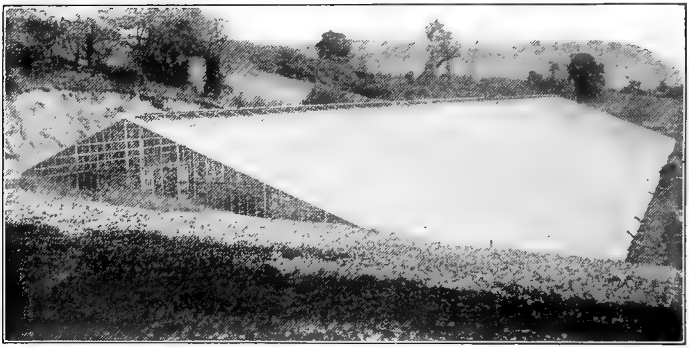

Fig. 3.—Two-acre, three-quarter-span hillside house near New Castle, Pa.

Commercial houses are built much higher than formerly. For many years it was the belief that to obtain the best results the glass must be near the plants. Successful growers, however, have learned that better crops may be grown in higher houses. The distance from ground to gutter varies from 5 to 9 feet in the large modern houses, 6½ feet probably being the most popular height. There must be ample room for the training of plants and, in connected ranges, for workmen to walk from house to house without striking their heads on the gutters. High houses make it possible to provide free ventilation without subjecting the plants to cold drafts or causing great fluctuations in temperature. On the other hand, great height increases the cost of construction, and renders more difficult painting and repairing.

Materials.—Efficiency and durability should be the chief aims in the construction of greenhouses, and these can only be attained by the use of the best materials. It is false economy to buy cheap lumber, poor pipe, inferior glass or low-grade materials of any kind. In bench construction, however, pecky or worm-eaten cypress, because of its relatively low cost, may be employed to advantage.

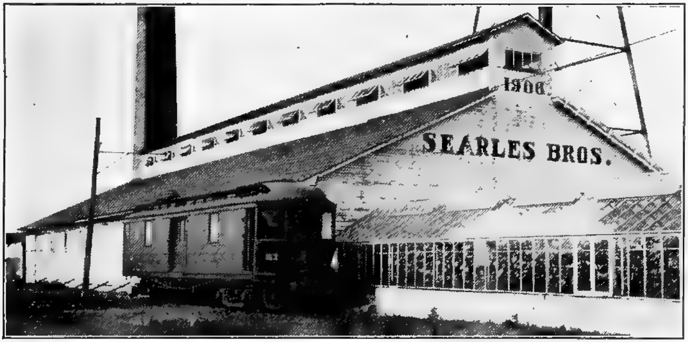

Fig. 4.—Boiler room and packing house of a ten-acre range near Toledo, Ohio.

Arrangement of houses.—Houses should be arranged with special reference to the boiler room and the workroom. The boilers should always be centrally located. This is especially important if the gravity system of hot water heating is used. A centrally located packing shed or workroom is equally important. Fig. 4 shows a very satisfactory arrangement. The trolley car is receiving a shipment of cucumbers at the entrance to the packing room. Coal is brought by trolley to the boilers at the other end of this building, and manure to the large ventilators along the sides of the houses. An office adjoins the packing room, and the pumps that supply the water are also located conveniently to the boiler. Wide alleys (Fig. 5) lead from various parts of this mammoth range direct to the packing room. When the products are loaded on wagons there is probably no better arrangement than a low, central building which serves as a driveway, packing shed, office and boiler room, with the greenhouses running out from both sides.

The greenhouses should not be shaded more than necessary by the central building. As a general rule, very wide houses should be separate because they shade each other more than do narrow ones. In the East, where wide houses are most used, it is customary to leave a space of 12 to 16 feet between them. The fact cannot be disputed that wide, separate houses admit the most light, and for that reason they are best adapted to the winter culture of vegetables. Separate houses are well suited to regions where heavy snowfalls occur. Nevertheless, because they are more expensive to construct and to heat, they do not meet with favor in many sections, especially in the West. Separation causes inconvenience in the daily care of the crops. Compact, connected ranges (Fig. 6) are entirely satisfactory under most conditions, especially when lettuce is the main winter crop. Many growers prefer the even-span type of construction with connected houses 30 to 40 feet in width. (Fig. 7.)

Forms of greenhouses.—There are three general forms or types of greenhouses, viz.: (1) Lean-to or half-span, (2) even-span, and (3) three-quarter span. Lean-to houses (Fig. 8) are generally built against the south side of walls or buildings. They were common in the early days of vegetable forcing. They are fairly satisfactory for the growing of a few vegetables for the home table, but should seldom be considered for the growing of crops on a large scale, for commercial purposes. They are inexpensive to erect and economical of fuel, but their limitations with regard to light and sunshine render them

FIG. 5.—WIDE CORRIDOR IN A TOLEDO, OHIO, RANGE.

unsuitable for vegetable forcing, especially during the short days of winter.

Even-span houses (Figs. 6 and 7) are in common use among vegetable growers. In this type of house the roof-bars on both sides of the ridge are of equal length, and are pitched at the same angle. As previously stated, the houses may or may not be connected at the sides, although the tendency is to connect them. Even-span houses are preferred by many growers.

Although uneven-span houses are popular in some sections, they are not used so generally in vegetable forcing

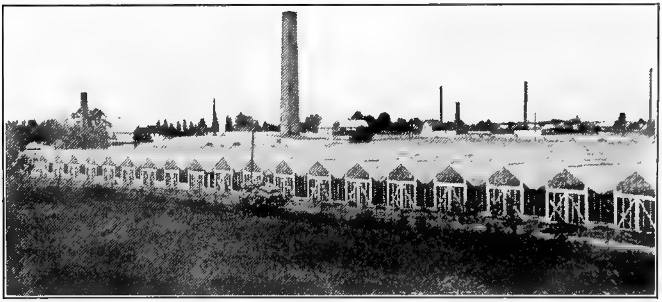

Fig. 6.—Typical even-span range of narrow units.

as are even-span structures. In this form, the roof-bars on one side of the ridge are longer than those on the other side. These houses usually run east and west; the southern slopes, being longest, admit the most light during the short days of winter. Some growers who produce cucumbers and tomatoes in midwinter claim great superiority for the uneven-span house, and others are doing equally well in even-span houses in which the distribution of light is more perfect. The length of the two spans varies more or less.

The three-quarter span is the most common. It is used almost exclusively in the Boston section (Fig. 2), where

FIG. 7.—EVEN-SPAN HOUSES WITH CONTINUOUS VENTILATORS

cucumbers are produced to a considerable extent in midwinter. Fig. 3 shows a hillside three-quarter-span house at New Castle, Pa. The house is 120 feet wide and 600 feet long. The soil for a distance of 70 feet from the south wall rises three inches to the foot, while the 50 feet of ground on the north side is practically level. This mammoth structure has been highly satisfactory for the growing of lettuce, cucumbers and tomatoes.

Two-third-span houses are used occasionally. Near Chicago and in other western sections what is known as the "standard house" meets with favor. The houses are 27 feet wide and they run east and west. The roof-bars on the north side are 16 feet long, and on the south side 14 feet, so that the northern slope is the longer. This is a radical departure from the three-quarter-span houses of the East. Perhaps the sole purpose of the 14 and 16-foot slopes is to avoid shading as much as possible in these connected houses, for the ridge runs slightly south of the center of the house, and the shadow cast by it during the short days of winter falls in line with the shadow of the north gutter; therefore, only one shadow is cast on the plants in the next house to the north.

It will now be seen that the form of a house is largely a matter of personal preference, and from the results of successful growers it cannot be said that this or that particular type is best adapted to vegetable forcing. Any form of modern construction will, with good management, produce satisfactory crops.

Wood construction.—In the early greenhouses all parts of the frame were made of wood, but in recent years iron and concrete have been substituted, wherever possible, because of their greater durability. If for any reason it seems desirable to use wood throughout, only the most durable should be selected. Cypress is now employed almost exclusively, and with proper care it will last for many years.

FIG. 8.—LEAN-TO HOUSE. NOTE PROTECTED FRAMES.

Semi-iron construction (Fig. 10) is becoming popular in all parts of the country. It provides for concrete walls, iron posts embedded in concrete, iron purlins and purlin supports, iron braces and sometimes iron eaves-plates. The iron may be in the form of pipe, angle irons, or simply flat bars, the form depending upon their function and the cost and preference of the builder. With the best forms of semi-iron construction, decayed wood parts are easily removed and replaced with new parts. When all exposed parts of wood and iron are kept properly painted, the house, with only slight repairs, should last 25 years, and then the renewal of decayed sash bars or other parts

Fig. 9.—A modern steel-frame house. Note large door.

should prepare it for many more years of service. The moderate cost and serviceability of semi-iron construction appeal to commercial growers.

Iron construction (Fig. 9) is the strongest and most durable. In addition to the iron parts used for semi-iron construction, the gutters, wall and side plates are metal, and there are a certain number of iron rafters to support the roof, so that interior posts are unnecessary. Iron construction gives the house greater rigidity, and there is less shading of the plants because of the absence of interior posts. Full iron construction costs considerably more than semi-iron, and this is the only reason why it is not more generally employed.

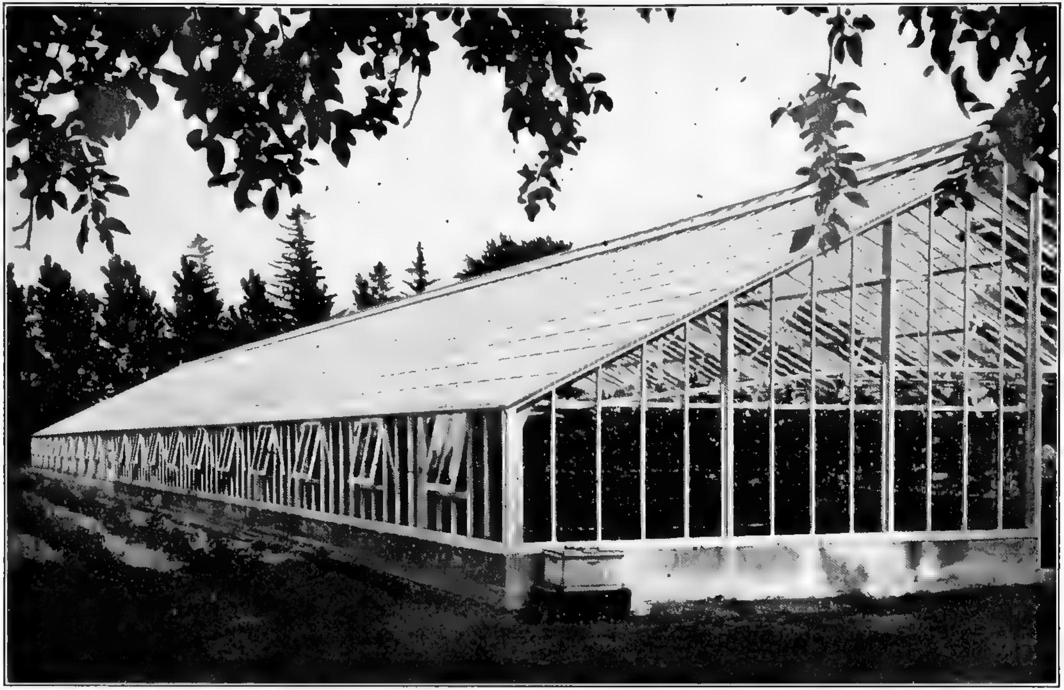

FIG. 10.—A SATISFACTORY TYPE OF SEMI-IRON CONSTRUCTION.

Truss construction.—In recent years the truss form of building (Fig. 11) has received considerable attention from greenhouse men. The trussed construction makes it possible to dispense with interior posts, except in very wide houses, and comparatively small pipe rafters are used instead of heavy, flat, iron rafters that are necessary in full iron-frame houses. The sash bars are also smaller than in other forms of houses, so that every detail of construction is favorable to admitting the maximum amount of light and sunshine. Theoretically, this is the ideal

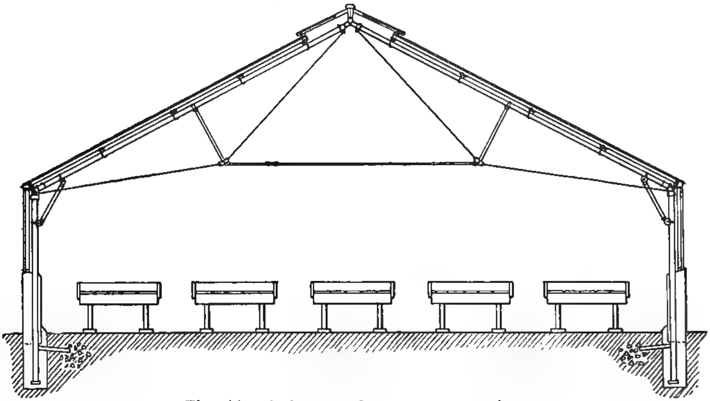

Fig. 11.—A house of truss construction.

house, and it is highly esteemed by many vegetable forcers. On the other hand, some trussed houses have been demolished by snow and storm, and growers are naturally rather reluctant about building houses of this type. It should be said, however, that improvements have been made which add to the strength of the trussed houses, and it is possible that the newer houses will prove entirely satisfactory. Certainly no type of construction could provide better conditions for the culture of winter vegetables.

Walls.—The greenhouse walls should be durable and give adequate support to the superstructure. They should also interfere as little as possible with the admission of light at the sides and ends of the houses. While wood, stone and brick are sometimes used for the walls, concrete is now almost universally employed because of its economy and durability. The wall must have a foundation starting below the frost line—there should be no uncertainty about this matter. For large houses it should be not less than a foot thick at the bottom and 8 to 10 inches at the top, except in types of construction

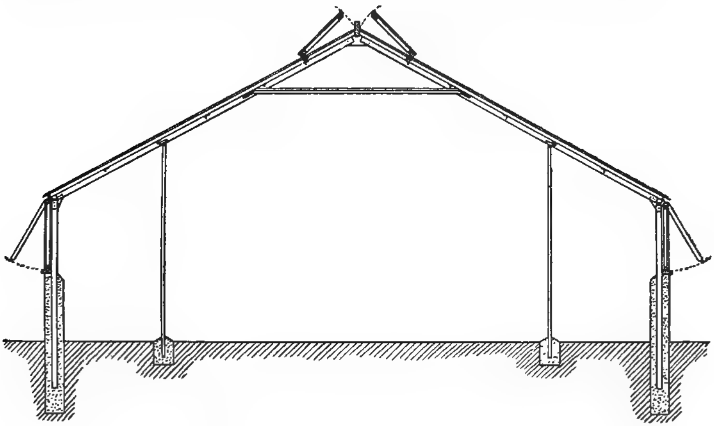

Fig. 12.—Semi-iron construction, showing posts and purlin supports set in concrete.

where practically no weight rests directly upon the wall. The walls in some of the largest houses are only 4 or 5 inches thick, and this may be ample if the structures are well braced and supported in the interior. It is a mistake to build the concrete walls very much above the surface of the ground. A foot is ample in some instances, and it is doubtful if more than 2½ feet should ever be allowed, because the extra height simply adds to the cost of construction, and shades the plants near the sides and ends of the house. In semi-iron construction (Fig. 12) the side

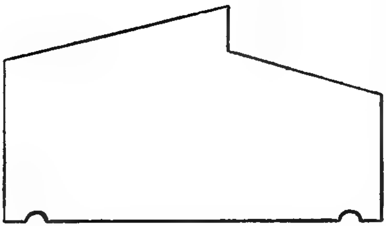

Fig. 13.—A common form of wood wall sill.

pipe posts are set in concrete walls and the posts supporting the purlins are also set in concrete. Glass occupies the space between the top of the wall and the gutter or side plate. Concrete walls are often banked with soil on the outside, to exclude cold. When this is not desired the walls may be given a more finished appearance by applying a thin coat of Portland cement.

Frame.—All wood parts of the frame, including wall plates, eaves-plates, headers, sash bars and ventilating sash, are prepared at the factories, so that the work of erection can readily be managed by a local carpenter or anyone who uses tools efficiently. The same may be said of the iron and truss forms of construction, although they are considered more difficult, and there is greater necessity for the employment of skilled mechanics.

Wall plate or sill.—The size and form of wooden wall sills are quite variable. Different means are used to secure them to the wall, one of the best being 8-inch bolts running through the plates at frequent intervals and embedded in the concrete. The lower end of the bolt may be bent to make it more secure in the concrete, and a burr is screwed on the upper end immediately above the plate. Fig. 13 illustrates a common form of wooden wall sill.

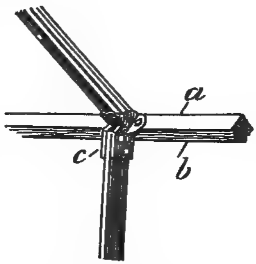

Fig. 14.—Iron eave plate. Note roof bar and post bracket.

The eaves or side plates of separate houses vary greatly in different forms of construction. The angle iron forms of eaves-plates (Fig. 14) are superior to all


Fig. 15.—Wooden gutter.

wooden plates because of their smaller size, durability and efficiency in preventing ice from forming along the eaves.

Gutters are expensive, difficult to keep in repair, and being wider than eaves-plates they cast a larger shadow upon the plants in the greenhouses. Wooden gutters, similar to the one shown in Fig. 15, are in common use. They must be kept well painted in order to prevent rapid decay. Cast-iron gutters (Fig. 16) are more satisfactory than wooden ones, and should be used more generally. They are made in great variety, but drip grooves are essential features.

Sash bars for the roof, sides and ends vary greatly in size and to some extent in shape. Fig. 17 shows typical forms of roof and side bars. The sash bars should be large enough to prevent sagging in any part of the house, but no larger than necessary, because of their obstruction to the light. Their size is largely dependent upon the strength and rigidity of the supporting structure of posts, purlins and braces. The sizes shown in the illustrations are in general use.

Roof.—The roof should not be heavier than necessary to secure proper strength, and it should be built in such a manner that there will be the least obstruction to light and sunshine. The pitch of the roof should receive careful consideration.

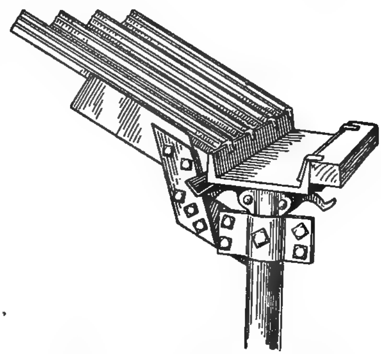
Fig. 16.—Iron gutter with roof bars connected. Also shows connection with iron post.

If too flat there will be danger of leakage, and snow will be likely to collect on the glass.

Light will thus be obstructed and the increased weight may damage the roof. In deciding upon the proper pitch, not only must snow and rain be taken into account, but the builder must bear in mind that the rays of heat and light admitted depend very largely upon the inclination of the roof. Modern greenhouses usually have a pitch of 30 to 32 degrees. A pitch of 30 degrees reflects 8.4 per cent of the sun's rays, and a pitch of 35 degrees reflects 5.7 per cent.

Ventilators.—In modern greenhouse management the houses are in use the year around, for the last tomato or cucumber is picked from August 1 to August 15, and lettuce is often planted early in September; the intervening time is used in cleaning the houses and sterilizing the soil. For the good of the plants and the health and comfort of the workmen, provision should be made for thorough ventilation.

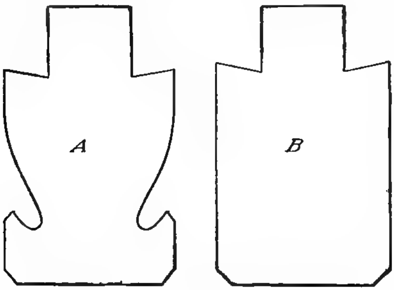

Fig. 17.—(*A*) A typical roof bar (*B*) Typical end bar.

In houses varying from 12 to 18 feet in width it is customary to place only one line of ventilators at the ridge, and this should not open toward the prevailing direction of the wind. In wider houses there should be a line on each side of the ridge (Fig. 18), and it is usually desirable also to have ventilators along the sides as shown in this illustration, although many ranges of mammoth proportions are operated without side ventilators. The size of the ventilating sash will be determined by the size of the house, but they should be amply large.

The ridge ventilators may be hinged to the ridge or to the header. Some growers prefer hinging them at the ridge (Fig. 1), because the sash practically prevent snow and rain from entering the houses, even when the ventilators are open very wide. Other growers prefer hinging at the header (Fig. 18), claiming that to be the proper place because of the fact that the condensed water on the glass of the ventilators runs off instead of forming ice to interfere with the closing of the sash—a frequent occurrence when the sash are hinged at the ridge.

The ventilating sash may or may not be continuous. When the ends of the sash are properly fastened to each

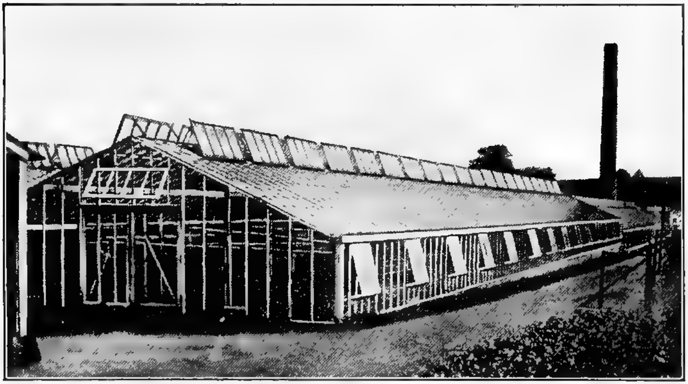

Fig. 18.—Semi-iron house. Note large door and ventilators on sides and end.

other, there should be no difficulty in operating them. A run or two of glass between the sash is preferred by many growers, but continuous ventilators are increasing in popularity. Sometimes ventilators are placed at the ends of the houses, as shown in Fig. 18.

The ventilating machines should be of the most approved type, and conveniently located. It is often best to have them near the doors at the ends of the houses. There are several excellent machines on the market.

Fig. 19 shows a superior type that is used in many houses.

Posts, purlins and braces.—Iron pipe is now used almost exclusively for posts and braces, and extensively for purlins. Advice regarding all details, such as size, distance between the posts and the arrangement of them, should be obtained from the manufacturers furnishing the supplies. Fig. 12 shows a properly supported and well-braced house. The posts should always be set in cement, to prevent the settling of the house and the lifting of the roof by hard winds. Angle iron, instead of pipe, is sometimes used for purlins.

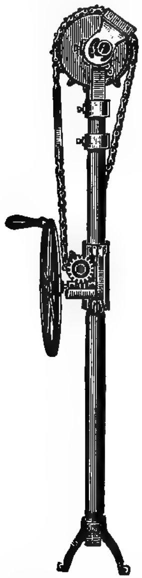

Fig. 19.—A satisfactory machine for operating ventilators.

Doors.—The doors should be made of cypress and amply large to admit carts and wheelbarrows. In extensive houses, at least one door should be large enough to admit wagons, horse carts, plows and harrows. (Fig. 20.) Double doors are perhaps the most convenient and the most serviceable for excluding cold.

Glass.—What is universally known as "A double strength" glass is practically the only kind used by greenhouse builders. Although single thickness admits the maximum amount of light, it should not be used because of the increased breakage by hail, snow and freezing at the laps. The glass should be clear, free from imperfection and of uniform thickness.

There has been much discussion regarding the proper size of greenhouse glass. Originally the panes were very small, 10 x 12 inches being a popular size, but the tendency is to use larger glass: 16 x 24 inches is by far the most popular size. Glass of this size is generally laid with the sash bars 16 inches apart, although a small percentage of vegetable growers lay the glass with the sash bars 24 inches apart. Except in full iron construction, it is doubtful whether the roof-bars should be so far apart, because of the increased breakage by the weight of snow, and the difficulty of making and maintaining tight joints at the laps. There is probably no objection to the bars being 20 inches apart; this distance makes it possible to use 20 x 24-inch glass, which costs only a trifle more than 16 x 24-inch glass.

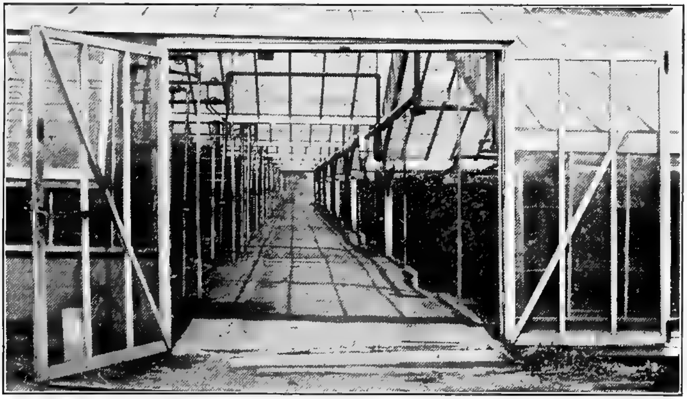

Fig. 20.—A corridor leading to the packing room in a large range.

The greenhouse grower has been quite successful in guarding against losses caused by snow, hard winds and very cold weather, but his houses are at the mercy of destructive hailstorms. To protect him against this loss, hail insurance companies have been organized. One of the leading companies charges 8 cents a 100 square feet of single-strength glass and 6 cents for double-strength. It is just as important for the grower to protect his property from losses by hail as from those by fire.

Glazing.—Greenhouse glass is usually lapped when laid, although it is sometimes butted. The glazing is performed more rapidly when the glass is lapped, and it is much easier to replace broken panes. There is also less leakage when the panes are lapped. The chief objection to lapping is that more or less dirt and soot collect between the laps. Butted glass must be set with very great care in order to make the joints water-tight. A variety of glazing points is on the market.

Previous to glazing, all wood parts of the greenhouse should be primed with one coat of paint. The sash bars

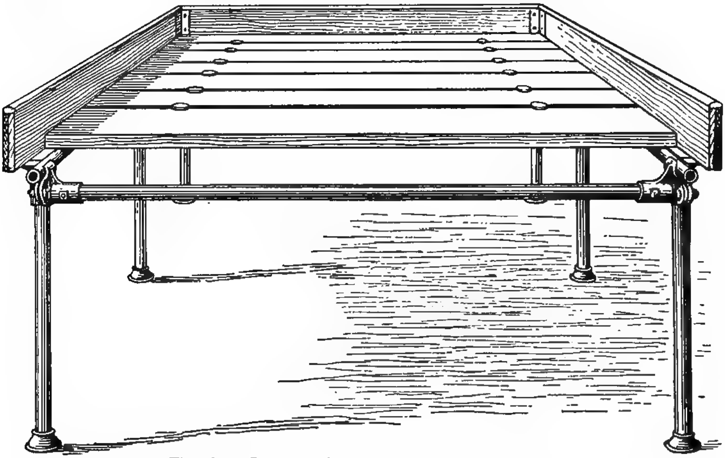

Fig. 21.—Bench with pipe frame support.

should be perfectly dry before putty is applied, and the putty should be of the best grade and kept soft by the use of linseed oil. It may be applied with a putty bulb, machine or knife. It is most convenient to begin at the end of the house and the eaves, and then to work up towards the ridge until the first row is completed, next laying the second row, and so on until the roof is finished. Sometimes the putty is applied on the outside of the

FIG. 22.—CONCRETE PILLARS FOR BENCH SUPPORTS.

house, but this is generally very unsatisfactory. It is far better to fill the rabbets with putty, and then squeeze out the surplus putty by forcing the panes into place.

Glazing points are used to fasten the glass, and when the work is properly done the joints will be air and water-tight. A matter of very great importance is often neglected in greenhouse glazing. Every pane of glass is curved. The panes must be laid with the curves always up or always down; otherwise there will be large air spaces between the laps. When the sash bars are provided with drip grooves, the curve should be up; if the grooves are lacking, the curve should be down.

Shading.—It is sometimes necessary to shade greenhouses. A cheap and rapid method of providing shade is a thin whitewash made of air-slaked lime and applied with a spray pump. Such a wash will adhere as long as it may be needed, and there will be no difficulty in removing it with brush and water. The green scum which often forms on old greenhouses may be easily removed with a spraying solution made by dissolving one pound of oxalic acid in a bucket of water. A crystalline deposit will be formed on the glass, and the first rain will wash it off. The work should be done on a clear day. One pound of oxalic acid is sufficient for 3000 square feet of glass.

Painting.—Immediately after the glass is laid, the house should receive two additional coats of paint, and thereafter the interior and exterior should be painted often enough to preserve the wood parts. Some growers paint the outside of the house every other year, although most of them paint at much longer intervals. There is some difference of opinion regarding the value of subsequent painting in prolonging the life of a greenhouse, but there is no question about the value of paint in respect to the appearance or attractiveness of an establishment. It is exceedingly important to lead properly all joints when

FIG. 23.—WALK WITH CONCRETE SIDES. PEERLESS TOMATO IN AN IRONDEQUOIT (NEW YORK) HOUSE.

erecting the frame, and water should be kept out of the joints by the frequent application of thick paint.

Beds and benches.—Formerly vegetables were grown almost entirely on benches, but benches are seldom seen in the large modern greenhouses used for vegetable forcing. It is argued by some that better results are obtained with benches, and there are doubtless instances in which this is true, but the disadvantages so far overbalance the advantages that benches should seldom be given serious consideration, except for midwinter forcing of warm crops and for sub-irrigation. Among the disadvantages of benches for vegetable forcing may be mentioned (1) the cost of construction; (2) the cost of repairs; (3) interference with the operations of handling the soil and manure, and of spading, plowing and harrowing, thus increasing the cost of production; (4) the soil on the benches dries out much quicker than the solid ground beds; (5) more skill is required in watering the soil on benches, unless sub-irrigation is employed.

In the modern greenhouse devoted exclusively to vegetable forcing there is no necessity either for benches or for sides to the solid beds. The whole area under glass is regarded simply as one unbroken plat which, with the exception of the necessary walks and alleys, may be cultivated with as much freedom as outside gardens. When benches are regarded as essential, they should be made of durable material. Concrete is becoming especially popular. The construction may be of separate blocks; or the benches may be made with a 1½ or preferably 2-inch bottom of concrete reinforced with poultry netting, and with concrete sides. The benches may be supported by iron pipe or concrete posts. (Figs. 21 and 22.) A combination of slate, iron and concrete is often used in bench construction. Sometimes water-tight concrete beds are made, so that sub-irrigation can be practiced.

Walks, alleys and roadways.—Walks in commercial greenhouses vary from 12 to 24 inches in width. Twenty inches provides sufficient space under most circumstances. In solid plantings of lettuce it is customary to omit two rows, or sometimes only one, while in cucumber and tomato plantations the walks are 30 inches or more. Special alleys (Figs. 5, 23 and 24) and roadways (Fig. 25) are important in very large ranges.

The walks in some of the best houses are made of concrete. These are especially desirable in heavy soils. They are inexpensive and simple to construct. The ground should be graded as level as possible before the walks are outlined. Use 2 x 4-inch pieces for the sides. Care must be exercised to get the sides straight. Tamp the soil inside the 2 x 4-inch pieces (the scantling may be laid flat if desired) until within an inch of the top. Stretch a piece of poultry netting over the tamped soil, and hold it in place with bent pieces of old wire stuck into the soil and hooked over the netting. Rather thin concrete is used, and the top leveled and smoothed in the usual manner. The poultry netting reinforcement greatly increases the strength of the walk, and economizes concrete. The netting should be permitted to bulge here and there over the soil so that the concrete will settle all around the meshes. Where freezing does not occur, as in the greenhouse, it is unnecessary to use ashes under the concrete. The 2 x 4 pieces of lumber are removed after the concrete is properly set.

Steam vs. hot water heating.—Modern greenhouses are heated either by steam or hot water. Hot water is almost invariably preferred for small greenhouses because the boilers may be left for a longer period at night without attention. About nine-tenths of the large establishments are heated by steam, and the growers claim that the steam system costs less to install and to operate, and that it gives them better control of temperatures. But some of the owners of very large ranges of recent construction are using hot water, and they also claim economy in fuel consumption, and better atmospheric conditions for the growth of the plants. Some growers have a combination of steam and hot water. They use the steam only in extremely cold weather and for sterilizing the soil, and also for operating the pumps.

The differences in the various methods of steam and hot water heating are so great that the two general systems can scarcely be compared. It may be said, however, that there is an increased tendency to use the improved methods of hot water heating in very large ranges, and that they are unquestionably more economical for small houses. The greater durability of pipes constantly filled with water is a strong point in favor of the hot water system.

Radiation required.—The radiation required to heat a house properly depends upon the exposure and the protection of the building, the area of glass exposed, the temperature requirements of the crops grown, the severity of the weather and the system of heating.

One of the leading manufacturers of greenhouse boilers uses the following data for finding the number of square feet of pipe surface required to heat the house to various temperatures with the gravity hot water system when the outside temperature is zero: For 60 degrees to 65 degrees divide square feet of glass and equivalent by 2.62; for 55 degrees to 60 degrees divide by 3; for 50 degrees to 55 degrees divide by 3.46; for 45 degrees to 50 degrees divide by 4; for 40 degrees to 45 degrees divide by 4.67. Six square feet of wall area should be figured as the equivalent of one square foot of glass. The divisors named undoubtedly provide much more liberal radiation than is common in most greenhouses which are devoted to vegetable forcing, but it is better to have too much radiation than not enough. Steam and the pressure systems of hot water require less radiation. So many factors enter into

FIG. 24.—AN ALLEY OF LIBERAL WIDTH IN A CUCUMBER HOUSE.

this problem that a greenhouse heating specialist should be consulted before a decision upon any given amount of radiation is made, unless the matter has been determined by actual experience or observation.

Systems of hot water heating.—There are three distinct forms of hot water heating, viz., the open tank gravity system, the pressure system and the forced circulation system. The gravity system is the oldest and is still used quite extensively. It provides for open tanks and large pipes. With it there must be ample radiation. Although plants thrive with this system, it is not popular with large commercial growers because of the excessive cost of installation, nor is it satisfactory in very long houses.

The pressure system secured by the use of mercury and sometimes by safety valves is quite popular and satisfactory when properly installed and operated. Of the three methods of heating by hot water, the forced circulation system is the most satisfactory for large greenhouses. In this system the velocity of the circulation is increased by means of propellers or pumps operated by motors or engines. With forced circulation the mains and coils need not be so large as with the gravity system, so that the cost of installation is not greatly in excess of steam. This system does not require a large volume of water in the boiler and radiating pipes, so that the temperature of the house is under more perfect control than with the gravity system, and all parts of the house are heated uniformly, a condition not possible in large houses in which the gravity system is installed.

Systems of steam heating.—There are three systems of steam heating. (1) The low-pressure, steam-gravity return. With this system the pipes are laid in the same general positions as with gravity hot water, care being taken to avoid water pockets.

(2) Low-pressure steam with steam-return trap. It is often impracticable or undesirable to excavate boiler pits

or cellars which are necessary for the gravity system of steam or hot water; but by means of a trap located above the boiler, the water of condensation is returned to the boiler without causing any trouble in the radiating lines. This system is strongly indorsed by many who are using it for the heating of large establishments.

(3) High-pressure steam. While this system is sometimes used in the heating of greenhouses, it is not satisfactory because of the intensity of the heat. Reducing valves may be used to lower the temperature so that the average temperature in the radiating pipes of the house will be considerably less than in the boiler or mains. In this case it is necessary to use a pump to return the water of condensation to the boiler. The pump may be operated by the high-pressure steam.

Location of pipes.—The pipes should be located where they will not seriously interfere with the work in the houses; nor should they be placed, unless unavoidable, where they will cast shadows on the plants. In practically all vegetable-growing establishments most of the pipes are placed along the walks, with just enough in the central part of the houses to secure the proper circulation of air. Sometimes the central pipes are placed near the ground, but more frequently overhead, and supported by the same iron posts which support the roof. In the Boston district the interior pipes are often 3 or 4 feet above the beds. In narrow houses it is unnecessary to have any central pipe lines, but in houses with a width of 20 feet or more central pipes are a great advantage.

The boiler.—Boilers are made either of cast iron or wrought iron. Cast-iron boilers are the more durable, because they do not rust so badly and there are no flues to be burned out as in wrought-iron boilers. On the other hand, fuel consumption is not so economical as in wrought-iron boilers, in which the waterways are thinner.

A great variety of steam and hot water boilers is available for the heating of greenhouses, but space will not permit a discussion of the merits and characteristics of each. A few general factors, however, should be taken into account in the selection of a boiler, and they may be enumerated as follows: (1) The boiler should be amply large. It is uneconomical in every respect to force a boiler which is too small for the required radiation. (2) The boiler should secure perfect combustion of the fuel used. (3) A long fire travel is essential to the greatest efficiency. (4) Thin waterways are a decided advantage. (5) Horizontal fire box surfaces are superior to perpendicular tubes or flues. (6) The boiler should be easily cleaned. (7) There should be at least two boilers, even for small houses, so that in case of accident to one, the other may be used.

Thermostats are used to some extent among greenhouse growers. They are electrical devices for the automatic regulation and indication of temperatures. An electric circuit connects with battery cells and a bell, if the thermostat is to be used as an alarm. Sufficient expansion or contraction of a substance, such as rubber or metal, closes the circuit and causes the bell to ring when the temperature has reached a dangerous point. Thermostats are sometimes used in greenhouses which are not large enough to require a fireman throughout the night. In such cases they may connect with a bell in the bedroom of the fireman, or, if preferred, to a small motor which will automatically open or close the dampers of the boiler.

Thermostats in large commercial houses are in keeping with the "safety first" policy. Why take chances on the damaging or perhaps total loss of a crop, when a few dollars will provide a sleepless night watchman that will sound a warning the very moment the temperature in the greenhouse has dropped to a dangerous point?

Furthermore, the night fireman and the foreman are

FIG. 25.—ROADWAY IN A TWO-ACRE HOUSE.

likely to be much more faithful in the performance of their duties if they know that a bell will inform the proprietor that the temperature is not being properly controlled.

It is not unusual for illness or accident to interfere with the work of the night men, and in more than one instance the sudden death of the fireman has caused serious damage to the crops if not their total loss.

CHAPTER III

SOILS

Selection.—The utmost care should be exercised in the selection of soil for vegetable forcing, for however skillful the grower may be, he cannot expect complete success without the most favorable soil conditions. Unfortunately, we possess very little basic information about greenhouse soils, for they have not been studied to any great extent by scientific investigators. Our knowledge of them and their management has been deduced mainly from the experiences of successful commercial growers.

Greenhouse soils abnormal.—The soils in most of the greenhouses devoted to vegetable forcing and to floriculture are abnormal in structure, color, organic content, and probably in chemical composition. Even the texture is often modified by the addition of sand and ashes. So great are the alterations in some instances that the soils would not be recognized as belonging to any particular classified types. The greenhouse grower strives to establish the best and most perfect soil conditions, and the returns usually justify the expenditure of as much time and money as may be required to accomplish this. His problem of soil management is radically different from that of the general farmer, who may gradually improve his land from year to year, while the greenhouse grower should secure the maximum production within a year or two. The glass structure over an acre of land represents a large investment. This fact and the cost of fuel and other operating expenses make it imperative to spare no effort in providing the very best soil.

Texture.—The texture of a soil is characterized by the proportion of the different-sized mineral particles which it contains. Classification is based upon mechanical analyses, excluding stones, gravel and fragments of rocks which do not pass through a 2-millimeter sieve.

Classification of soil material

The figures in the following classification,* represent per cent; the minus sign (—) less; plus sign (+) more; the hyphen (-) when used between two numbers, as 20-50, should read from 20 per cent to 50 per cent.

Soils containing —20 silt and clay:
- Coarse sand: 25+ fine gravel and coarse sand and less than 50 any other grade.
- Sand: 25+ fine gravel, coarse and medium sand, and less than 50 fine sand.
- Fine sand: 50+ fine sand, or —25 fine gravel, coarse and medium sand.
- Very fine sand: 50+ very fine sand.

Soils containing 20-50 silt and clay:
- Sandy loam: 25+ fine gravel, coarse and medium sand.
- Fine sandy loam: 50+ sand, or —25 fine gravel, coarse and medium sand.
- Sandy clay: —20 silt.

Soils containing 50+ silt and clay:
- Loam: —20 clay, —50 silt.
- Silt loam: —20 clay, 50+ silt.
- Clay loam: 20-30 clay, —50 silt.
- Silty clay loam: 20-30 clay, 50+ silt.
- Clay: 30+ clay.

It is seen from the foregoing classification that soils vary greatly in the proportion of the different-sized mineral particles. In the coarse sand the particles are the largest; in the clay they are the smallest.

The proper soil texture is an exceedingly important matter with reference to the production of crops under glass. The heavier types, such as the loams, silt loams and clay loams, are universally regarded as pre-eminently adapted to the culture of the staple farm crops. Likewise, the value of the sandy types has been recognized for trucking and market gardening, although many classes of

* Bulletin 78, Bureau of Soils, United States Department of Agriculture.

vegetables are grown successfully upon the heavier types of soils. In the forcing of vegetables sand, and presumably fairly coarse sand, is more important than in trucking or market gardening. The air spaces between the particles are much larger in coarse-grained soils than in the fine silts and clays, and for that reason such soils are not so solid and compact. As explained by the following statements, the open, porous character of sandy soils makes them peculiarly well adapted to the culture of greenhouse vegetables.

(1) Tillage is less difficult and less expensive than in heavy soils. This factor is important in general farming, but vastly more important in the handling of greenhouse soils, since so much of the work must be done by hand. When plows and harrows can be used under glass, texture from the tillage standpoint is not so important.

(2) Sandy soils are well aerated, and this condition accelerates chemical activity. In other words, oxidation is more rapid in sandy soils, fertilizers act more quickly and stable manures decompose and become available sooner than in heavy soils.

(3) Sandy soils are valued for trucking and market gardening because they are light and warm, and crops mature earlier in them than in heavy soils. The same influence exists in the greenhouse, though to a less extent, because moisture and temperature conditions are artificially controlled. In greenhouse management, time of maturity is determined mainly by the date of planting; nevertheless, sandy soils are favorable to rapid growth and quick maturity.

(4) It is important for greenhouse soils to dry quickly on top after watering, because an excessive amount of moisture at the surface is conducive to plant diseases. This is especially true in lettuce culture. Surface evaporation is most rapid in the coarse sands and slowest in the fine silts and clays.

(5) Greenhouse soils should absorb water rapidly without subsequent baking, and the sandy soils are ideal from this standpoint. Their power to retain water is not so great as that of silt or clay, but this is unimportant in the greenhouse, where it is possible to water at any time. A somewhat heavier subsoil, however, with its greater power to hold moisture, is an advantage because it requires less frequent applications of water.

(6) Interior evaporation is more rapid in sandy soils, and this is thought to be of considerable consequence in relation to oxidation and nitrification, both of which processes are very active in the best greenhouse soils.

(7) Sandy soils do not bake seriously. This is a great advantage in dispensing with frequent cultivation. In the large forcing establishments many of the sandy soils, which contain a large amount of organic matter, are never stirred or cultivated at any time after the final preparation for planting.

(8) Sandy soils offer no resistance to root penetration and they encourage the development of the most extensive root system.

(9) The root crops, such as radishes and beets, are smoother and more uniform in shape, and they develop fewer fibrous roots when grown in sandy soils.

(10) Walking on the ground, required by harvesting the crops, does not injure the physical properties of sandy soils as is often the case in heavy soils.

(11) Seed sowing and transplanting are facilitated in sandy soils.

(12) Apparently it is less difficult to maintain satisfactory sanitary conditions in sandy soils. There are evidences that various diseases appear earlier in heavy soils, from which they seem more difficult to eradicate by any method of soil management or sterilization.

(13) Sandy soils are easily sterilized. If the soil must be shoveled over and over again, as when steam is used

in pipes, the sandy soils are handled with the greatest ease. There is always danger of injuring the physical properties of heavy soils when either steam or formalin is used for sterilization.

(14) Sandy soils have a wider adaptation to greenhouse vegetables than do the heavier types.

So important is sand in greenhouse soils that it is often transported long distances and mixed with the heavier soils that must be used. The financial returns from greenhouse crops probably justify the practice; and yet it is better to select soils, if possible, which make this expenditure unnecessary. There is an increased tendency to mix muck with various types of soils to be used for the forcing of vegetables. This practice deserves consideration wherever a supply of muck is easily available. Both light and heavy soils seem to be improved by its addition.

Although special emphasis has been given to the importance of coarse-grained soils, there are numerous examples of success on heavy types. When a first-class market is easily accessible, no one should hesitate to engage in vegetable forcing simply because a light soil is not available.

Structure.—This term applies to the arrangement of the mineral matter of the soil. In some instances, as in fine silts, the particles are in such intimate contact that the soils are very compact; they form a mass that is not easily penetrated by roots. This condition is most unsatisfactory to aeration, surface evaporation, tillage, soil sterilization, seed sowing and transplanting. Soils of unfavorable structure for vegetable forcing can be greatly modified by proper cultural methods. Tillage may be the means of breaking up the soil into granular masses, and lime may cause the particles to flocculate, while the fiber of stable manures separates the soil into small masses. It is important, however, to avoid if possible the selection of soils of compact structure for the forcing of vegetables.

Color.—Black soils are usually more fertile than light-colored soils, although there are many exceptions. The color of the soil is of greater importance in the forcing of vegetables than it is in the production of crops in the open ground. This is due to the great power of dark soils to absorb the heat rays of the sun, thus reducing the amount of fuel required to maintain proper temperatures. Black soils are also good radiators; the heat absorbed during the day radiates throughout the night. The advantage of heat gained in this way is particularly noticeable in the management of coldframes. How much of a factor it is in the heating of greenhouses has not been determined, but it must be of considerable importance, especially when a large proportion of the ground is not shaded by plants. The absorption of heat accelerates chemical activities in the soil and also has some influence upon the soil's physical properties.

Organic content.—All classes of cultivators have long recognized the value of a liberal quantity of soil organic matter. Of the various factors which contribute to plant growth, this, with the exception of water, is unquestionably the most important. The organic matter furnishes plant food; secures better aeration; promotes chemical activities; improves physical properties; darkens the color; increases the water-holding power; supplies the best conditions for the work of friendly bacteria; increases the rapidity of water absorption; favors root penetration; and reduces the cost of tillage operations. No class of soils, except the mucks, contains such large amounts of organic matter as do greenhouse soils which have been used for many years in producing vegetables for commercial purposes.

Water content.—Greenhouse soils are generally quite constant in moisture content because water is applied whenever needed. See page 149, which relates to watering.

Chemical composition.—As previously stated in this chapter, chemical changes are very rapid in greenhouse soils, and with the perfect cultural conditions that are maintained in well-managed houses there never should be any deficiency of soluble plant food. See Chapter IV on Manures, Fertilizers and Lime.

Depth.—Greenhouse soils vary in depth from 6 to 15 inches, and even greater depth may be found in some of the soils used in the Boston district. Very deep soils hold more water, of course, than do those of medium depth, and this is probably their greatest advantage. Exceedingly heavy crops have been grown in soils ranging from 6 to 8 inches in depth, so that it is not so much a question of depth as of perfection of all other cultural requirements, for well-prepared shallow soils give better results than poorly-prepared deep ones. Although very deep soils require less frequent watering, they are more expensive to prepare for planting because of the necessity of spading, or even trenching in some instances.

Drainage.—It is sometimes necessary to tile drain greenhouse soils, although the necessity for drainage is never so great as in the uncovered open field. When tiles must be used they should also be available for steam sterilization, and they may be used for sub-irrigation. See pages 97, 155. If suitable soils are selected for vegetable forcing there will seldom be any necessity for artificial drainage.

Muck soil.—Pure muck soil is not adapted to the forcing of the standard greenhouse vegetables, except head lettuce, but when mixed with heavier soils the organic content has an ameliorating influence. A vegetable grower in Pennsylvania built a modern house covering two acres of Dekalb gravelly loam, and then hauled muck several hundred yards and spread it to a depth of 4 or 5 inches over the entire area of the greenhouse. The soil was plowed and harrowed until the muck was thoroughly incorporated. The splendid crops grown in that house testify to the merits of the radically modified soil. While many tons of organic matter were added by the use of muck, annual applications of stable manure have also been required to produce maximum crops.

Boston soils.—The soils of the Boston greenhouse section belong to the Glacial and Loessial province. Inasmuch as the region has not yet been surveyed, the soil types cannot be designated. The following is a mechanical analysis of a typical soil from one of the Boston greenhouses:

Water-retaining capacity	67.90
Organic matter	15.18
Gravel	5.75
Coarse sand	8.12
Medium sand	7.07
Fine sand	12.06
Very fine sand	34.01
Silt	2.10
Fine silt	0.20
Clay	3.82

It is evident that sand largely predominates and that there is also a liberal proportion of gravel. The large amount of organic matter is due to the frequent applications of horse manure. The soils are well aerated, absorb water rapidly, dry quickly on the surface and are well adapted to forcing cucumbers, tomatoes and head lettuce.

Chester fine sandy loam.—Three-tenths per cent, or 1,472 acres, of the soils of Chester county, Pa., belong to this type. A mechanical analysis* of a typical sample of the Chester fine sandy loam gave the following results, expressed in percentages:

Fine gravel	2.1
Coarse sand	10.4
Medium sand	6.9
Fine sand	23.3
Very fine sand	19.7
Silt	26.8
Clay	10.8

* Soil Survey of Chester County, Pennsylvania, U. S. Bureau of Soils.

This is probably the best tomato soil in Chester county, but because of its location and other general reasons it is not used so extensively as the Chester loam in forcing either tomatoes or carnations. The following table shows a mechanical analysis of the Chester loam:

Fine gravel	3.3
Coarse sand	7.5
Medium sand	3.3
Fine sand	8.9
Very fine sand	9.3
Silt	48.2
Clay	19.8

This soil contains enough sand to make it fairly satisfactory for tomatoes and cucumbers. It is regarded as a good soil for general farm crops rather than for special crops, though it produces probably half of the greenhouse tomatoes sold in Philadelphia.

Ashtabula soils.—The soils of the Ashtabula forcing district belong to the Glacial Lake and River Terrace group, and to the Dunkirk series, the Dunkirk sandy loam being the best of the series for vegetable forcing. This soil is from 6 to 10 inches deep, with a subsoil of medium or fine sand. Both the soil and subsoil contain scattered pebbles, which are not objectionable in the forcing of vegetables. The following is a mechanical analysis of a sample of Dunkirk sandy loam:

Organic matter	2.23
Gravel	0.80
Coarse sand	3.44
Medium sand	3.90
Fine sand	42.70
Very fine sand	26.14
Silt	13.02
Clay	9.80

It should be noted that the sample was selected out of doors and not in the greenhouse, and this accounts for the very small percentage of organic matter as compared with the Boston greenhouse soil. The Ashtabula soils are famous for their production of lettuce and cucumbers, and tomatoes are also grown to a considerable extent in this soil.

Cleveland soils.—The best vegetable forcing soil of the Cleveland district is known as the Dunkirk fine sandy loam. Although not quite so coarse in texture as the Dunkirk sandy loam used at Ashtabula, it is highly satisfactory for the growing of lettuce and tomatoes. Cucumbers are also grown in this soil to some extent. A mechanical analysis shows the following results:

Fine gravel	0.7
Coarse sand	2.7
Medium sand	3.7
Fine sand	39.5
Very fine sand	32.4
Silt	11.2
Clay	9.2

Toledo soils.—The typical trucking soils of the Toledo district belong to the Miami series. The Miami sand is best adapted to vegetables. It is variable in composition, but contains, according to mechanical analysis made by the U. S. Bureau of Soils:

Gravel	Less than one per cent
Coarse gravel	1.64 to 3.74
Sand	7.08 to 24.74
Fine sand	37.66 to 51.34
Very fine sand	5.50 to 33.54
Silt	5.45 to 15.60
Clay	2.54 to 3.59

Lansdale silt loam.—Tomatoes are grown quite extensively in this soil, near Lansdale, Pa. It is regarded as a good soil for general farm crops. The drainage is good and the soil does not puddle very easily. The following is a mechanical analysis of the soil:

Fine gravel	0.2
Coarse sand	1.6
Medium sand	1.1
Fine sand	4.5
Very fine sand	5.1
Silt	68.2
Clay	19.1

This cannot be regarded as a first-class soil for vegetable forcing, and yet it does not seem difficult to maintain good physical properties in the Lansdale silt loam.

Norfolk series.—The various types of sandy soils of the Norfolk series are used extensively in vegetable forcing, especially in the growing of frame crops. They are warm and well drained, and respond readily to the use of manures and fertilizers. The following table shows the texture of a sample of Norfolk fine sandy loam:

Gravel	1.34
Coarse sand	21.14
Medium sand	21.90
Fine sand	15.84
Very fine sand	5.66
Silt	26.69
Clay	7.46

Irondequoit soils.—The Dunkirk soils are found in the Irondequoit greenhouse section. A mechanical analysis of soil from Irondequoit is not available, but the Dunkirk gravelly sandy loam analyzes as follows:

Fine gravel	3.7
Coarse sand	7.4
Medium sand	6.4
Fine sand	14.9
Very fine sand	20.5
Silt	37.0
Clay	9.8

Soil adaptation.—The student has probably concluded from the discussion in this chapter that a great variety of soil types are adapted to vegetable forcing, or at least that greenhouse vegetables are grown on soils that have a wide range in texture and structure. The latter statement undoubtedly is true, for examples can be cited of greenhouse crops having been grown with entire success in soils which in their unimproved state possessed few if any of the characteristics that are regarded as important by greenhouse growers. Production, however, under adverse soil conditions is always more costly and more difficult. As previously stated, the sandy types are best adapted to all of the vegetables which are grown in frames or greenhouses.

CHAPTER IV

MANURES, LIME AND FERTILIZERS

Need of plant food.—Greenhouse vegetable forcing is the most intensive type of agriculture. The plants are set very close together, so that a maximum draft is made on the supply of available plant food. One crop follows another in close succession, and in a well-managed house there is practically no loss of time or space from September 1 to August 15. Continuous heavy cropping under glass requires much more plant food than any line of outdoor cropping that can be followed in temperate regions.

Again, the greenhouse vegetable grower raises products of high money value, and the cost of the plant food required for maximum crops is so insignificant, compared with the net returns, that he cannot afford to take chances by not supplying sufficient nourishment. It is not uncommon to see greenhouses which are properly heated and ventilated filled with crops that are small and inferior because the plants have not been properly fed and perhaps watered. There must be perfect cultural conditions in every respect in order to realize the utmost returns. No greenhouse soil has yet been found which does not need frequent and liberal applications of plant food.

Value of manures.—Numerous investigations have shown that the crop-producing power of a soil is more dependent upon its physical than upon its chemical composition. In other words, if a soil possesses the best physical properties, plant foods are not likely to be wanting to any considerable extent. The probabilities are that this conclusion of the soil specialists does not apply so much to the artificial conditions of the greenhouse as it does to the open ground, for our best growers have found it necessary to make very heavy annual applications of plant food, notwithstanding the fact that their soils, which have been managed skillfully for so many years, are acknowledged to be most superior in their physical properties.

It should be noted, however, that in greenhouse management stable manure has been relied upon almost wholly as the source of plant food, and it has also been the means of creating and maintaining physical conditions which are regarded ideal for greenhouse cropping. The action of the manure in decomposing also has a sanitary influence on the soil, and the presence of the organic matter is essential to the bacterial life. There are scores and perhaps hundreds of vegetable growers who believe that manure properly used meets all the requirements of greenhouse soils and of greenhouse crops. It has been the chief source of organic matter as well as of plant food.

Rhode Island experiments.—Interesting experiments with fertilizers, manure, cut hay and cut straw were made at the Rhode Island station, and reported in Bulletins 107 and 128 of that station. The greenhouse bench was divided into four plots. Horse manure was applied to No. 1 at the rate of 75 tons to the acre. Thirteen pounds of cut hay or cut rye straw (1½-inch lengths) was used on No. 2 and No. 3, in addition to various chemicals which constituted a complete fertilizer. No. 4 was also treated with chemicals, but the hay or straw was omitted. Radishes, tomatoes, cucumbers and carnations were grown in the series of experiments which were conducted for two seasons. The decreasing yields of plot 1, as each season advanced, compared with the other plots indicated that "possible denitrification and the loss of some of the nitrogen in a gaseous condition, also the fact that sufficient time had now elapsed for a considerable degree of decomposition of the cut straw to occur, which may have

FIG. 26.—MANURE SPREADERS, PLOWS AND HARROWS ARE OFTEN USED IN MODERN HOUSES

been especially beneficial to the physical condition of the soil." As a whole, plot 5, which received no cut hay or straw but the same chemicals as No. 3, did not produce as high yields as the other plots. This experiment seems to indicate that any kind of organic matter of proper texture improves the physical properties of greenhouse soils, but growers should not conclude that it would be a safe practice to abandon the use of stable manure and substitute chemicals and cut hay or cut straw, although it is possible that this could actually be done. The straw was used at the rate of about 10 tons to the acre.

Horse manure.—Of the various stable manures, horse manure is used the most extensively in the forcing of vegetables. It is sometimes purchased at the livery stables in the large cities for 50 cents a two-horse load. A dollar a ton is a common price in the smaller towns and cities. Horse manure is drier and looser in texture than cow manure, and it is also quicker in action and more convenient to fork, especially when used as a mulch for tomatoes and cucumbers. Fresh horse manure contains an average of 0.59 per cent of nitrogen, 0.26 per cent of phosphoric acid and 0.48 per cent of potash. See page 423. for the value of horse manure from mushroom beds.

Cow manure is valued by some greenhouse vegetable growers. It is slow in action, and the fresh manure may be applied nearer the time of planting than is desirable with fresh horse manure. Cattle manure of fine texture may be bought from city stockyards. Sometimes it is dried and pulverized, and then shipped in bags. This special product is convenient to use, but the high cost prohibits its use in large commercial establishments. Fresh cow manure contains about 0.42 per cent of nitrogen, 0.29 per cent of phosphoric acid and 0.44 per cent of potash.

Sheep manure has long been popular for use in floriculture, and it also finds some sale among greenhouse growers. It is commonly known as a hot manure and it decomposes very rapidly in the warm, moist soil of the greenhouse. Sheep manure contains about 0.76 per cent of nitrogen, 0.39 per cent of phosphoric acid and 0.59 per cent of potash. The high nitrogen content makes it imperative to use the manure with caution, in order to avoid injury to the plants. It is especially valuable for lettuce. The fine texture of the manure also enhances its value.

Poultry manure is not often used in greenhouses, but it possesses special merit for lettuce on account of the large amount of nitrogen which it contains. Analyses show that hen manure contains 0.8 to 2 per cent of nitrogen, 0.5 to 2 per cent of phosphoric acid and 0.8 to 0.9 per cent of potash. Like sheep manure, it cannot be used freely without danger of injury to the plants. The fine texture of chicken manure, when properly preserved, increases its value for mixing with greenhouse soil.

Rate of application.—There are no rules governing the rate of applying manures to soils for vegetable forcing. The factors which enter into this problem most largely are, first, the cost of the manure and, second, the cost of transporting it to the greenhouses whether by teams, electric power or steam power. Wherever it can be delivered at low cost there is a tendency to use large amounts, perhaps excessive amounts, of manure. The annual applications range from about 25 to 60 tons of horse manure to the acre, 35 perhaps being the average. A ton of manure applied every year to 1000 square feet of ground should be ample to produce good crops.

The texture of the soil, however, should be considered in this connection. Heavy soils demand larger and probably more frequent applications than light soils, for a few years at least, until there is a marked increase in the supply of organic matter. In a new range 75 tons of rotten manure to the acre was applied to the Hagerstown clay loam (limestone soil) before starting the fall crop of lettuce, and there was no evidence that the application was too heavy. In the clay and silt soils it is practically impossible to use too much rotten manure, and it is seldom that manuring is overdone in the lighter soils. The soils in many of the large establishments, where vegetables have been forced for a long term of years, seem to be too loose and porous, and to be lacking in body, but the excellent crops which are harvested at regular intervals do not indicate any fault in the composition or character of the soils. When rotten manure is to be applied to benches or solid beds in small greenhouses, two or three pounds may be used to each square foot of space.

Liquid manure is often used to advantage in small greenhouses. It is easily prepared by placing about a bushel of fresh horse manure or old, unleached cow manure in a half barrel of water. The contents should be stirred occasionally for a few days. Before making applications, dilute with three or four parts of water to one of the liquid. It may be used for all of the greenhouse vegetables without any danger of injury. In small greenhouses it is customary to pour a cupful around each plant which may be in need of nourishment. The plan is too slow and tedious for use in large establishments, where nitrate of soda is preferred, if special feeding is regarded as necessary. The more economical plan, however, is to prepare the soil with sufficient plant food, so that subsequent applications will be unnecessary, except for the mulching of tomatoes and cucumbers. In some of the large floral establishments liquid manure is prepared in large tanks, from which it is piped to the various houses and applied with a hose and nozzle.

The functions of lime.—The use of lime in the forcing of vegetables is on the increase. Apparently it is just as important—perhaps even more important—in greenhouse management than in out-of-door cropping. The functions of lime are varied and may be enumerated as follows: (1) It is an important food element of plants, although all soils probably contain sufficient lime to meet the needs of greenhouse vegetable crops, so that it is not considered a normal fertilizer, such as nitrogen, phosphorus and potassium. (2) It maintains a neutral or alkaline soil solution which is essential to the most satisfactory growth of some crops, especially the clovers. (3) It is favorable to the micro-organisms of the soil which are so important in relation to the supply of available nitrogen. (4) It helps to maintain satisfactory sanitary soil conditions; that is, it promotes the work of friendly bacteria and retards the action of injurious forms, and of certain disease germs which are harmful to forcing crops. In the management of greenhouse soils it probably pays to use lime for its beneficial sanitary effects, were there no other considerations. (5) It liberates plant food, including both of the important mineral constituents—phosphoric acid and potash—although this function may not be of great consequence in heavily manured greenhouse soils. (6) It is destructive to toxic substances in the soil, and this function may be of great importance in greenhouse management where there is little opportunity for long-time rotations. (7) It aids in the breaking down of insoluble compounds and in making them available to plants. (8) It forms a base for fixing and retaining humus. (9) It flocculates the finest particles of silt and clay soils into granular masses, thus materially improving the physical structure of such soils. After treatment with lime, these soils are more open and porous, better aerated, more easily penetrated by plant roots; they dry quicker at the surface and possess better physical properties in every respect for the forcing of vegetables. All heavy soils used in vegetable forcing should receive frequent and liberal applications of lime.

(10) It has some effect in binding sandy soils, but this function is of no practical value in relation to greenhouse soils.

The yields of greenhouse crops are often materially increased by the application of lime, and every commercial grower should conduct simple experiments to determine its full value. It is improbable that any harm can result from the use of reasonable amounts.

Commercial fertilizers.—As previously stated, commercial fertilizers are not used extensively by the market growers of vegetables under glass. In the chapters relating to the various classes of vegetables, experiments will be cited in which fertilizers have been used advantageously. There is a strong impression among growers, however, that little if anything is to be gained by the use of chemicals, and the statement "that more harm than good has been done by the use of fertilizers in vegetable forcing" is very likely a truthful assertion.

As early as 1892, Prof. W. J. Green of the Ohio station, after conducting some careful experiments, reported the following in Bulletin 43 of that station:

"It may be urged that no results could reasonably be expected from the use of any fertilizing ingredient upon a soil already well supplied with plant food. The persistency with which the virtues of nitrate of soda for garden crops have been urged has led many to believe that it can be used with profit, even upon soils already full of fertility.

"This experiment does not show that nitrate of soda, or any other fertilizer, cannot be used to advantage in any case, but rather that the limitations to their use are narrower than is commonly supposed. The soil used in this experiment was a clay loam. To fit such a soil for use in the greenhouse the best method is to compost it with stable manure, and such is the course generally followed by gardeners. The case would be different with a sandy soil, as the addition of stable manure, in order to make it friable and to prevent baking, is not so essential as with clay. Less stable manure would be needed with a sandy soil than with clay, and the deficiency in plant food could be made up with commercial fertilizers, and no doubt at a profit. A clay soil could be made friable by the addition of sand or coal ashes, and the deficiency made up as above stated, but the feasibility of this plan has not been tested.

"The problem, however, was not to determine to what extent stable manure may be displaced by commercial fertilizers, but rather to what extent the latter may be used in connection with an abundance of the former. We have taken the conditions as we find them in most gardens and greenhouses, and the verdict of our experiment is that under such circumstances, and with the crops grown in this experiment, there is likely to be no profit arising from the use of the commercial fertilizers named."

In the same connection, Prof. Green writes: "The growth of plants upon the separate plots was noted from time to time, and weights and measures taken at time of harvesting. No effect from the use of any fertilizer could be detected; the plots were as uniform as though the same treatment had been given to all. The crops grown were lettuce, radishes and tomatoes."

Complete fertilizers were used in larger amounts than is customary out of doors, but not so freely as to injure the plants. It is probable, though, that with the decreasing supply of city stable manure, greenhouse growers and market gardeners will be forced to resort more largely to the use of commercial fertilizers. It is also probable that less manure and the skillful use of fertilizers would give just as good results as the exclusive use of large amounts of manure.

Sources of nitrogen.—Some nitrogenous fertilizers become available much more quickly than others. High solubility is desirable, for the grower can then adjust the supplemental applications more accurately to the needs of the crop. It is assumed that every grower is using at least some stable manure, and the practical and often perplexing problem is, how much and what kind of fertilizer is needed to produce the best results.

Of the mineral materials which contain nitrogen, nitrate of soda is used the most generally, and no doubt more largely as a source of nitrogen than any other commercial fertilizer. It contains about 15 per cent of nitrogen. The salt dissolves quickly in the moisture of the soil, when it immediately becomes available to plants. This is usually the cheapest form of nitrogen.

Sulphate of ammonia, which is formed from waste materials produced in the manufacture of illuminating gas, is used sometimes in the fertilizing of greenhouse crops. It is more concentrated than nitrate of soda, since it contains about 20 per cent of nitrogen. Lime should be used in conjunction with large applications of sulphate of ammonia in order to prevent unfavorable chemical conditions in the soil.

Of the organic fertilizers, dried blood is probably the most popular. It consists of blood from the animals slaughtered in the great packing houses, and is prepared for market by evaporating, drying and grinding. The best grades of dried blood contain from 12 to 15 per cent of nitrogen. While dried blood is not nearly so available as nitrate of soda, it decomposes very rapidly in the warm, moist soils of the greenhouse, and when properly applied produces most excellent results.

Different grades of tankage are also available for greenhouse crops. They vary greatly in the amount of nitrogen which they contain, and also in the fineness of the particles. Tankage consists of all sorts of miscellaneous refuse of packing houses.

Other forms of nitrogenous fertilizers are used occasionally in the greenhouse, but they are not important, except the various forms of animal bone which contain some nitrogen. These are especially popular among florists. The bone preparations seldom contain more than 4 or 5 per cent of nitrogen. The nitrogen in bone meals becomes available very slowly, and this is the most serious objection to their use for greenhouse crops. On the other hand, large quantities of bone meal may be used with perfect safety, and this knowledge adds greatly to its popularity. The availability of bone meal depends primarily upon its state of division, the finest decomposing most rapidly.

Sources of phosphoric acid.—As previously stated, ground bone is used extensively by florists and to some extent by vegetable forcers. The phosphoric acid in bone meal ranges from 20 to 30 per cent. There are two classes, viz., raw bone and steamed bone. Raw bone meal is coarser in texture, contains the natural fat and decomposes slowly. Steamed bone meal has had the fatty material removed by treating the bones with steam under high pressure before they are ground. The steamed bone meals and flours are of fine texture, and for this reason and because of the absence of fats they decompose and become available much more quickly than the raw bones.

Acid phosphate may also be used in greenhouse soils. In this form, from 14 to 17 per cent of the phosphoric acid is available. Floats, or the untreated ground rock, might also be used to advantage in greenhouse soils which are so heavily charged with organic matter.

Thomas slag, which contains from 15 to 20 per cent of phosphoric acid, should prove satisfactory in vegetable forcing.

Sources of potash.—Of the various forms of potash, muriate of potash is used most extensively for open ground crops, and there is no evidence that it is not as satisfactory as other potash materials for greenhouse work. It contains about 50 per cent of actual potash. Sulphate of potash, another product of the German mines, contains about the same percentage of potash as does muriate of potash, though the purer grades carry larger amounts. Tobacco stems and wood ashes are also available as sources of potash.

CHAPTER V

SOIL PREPARATION

Ideal conditions in the greenhouse must be created, for no soil in its natural state possesses all of the requisites for the successful production of forcing crops. The vegetable forcer should be able to grasp the particular problems relating to the preparation of the soil to be used. Hard and fast rules cannot be laid down, because conditions are extremely variable. Different soils demand different treatment. But whatever the soil, it must have the required physical properties and contain an abundance of available plant food. It must also be as free as possible from harmful insects and plant diseases. The greatest care should be exercised in the preparation of soils for forcing purposes.

Changing soils.—In the early stages of the greenhouse business gardeners and writers on vegetable forcing considered it necessary to change the greenhouse soil every year or two. Renewal was regarded necessary in order to provide a soil which possessed the correct physical and chemical properties. It was found, too, that insect pests and plant diseases became troublesome unless the soil was changed quite frequently. The custom is a good one for small greenhouses and private places where it is not practicable to employ modern methods of soil preparation. There are hundreds of private and small commercial houses where steam is not available for sterilizing the soil. Under such circumstances it may be best to renew the soil quite frequently. On the other hand, it is highly probable that summer mulching with manure and sterilizing with formalin would be just as satisfactory in most instances as changing the soil. Furthermore, the grower must not lose sight of the fact that a properly handled greenhouse soil improves in its physical properties from year to year. This is particularly true of the heavier types.

In greenhouses covering thousands of square feet of land, soil renewal is quite out of the question and rarely practiced. To take out the old soil and bring in the new is an exceedingly expensive operation, the cost far surpassing that of sterilization. The expense of soil preparation outside of the greenhouse should also be considered before one decides to make frequent renewals.

Fig. 27.—Manure is usually placed in compost piles near the houses. (In this instance, mushroom houses.)

Composting.—In many of the smaller greenhouses there will always be more or less necessity for the changing of soils, and the managers should have a thorough knowledge of the principles and practice of composting.

Horse manure is almost universally employed in composting (Fig. 27), although cow manure is often used for this purpose by florists. To make composting effective, three things must be accomplished: (1) The fiber of the manure must be well decayed so that it will be short and fine before the soil is used for forcing purposes. (2) The fiber must be thoroughly mixed with or incorporated throughout the mass of soil. (3) The soil must be thoroughly saturated with the liquid of the manure. To accomplish these results it is necessary to start composting well in advance of the time when the soil will be wanted for use in the greenhouse. The actual length of time required to make a good compost depends upon the character of the soil as well as upon the manure. If the soil is heavy and the manure fresh and coarse, much more time will be needed than if the soil is light and the manure old and of fine texture. The time required for composting also depends upon the method employed.

One of the oldest and most satisfactory methods is to stack manure and sods in alternate layers. The piles are generally 4 or 5 feet deep and large enough to meet the needs of the house. Thick, heavy clover and grass sods are preferable. They may be cut with spades and hoes, or more rapidly with a plow set to run very shallow, and then cut across the thin furrow slices with a spade or an old axe. The sods and manure are hauled and stacked as near to the greenhouse as possible, so that the composted materials may be placed in the greenhouse without further hauling or unnecessary handling. The relative thickness of the alternate layers of manure and compost should be determined mainly by the character of the soil used. More manure is needed for the heavier soils than for the lighter types. When the sods are grown in silt and clay soils, the layers of manure and sods should be of about equal thickness, and they may range from 10 to 15 inches.

In sandy soils the layers of manure may be several inches less in thickness than the sods; 10 inches of manure and 14 inches of soil give excellent results. Compost piles of this character should be started at least six months in advance of the time when the soil will be needed, and in the heavier soils a year will give a better compost. After the material is well decayed, it is customary to cut down the pile in thin slices with a sharp hoe or spade, thus reducing the fiber to a finer state of division. Sand may be added to the compost and this is a great advantage in the heavier soils. One part of sand may be used to four parts of compost. This plan of composting has been popular for many years among florists, and so far as results are concerned no method is superior.

It is not always possible or practicable, however, to use the method of composting which has just been described. Excellent results may be had by simply piling together good soil and short, fresh horse manure in the proportion of about one part of manure by bulk to three or four parts of soil. At least three or four months should elapse before the compost is used, and the pile should be turned occasionally to obtain a finer and more homogeneous mass. If it is desired to use the soil immediately after mixing, old, fine unleached manure should be used instead of fresh manures. As good results, however, cannot be expected from newly-mixed composts.

A third plan of composting is to stack sods for a year or two, and then mix one part of the decayed sods with one part of good soil and one part of manure, adding another part of sand if that seems desirable.

Manuring in the field.—Because of the large amount of hand labor involved in the various methods of composting, other methods of soil preparation have come into general use which are more economical of labor, and productive of highly satisfactory results. One of the most popular methods, especially among florists, is to spread manure on the field and to give it such tillage as may be required. Good soil, preferably a clover sod, should be selected for this purpose.

As early in the spring as the ground is dry enough to be worked, and after some manure has been applied, use a disk or cutaway harrow repeatedly until the sod and manure are thoroughly cut up. Then apply as much more fresh horse or cow manure as can be turned under with a two-horse plow. It may be an advantage for a boy to follow the plow with a fork to draw into the furrow the manure which would interfere with the next furrow slice. By proper management it will be possible to plow under 40 tons or more of manure to the acre. After plowing, disk the soil, apply lime if desired, and harrow again. More rotten manure, if it is needed, may be added at any time during the summer. It may be necessary to plow the land two or three times during the summer, and the plot should be harrowed often enough to thoroughly reduce the fiber. In the stiffer soils, a spring-tooth harrow should be used occasionally instead of a disk harrow. By September the soil should be in prime condition for use. The old soil, when hauled back to the field from the greenhouse, furnishes ideal conditions for market garden crops. But whatever may be said regarding the merits of this method of soil preparation, it is too expensive to receive the serious consideration of extensive commercial growers, although far more economical than any of the usual methods of hand composting.

Green manuring.—It is often an advantage to use green manures in conjunction with field applications of stable manures. This practice will be found of special value in naturally poor soil and when liberal quantities of stable manure are inaccessible or very expensive. This process of increasing the supply of humus may be begun in the fall by sowing rye at the rate of three bushels of seed to the acre. When the rye is about a foot high the following spring it may be plowed down and followed with oats and Canada field peas, or with cowpeas or soy beans.

Michigan growers sow rye and vetch together when the seeding can be done fairly early in the fall.

It is always important to use liberal amounts of seed. Crimson or medium red clover may be sown in August. At each plowing, manure, fertilizer and lime may be applied in such amounts as seem desirable. Ultimately, the sods may be cut for composting, or the soil prepared for the greenhouse as described on page 72, except that less manure may be required. Green manures have also been grown inside of the greenhouse, but the interval between the harvesting of the spring crop and the planting of the fall crop is too brief for the development of much organic matter, although such cropping may have a sanitary effect upon the soil and also improve its physical and chemical composition.

Manuring in the greenhouse.—It is the almost universal practice in the large vegetable-forcing establishments to apply the manure to the soil in the greenhouses where the crops are to be grown. It is not difficult to understand why this is the favorite practice. There is no question that it is the most economical from the labor-saving standpoint, for in many of the best-managed places the manure is transported from the car or compost heap in manure spreaders, with which it is applied in the greenhouse, or by wagons or carts and spread with a fork. There is no reason why manure spreaders should not be used for this purpose, although carts are more convenient to handle, especially in houses containing pipe posts or roof supports. In the smaller houses it is customary to transport the manure into the houses by means of wheelbarrows or hand carts.

The manure must be well decayed when applied direct to the soil of the greenhouse (unless used for a mulch), and this requires composting by the same method that is so common among market gardeners. That is, the manure is hauled from the cars and stacked firmly in large, flat piles 4 or 5 feet deep and with perpendicular sides. If the sides are built up straight, there will be practically no leaching. Water is applied to the manure as often as is necessary to prevent fire fanging. There can be no leaching in the interior of the pile, because no rainfall is ever heavy enough to percolate through 4 feet of manure. The piles should be turned once or twice during the process of decay to assist decomposition and to secure a product of finer texture. Railroad sidings have been constructed at some of the largest establishments so that the manure may be thrown on the compost piles without the expense of hauling on wagons. In other instances partly decayed manure is thrown from the cars through side openings of the greenhouse.

Practically all growers apply the manure in August or September before the work of sterilization begins. A very successful grower at Erie, Pa., has been spreading short, fresh horse manure immediately after the harvest of tomatoes and cucumbers, and this is usually from August 1 to 15. The soil is then plowed, limed, harrowed and watered. Repeated tillage and watering during the summer seem to have a most beneficial effect by destroying weeds and disease germs, and these operations leave the soil in excellent physical and chemical condition for the fall and winter crops. With this plan of soil manipulation diseases did not appear for many years, although steam sterilization is now practiced in these houses, but more as a matter of insurance against loss than from any knowledge of serious infection by disease.

Drying greenhouse soils.—In hundreds of small greenhouses the soil is permitted to become very dry during the summer months when the houses are not in use. The desiccation is particularly rapid and complete when the soil is on raised benches. A house temperature of 100 degrees or more is an almost daily occurrence, and under such conditions only a few days are required for the soil to become very dry. In general farming, drought is thought by some to have a beneficial effect upon the soil, or at least upon the following crop, but it is possible that this is due largely to the absence of leaching and the small draft upon the food supply of the soil when there is a marked deficiency in the supply of capillary water. Though drying may be an advantage to soils out of doors, there is evidence that it is a great disadvantage in the management of greenhouse soils, except for the destruction of nematode worms.

Stone, of the Massachusetts station, made the following report in 1902: "The practice of desiccation or drying greenhouse soil by the aid of the heat of the summer sun has been in vogue with us for some time, for the purpose of observing what effect such treatment would have on certain organisms. We have already shown that the sclerotina or the drop fungus when dried is greatly accelerated in its activity, which increases to a great extent the amount of infection in the succeeding crop of lettuce."

In this connection Stone further reported as follows in Bulletin 69 of the Hatch station: "In this test the house was closed during the greater part of August, September and October, at which time the soil was subjected to the intense rays of the sun, which heated the soil up to a temperature of 123 degrees, and the air thermometer registered 140 degrees. As the top layer of the soil became dry a lower layer to the depth of a foot was forked over two or three times, so that practically the whole amount of soil became desiccated. The results of drying out the soil in one bed containing 308 plants was that 235, or 76 per cent, were subject to drop, and 66, or 21 per cent, to Rhizoctonia. The number of plants which succumbed to the two diseases was 301 out of a total of 308, or 97 per cent. The other half of the house, containing

264 plants, was treated similarly, with about the same results."

The 1902 report of the Hatch station says also: "There are other effects of drying on the soil which prove very destructive to the development of lettuce plants, although we have not observed this effect on other species. On lettuce we have observed this repeatedly, and the characteristic results of such drying are manifested in a stunted growth and an abnormally colored and worthless crop. The crop scarcely ever attains more than one-third of its size. The texture of the plant is poor, being thick and tough, and inclined to crinkle. That this is caused by desiccation alone is shown by the fact that wherever any drip fell from the roof upon the soil during the summer rains, the plants growing in such places were always normal. Distinctly sharp lines can be observed in a lettuce crop grown under such conditions, owing to the difference in development brought out by desiccation and the presence of a small amount of water due to dripping. Instances have come to our notice where large houses devoted to lettuce have been allowed to become too dry in summer. If such drying occurs, the soil can be entirely renovated by applying hot water or steam to it."

The drying of greenhouse soils not only increases the difficulty from disease, but it is decidedly harmful to the silt and clay types, which, after thorough desiccation, break up lumpy in the course of preparation for planting.

Summer mulching.—The Ohio station has been conducting a series of experiments with mulches used during the summer period of non-cropping. Horse manure has been the most effective. For seven years practically no disease has appeared upon any of the standard vegetables grown in the experimental houses. It should be noted that not only was the soil kept moist, as advocated by the Massachusetts station, but plant food and humus were added by the system used at the Ohio station by Green and his associates. The experiments, which are of such general interest and value, are reported as follows in Circular 69:

"Three years ago the Ohio station began an experiment to see what effect the use of strawy manure would have on the soil when used as a mulch during that part of the summer when crops are not growing in the greenhouses. This manure was applied as soon as the tomato and cucumber vines were removed from the houses, or about the first of August. It was put on to a depth of five or six inches and spread evenly over the entire surface of the beds. As soon as it was on, water was applied in the form of a spray until the manure and soil were thoroughly wet.

"The object of this wetting was first to leach the fertility of the manure into the soil and second to wet the soil sufficiently so that with the strawy mulch it would remain moist for several days. The operation of watering was repeated as often as needed; two or three times a week in bright weather.

"When we started to plant the lettuce, about the middle of September, the coarse part of the manure was removed from the beds and carried outside. The finer portion of the manure was worked into the soil at the time of spading.

"It was noticeable that the soil which had been treated with the mulch was in excellent condition when it was worked up for the first crop. There were no lumps, as there often are in the soil which has been allowed to bake in the sun for weeks at a time. It was also darker in color than unmulched soil. The lettuce plants which were planted in this soil started off nicely and grew rapidly and satisfactorily in every respect. No further application of manure or fertilizer of any kind was made for the second or third crops of lettuce. The growth of these crops was very satisfactory, as was that of the first crop. Liquid manure was applied to the tomato plants when the fruit began to ripen. This fertility might have been applied in the form of manure as a mulch, and probably it is best applied in that way rather than in the liquid form.

"This method of treating the soil during the summer gave such favorable results the first season it was tried that the station induced several practical greenhouse men to try it last season. One firm at Toledo, Ohio, began the use of the summer mulch the same season the station began it, neither party knowing that the other was trying this method of soil treatment. They have continued this practice and are well pleased with the results. Of those who tried the mulch, some did not apply water frequently enough, thus allowing the soil to become dry and destroying the value of the test. Others grew tomatoes as a fall crop on the mulched area and lettuce on the unmulched area, thus preventing a fair comparison. Still others mulched all of their soil, not leaving any without mulch for comparison. In one case where a careful mulch test was made other conditions entered in such a way that safe conclusions could not be drawn.

"Taking the results of the station tests, together with the results secured by the Toledo firm, and gleaning what information it has been possible to obtain from various sources, the station does not hestitate to recommend this treatment of soils to be used for vegetable forcing. It must be borne in mind, however, that no half-way or slipshod methods of using the mulch will give satisfactory results. There should be sufficient fertility in the manure to furnish enough plant food, when leached into the soil, to supply the three crops of lettuce. The quantity of manure must be sufficient also. At least 5 or 6 inches must be applied. A considerable quantity of coarse material in the manure, such as straw, corn stover, etc., is an advantage. Fresh manure has been used at the station each time, and while we have had no chance to see the effect of the use of well-rotted manure, we are satisfied with fresh manure, as we know that it will give good results.

"Where it is the practice to mulch the cucumber or tomato crop the manure used for that purpose can be left on and more added, provided the cucumbers or tomatoes have been free from disease. In case these crops have been diseased, it would be advisable to remove the mulch used on them and to apply new mulch.

"Frequent sprinkling of the manure on the beds is very essential, and where a mechanical system of watering is in use this can be done thoroughly and with the expenditure of little time and labor. When it is necessary to water by hand it will be harder to get the work done, but it must not be neglected, as failure is sure to follow the lack of sufficient water to properly leach the fertility of the manure into the soil and to keep it moist.

"When the time comes to put in the first crop, if the soil is in need of humus the entire mulch may be spaded into the soil, but most greenhouse soils do not need the addition of so much coarse material. Where the soil is fairly well supplied with humus the coarser part should be taken off and removed from the houses, and the finer portion worked into the soil.

"We are not prepared to say what effect the use of summer mulch may have on the diseases affecting lettuce, except that the station greenhouses have been very free from all diseases of lettuce since we have been using this method of treating the soil. The lettuce in the Toledo house has also been practically exempt from these diseases during the two years they have been mulching. In no case where the mulch has been used have we observed an increase in the number of diseased plants over an equal area not mulched. These facts, taken together with results secured by Stone and reported in this circular, would lead us to expect beneficial rather than detrimental results from the proper use of summer mulch, in so far as it affects the disease of lettuce."

The Ohio station later compared manure mulch with straw mulch. The details of the experiment are published on pages 85 and 86 of the official proceedings of the Vegetable Growers' Association of America for 1909, 1910 and 1911. The yields varied little at first, but the fertility under the straw mulch became depleted quite rapidly, as shown by the following report of 28 tomato plants on an area of 120 square feet:

PLOT 1—MANURE MULCH

Variety	Total number fruits	Pounds	Ounces
Magnus	326	102	9
Stone	299	104	13
Beauty	256	72	5
Total	881	279	11

PLOT 2—STRAW MULCH

Variety	Total number fruits	Pounds	Ounces
Magnus	234	63	6
Stone	234	75	11
Beauty	254	76	12
Total	722	215	13

The results with lettuce were not so marked. There were 16 rows of Grand Rapids plants. The results were as follows:

Manure mulch	Pounds	Ounces
First crop	48	9
Second crop	55	0
Total	103	9

Straw mulch	Pounds	Ounces
First crop	48	8
Second crop	51	2
Total	99	10

Notwithstanding the striking results of the Ohio experiments, especially with regard to disease, mulching has not become widely popular. It is apparently an ideal method of soil preparation in small houses, and it is worthy of more general trial in the large commercial establishments. Except for the destruction of nematode worms, mulching might take the place of steam sterilization. There is also evidence that the constantly moist condition of the soil under the mulch is unfavorable to the existence of nematodes.

Plowing and harrowing.—The plow is becoming increasingly popular in the preparation of greenhouse soils. Experience has demonstrated its entire success. It is a labor-saving device and a relief to the drudgery of soil preparation. There is no evidence to show that spading is any better than plowing, especially if the soil is well filled with organic matter. A horse can be handled better than a team, and with the light, level, easily tilled soil of most greenhouses a strong horse will have no difficulty in drawing a two-horse moldboard plow, although some growers prefer the smaller, one-horse plows. After plowing, a half section of any of the standard types of harrows may be used until the soil is thoroughly pulverized. The surface should be left smooth and even. Plankers or plank drags will be found desirable for that purpose. One of the best tools for greenhouse work is the smallest-sized smoothing harrow (Fig. 28) with a second leveling board adjusted behind the last row of disks. When it is desired to use the plow, the lettuce should be planted in long, narrow strips, so that when the successional crops of lettuce are harvested the strips can be plowed, harrowed and replanted with the minimum loss of time. When horse implements are used (Fig. 26), some hand work will be required along the sides and ends of the houses, to secure a finished appearance.

Spading and raking.—In the smaller houses and in most of the large establishments the soil is prepared by the use of the spade and rake. Spading forks are often used instead of spading shovels. Whatever the method

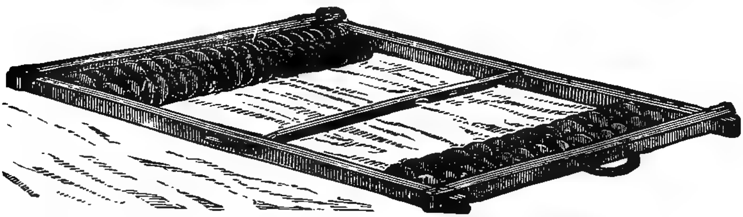

Fig. 28.—Small smoothing harrow.

employed, the soil should be left in a fine state of division.

Applying lime.—The various commercial forms may be used for the treatment of greenhouse soils. While ground stone lime is most convenient to apply, unslaked stone lime and hydrated lime are used more generally than other forms. Stone lime is simply deposited in small piles in the greenhouses and sufficient water applied to it with a hose to cause prompt slaking, and the lime is then spread with a shovel. There is no better time to apply lime than after plowing or spading and before harrowing or raking. It should not be mixed directly with manure because it will release the ammonia.

No experiments have been conducted to determine the proper amount of lime for greenhouse soils. One pound of unslaked stone lime is considered sufficient for 20 square feet of space, and double that amount will do no harm. It should be scattered evenly over the surface and thoroughly mixed with the soil. See page 64 relating to the functions of lime.

Applying fertilizers.—When commercial fertilizers are employed they are usually applied after plowing or spading and mixed with the soil by subsequent harrowing or raking. Nitrate of soda is often used as a top-dressing, applied either in dry or liquid form. Excessive amounts of fertilizers may cause curling, wrinkling or burning of the leaves. About ¼ ton to the acre of mixed mineral forms of commercial fertilizers is probably as much as can be used with safety on any of our greenhouse crops. One ounce of nitrate of soda to each gallon of water may be applied to lettuce and other crops without danger of injury unless the soil already contains a large amount of mineral fertilizers. For more specific information, see the discussion of fertilizers in connection with each class of vegetables.

CHAPTER VI

SOIL STERILIZATION

The necessity of sterilization.—In the great commercial forcing establishments the soil is not changed, but it is used over and over again with yearly additions of stable manure. The amount of vegetable matter increases and the physical properties improve so that in most instances there are serious objections to changing the soil aside from the labor of moving it. As previously stated, vegetable forcing is the most intensive branch of olericulture. Crops follow each other in quick succession. There may be no rotation whatever, for often the same crop is grown year after year. With such a system of cropping there is naturally an accumulation of destructive parasites.

Continuous cropping in the open ground nearly always leads to trouble, and the conditions of the greenhouse are even more favorable for the breeding and multiplication of all classes of parasitic enemies. The accumulation of soil organic matter is equally advantageous to insect life and to fungous foes. Soil desiccation, inundation, freezing, spraying, mulching and fumigating have their values, and may be the means of checking or even controlling many of the foes, but other measures have become a necessity in most of the large commercial houses. In fact, soil sterilization is now universally regarded as essential to success, although there are instances where splendid crops have been grown for many years without resorting to sterilization.

There is a wide difference of opinion among successful and intelligent growers regarding the value of sterilization. Some consider it an essential operation to sterilize the soil every year as a matter of insurance, though there may be little evidence of the presence of destructive insects or diseases. Others practice sterilization only when they regard it as absolutely necessary, and they may have large ranges in which the soils of some houses are sterilized every year, and others in which the soils have never been sterilized. Conditions are so variable that no rule can be laid down for all growers in regard to the desirability or importance of soil sterilization. It is certain, however, that hundreds of growers will be compelled to resort to this practice unless desiccation (for

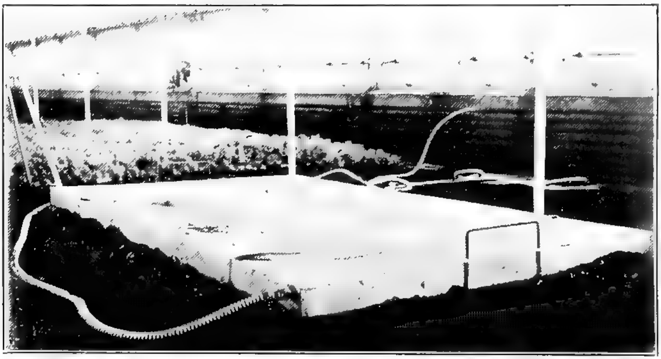

Fig. 29.—Pan steam sterilization in operation at the Indiana Agricultural Experiment Station.

nematodes) and mulching are found to be satisfactory and become more generally employed.

Methods.—Although dry heat and hot water are employed to some extent, steam and the formalin or formaldehyde drench are the methods in most general use; of these two methods steam is very much the more popular in the largest commercial establishments, though the hot water method is gaining in popularity. Steaming, when properly managed, destroys all animal life as well as fungous and bacterial enemies. The nematode, which is considered the most serious of the animal foes, is repressed both in the egg and worm state by thorough steaming. Weed seeds are also destroyed and plant food is made more available. Several investigators have shown that steam sterilization increases the amount of soluble or available nitrogen, potash and phosphoric acid. It also increases the absorptive power of the soil for water. Some of the experiments indicate that steam sterilization tends to develop certain toxics and also increases the acidity of the soil. If lime, however, is applied before the soil is sterilized, there need be no fear of any harmful effect.

In this connection, Stone and Smith state the following in Bulletin 55 of the Massachusetts station: "In the numerous crops of cucumbers, tomatoes and lettuce which we have grown in sterilized earth we have never noticed anything of a detrimental nature, but on the other hand a decidedly beneficial effect as the result of sterilization. Not only is this shown in the difference in color which the plants take on, but in an appreciable acceleration of their growth. We have repeatedly run parallel cultures of sterilized and unsterilized soil and have invariably noticed these effects on cucumbers and lettuce."

Rudd, whom we have already quoted as having tried the sterilized method, says:*

"It has long been known among practical gardeners that heating the soil produces beneficial results. Every greenhouse soil contains humus or vegetable mold, and it is recognized by vegetable physiologists that the presence of humus in the soil plays an important part in the assimilation and plant growth, but its efficiency depends partly upon the stage of decomposition at which it has arrived. It has been shown by experiments in which plants are treated in one case with humus in the raw condition, and in the other with humus which has been subjected to the action of steam for several hours

* American Florist, Vol. IX, p. 171-197.

at a temperature of 212 degrees, that there is considerable difference in the yield of the crop. It has been found that the same quantity of soil, after the action of heat, yields a crop many times in excess of the former or untreated soil. In other words, by heating we convert the humus compounds in the soil into a more available form for the utilization of the plant. That heating of the soil gives rise to some changes is shown by its darker color and more porous condition, and it is undoubtedly due to these changes which have taken place in the humus compounds, which account for the accelerated and vigorous growth of the plants.

"Another feature which is characteristic of sterilized soils is the unusual occurrence of humus-loving plants, or saprophytes, that grow upon it, which is a good indication that the organic matter contained in the soil has undergone changes through the action of the heat. We have ourselves observed more than once certain species of saprophytic fungi growing upon our steamed beds which have never shown any tendency to grow in unheated soil, although with the exception of being steamed the soil was exactly the same as that upon which they never appeared."

Evil results sometimes follow the use of steam, probably because of injurious effects upon the physical properties of the soil, especially when the soil has not been properly handled after sterilization. All things considered, steaming is the most complete, effectual and practical method of soil sterilization.

Formalin, however, has a useful place in the management of many greenhouses. While the usual strengths have little effect upon the animal life of the soil and do not destroy nematode eggs, many of the diseases may be controlled by the use of this disinfectant. Small areas of soil sometimes show infestation at midwinter, and they may be drenched with formalin when it would not be practicable to use steam. Again, there are hundreds of small houses heated by flues or hot water where steam is not available and formalin can be used to advantage. Its use is not so harmful to silty and clay soils, the structure of which is often injured by steaming.

Steam Sterilization

Temperature required.—Definite information gained from experiments relating to this question is contained in Bulletin 55 of the Massachusetts station, from which is quoted the following:

"Our experiments upon this point were numerous, and they were made with earth containing abundance of nematodes of various species in all stages of development. For the sake of convenience we will designate these experiments as a, b, c, etc. In all of these experiments we employed cucumbers in pots of various sizes (from 4 inches to 10 inches), and the plants were left until they were sufficiently large to show root galls upon them if nematodes were present in the soil. In every case except 'a' the pots containing the infested earth were sterilized in an Arnold steam sterilizer, and when moderate heating was required they remained in the sterilizer only a few minutes.

"The earth in experiment 'a' was part of a large lot which was sterilized in a box by means of steam from a boiler. In every instance numerous microscopic examinations were made of the soil and roots of the plant in order to determine whether nematodes were present. The non-parasitic species are generally present in almost every soil, and their presence can very often be suspected by the coloration of the root. They are generally found on the older parts of the root near the surface of the soil, as indicated by the dirty brown color of the epidermal tissue. The experiments are as follows:

"Exp. a. Six 4-inch pots were filled with infested earth which had been heated to 212 degrees. The pots were also sterilized and the cucumber seeds after soaking 12 hours in water were placed for 10 minutes in a saturated solution of corrosive sublimate, and before using were rinsed with sterilized water. During germination and the growth of the plants they were always watered with filtered water. Hence all source of contamination was eliminated. Results, no nematodes.

"Exp. b. Six plants treated as above. Result, no nematodes.

"Exp. c. Twelve pots of cucumbers, the seeds of which were treated as in Exp. 'a' and the plants watered with sterilized water.

Instead of the soil in the pots all being heated to 212 degrees they received the following various degrees of heat before planting:

No. of pot	1	2	3	4	5	6	7	8	9	10	11	12
Temperature	114	118	127	140	147	150	159	161	163	163	170	176

"Result: Nos. 1, 2 and 3 all damped off. The remainder were perfectly free from the damping-off fungus and nematodes.

"Exp. d. Sixteen pots of cucumbers were treated the same as 'c.'

No. of pot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Temperature	147	149	154	159	163	167	168	172	176	183	185	186	192	194	196	199

"Result: No nematodes.

"From these experiments, which only represent about one-half of what was done, it appears that a very high temperature is not necessary in order to free infested soil of nematodes. The number of degrees of heat necessary is about 140 degrees, but as a matter of safety the temperature should go above this, inasmuch as in large areas of soil the distribution of heat is always unequal, and while one portion may be heated as high as 190 degrees another portion may not exceed 110 degrees. The conclusion, then, that the soil must be heated under pressure to a temperature of 225 or 235 degrees in order to kill nematode life is therefore not valid in all cases. These experiments were made with sufficient care and were repeated often enough with the same results to consider them trustworthy."

Stone has since stated, and his statement is based upon further research, that the soil should be heated to a temperature of 180 degrees and that 212 degrees is better. This corroborates the views of growers who have been successful in steaming soils. While 140 degrees will kill insects and nematode eggs, there are disease germs which require higher temperatures. A high temperature is also necessary to secure the thorough permeation of the soil particles which harbor and protect insects and disease germs.

Time required.—Steam sterilization is really the cooking of every particle of soil, and considerable time is required to accomplish this. Steam under pressure passes through open, coarse, sandy soils more rapidly than through compact silts and clays. Again the time required will depend upon the pressure and volume of steam, and the volume of soil to be sterilized. In most of the greenhouses using high pressure steam with 100 horse power boilers or more, sterilization goes on for an hour. One large establishment with a 350 horse-power boiler regards 45 minutes as ample time. Others with high pressure steam sterilize for an hour and a quarter, while occasionally an hour and a half is regarded as necessary. The safe practice of one very careful grower is to continue steaming for half an hour after the soil reaches a temperature of 212 degrees.

The shortest period of sterilization is used by a very large establishment at Toledo. This firm uses a 350 horse-power boiler and sterilizes for only 10 minutes with a pressure of 90 degrees at the boiler. In this case the peg method is employed as described later in this chapter. It is claimed that the plan has given entire success. With low pressure steam a much longer time is required to heat all the particles of soil to the required temperature. Four or five hours is not too much time, and then the beds should be covered over night to retain the heat.

Boiler and pressure.—Large boilers and high pressure steam are advantageous in every respect. Less time is required to raise the temperature of the soil to the required temperature than with small boilers and low pressure steam. A large volume of steam under high pressure makes it possible to sterilize a larger area at one time, and this is usually a matter of great economy from the labor standpoint. Boilers of 300 horse-power or more are used for the steaming of soils, although much smaller boilers are often employed.

One of the largest and most successful greenhouse plants maintains a boiler pressure of 90 to 100 pounds for 45 minutes. Many establishments sterilize with a boiler pressure ranging from 50 to 70 pounds. A highly successful grower has found 20 pounds satisfactory when pans are used over loose soil.

Preparing soil.—Previous to sterilizing with either steam or formalin, the soil should be manured and plowed or spaded ready for planting. If lime is to be used, it also should be applied before the soil is sterilized.

It is important for the soil to be rather open in structure, so that the steam will penetrate every particle. It should also be quite moist, but not wet. More formalin is required in dry soil, and the results in dry soil with either method are unsatisfactory. The various organisms are in a live state or more active in moist soils, and in this condition they succumb more quickly to the sterilizing agents.

Devices for sterilizing.—Various devices are employed for sterilizing by steam. Among them may be mentioned boxes, pans, perforated iron pipe, perforated pipe pegs and ordinary drain tile. In the selection of a plan there are two main considerations, viz., efficiency and economy. A plan may be very efficient but highly expensive, especially in regard to the amount of labor involved. There is very little specific information on the relative efficiency of the various plans, and it is probably not so much a question of plan as of thoroughness and good management. All of the five devices which will now be described have been used with success.

Boxes.—During the earliest days of steam sterilization, boxes were used exclusively. They varied greatly in size, proportions and construction, but fundamentally they were similar. The general scheme was to make wooden boxes of convenient size, and to place perforated pipe in the bottom of them. The boxes were covered to confine the steam, and the joints were made as tight as possible. The pipe in the bottom of the boxes was usually 1 inch or 1¼ inches in size and connected with headers ½ inch larger. They were placed 12 to 15 inches apart and closed at the ends opposite the headers. The holes in the pipe were usually 1/8 or 1/4 inch in diameter, about a foot apart, and turned down to prevent them from being stopped with dirt. It is probable that the boxes should never be more than a foot deep. Two-inch drain tile may be substituted for iron pipe. With an ample volume of steam under high pressure thorough sterilization can be effected in an hour. The boxes may be covered with heavy canvas or hotbed sash. When a large amount of soil is to be sterilized there should be at least two boxes to facilitate handling the soil. While the box method is convenient for sterilizing potting soils, flats, tools, etc., it is now seldom used in vegetable-growing establishments because of the excessive cost of handling the soil.

Pans.—The inverted pan method is used by a great many large growers, especially in the Cleveland district. It is regarded by some as not so thorough as the tile and perforated pipe plans, although some of the most careful and successful growers are unwilling to concede this point. There are examples of perfect pan sterilization of soils which had become most seriously infested with nematodes and many other destructive pests. The pan method does not require any handling of the soil, and this is unquestionably its greatest advantage. The plan is becoming more popular every year. It is particularly valuable for open, porous soils which are easily penetrated by steam.

Galvanized iron pans are the most durable. They may be of any convenient size. Fig. 29 shows a pan which is used at Purdue University. Sometimes they are only 4 feet wide and 8 to 12 feet long. The pans are usually 6 to 8 inches deep. Pipe connection is made at the side or end as shown in the illustration, or in the bottom of the middle of the sterilizer with an ell and a nipple on the outside for the attachment of a hose of inch size or larger.

The pan is inverted and the sharp edges forced 2 to 4 inches into the ground. The pans should be of the proper proportions to work conveniently between posts and walks. They are simply shifted along the beds as fast as the soil is sterilized. In large greenhouses it is important to have at least half a dozen pans, for two men can easily tend to this number. In small houses heated by hot water it is possible to connect a steam hose with a portable engine, as shown in Fig. 30.

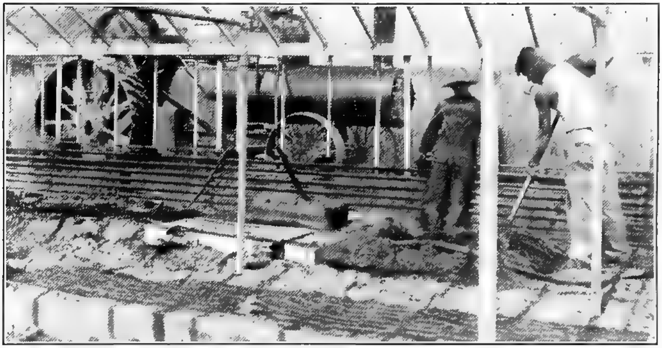

Fig. 30.—A portable steam engine may be used for sterilizing small houses.

A prominent Ohio grower has devised an apparatus for lifting and shifting soil-sterilizing pans which has proven highly satisfactory. He has kindly furnished the following description:

"It consists of a square wooden frame slightly larger than the pan and about 30 inches high, with a small car wheel at each corner. Across the top of the frame is fitted a 1½-inch pipe with a bearing at each end, and on one end a worm gear with crank. Near each end of this pipe a ⅜-inch hole was drilled, and a ⅜-inch wire tiller rope was passed and fastened. This cable must be of sufficient length to reach across the frame, over a pulley at each corner of the frame at that end, and down to a hook in the corner of the pan. Thus, when the cables are properly adjusted as to length, the turning of the pipe by means of the worm gear will wind the cable and lift the pan at all four corners, transferring the weight to the car wheels. The whole apparatus is then rolled along, the width of the pan, and if the worm gear is well oiled, a sharp throw of the crank will cause it to spin in lively fashion, lowering the pan to its new position. The gear is intended for raising short lines of light ventilators, but fills this purpose admirably. Steam is delivered in the center of the pan by means of a hose from a temporary steam line into a pipe running lengthwise beneath with a few holes drilled through to spread the steam."

Perforated pipe.—The perforated pipe system is popular and highly satisfactory. There are many modifications in its installment, but the general plan is to provide gangs or sets of perforated iron pipe. These may

Fig. 31.—Peg or rake steam sterilizer used by some growers at Toledo, Ohio.

be 25 to 90 feet long, depending upon the supply of steam, size of house and number of men available to move them. Fifty-foot lengths are convenient to handle. The number of pipes in each set is variable, although five is a common number. The perforated pipes are usually 1¼ inches in size, although 1½-inch pipe is used in some of the largest greenhouses where the gangs are very long. The holes are ⅛ or ¼ of an inch in size, sometimes larger, and about a foot apart. The pipes are laid 16 to 18 inches apart and connected with a 2-inch header.

A successful grower at Irondequoit, N. Y., uses a 2-

inch header with six 1¼-inch outlets or laterals, placed 17 inches apart, the laterals being 45 feet in length and perforated with ⅛-inch holes 10 inches apart. The header is placed crosswise of the bed to be sterilized, with the laterals running lengthwise. The pipes are buried to a depth of about 6 inches and the whole bed is then covered with a heavy canvas. The header is connected with the heating system at the center, giving three lines on each side. The Irondequoit grower referred to has also found ordinary 2-inch corrugated galvanized conductor pipe highly satisfactory. The pipes are light, easily forced together and they cool very quickly so that shifts may be made without discomfort. The perforations may be made with a ten-penny nail. It is desirable to turn the pipes with the perforations down, or to cover them with burlap to keep dirt out of the holes. The perforated pipes are simply buried in the ground beds under 6 or 7 inches of soil, and the bed is covered with heavy canvas to retain the heat. In a very large range at Ashtabula, Ohio, eight gangs of pipe are used to keep quite a large force of men busy shoveling soil and shifting the pipes. A 300 horsepower engine is used in this establishment.

Perforated pegs (Figs. 31 and 32) are used successfully in some sections. This is sometimes called the "steam rake" or the "steam harrow" method. These devices may be made of any convenient size and dimensions. The feed lines and arms are composed of a series of reducing nipples with T's located so that the pegs will be about 8 inches apart, giving the appearance of a harrow. The arms of the feed lines may start with ¾-inch pipe, the second joint ½-inch and the third ⅜-inch. The ¼-inch pegs are flattened at one end into the form of a wedge with a 3-16-inch perforation at the lower end for the escape of steam. A heavy 1-inch hose connects with the steam pipe that leads to the boiler. The sterilizer is forced into the ground and covered with canvas which extends 12 feet or more behind it. Four such devices are in operation at the same time in a large range at Toledo, and they are moved every 10 minutes. Two men can easily take care of this number and also rake down the beds as rapidly as the sterilizers are moved. It is a much less laborious system than when perforated pipes are used, as explained on another page in this chapter.

Tile.—The tile method has some advocates, although it has seldom met with favor in large houses. In principle and practice the system is similar to the perforated pipe plan of sterilization, except that the tiles are sometimes laid permanently and not disturbed from year to year. When tiles are employed they may also be service-

Fig. 32.—Peg steam sterilizer in operation at Toledo, Ohio.

able in sub-irrigation, and be used to raise soil temperatures by the admission of steam whenever this is considered desirable. When laid permanently the initial cost is rather heavy, but there would be a great saving in labor when a long term of years is considered.

Frequency of sterilization.—When sterilization is once started, nearly all growers seem to favor attending to it every summer. One successful grower has found every two or three years sufficient. Sterilization, however, is universally regarded in the same light as fire insurance, and most growers feel that it is unwise to take chances of losses that can be averted by proper methods of disinfection.

After-treatment.—Soils that have been sterilized by either steam or formalin require careful after-treatment. This is particularly true of silty and clay soils, the structure of which is affected by these treatments. They become more compact, and their water-holding power is increased so that there is danger of overwatering such soils until normal relations become established. As soon as dry enough the surface of the ground should be stirred and water applied with extreme caution after the plants have been set.

Formalin Sterilization

Strength of solution.—Most growers who employ this method of sterilization use either three or four pints of commercial formalin of 40 per cent purity to 50 gallons of water. Two pints often prove effective. but a stronger solution is generally preferred. Rhizoctonia or rosette of lettuce may be controlled with less than two pints to 50

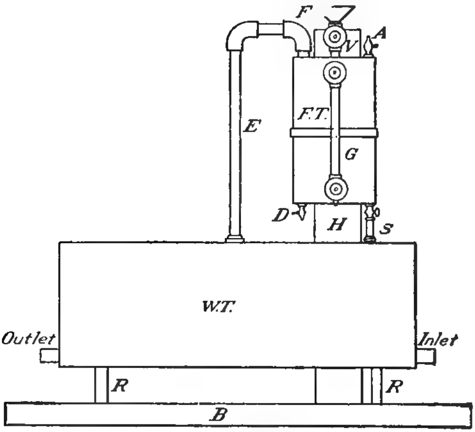

Fig. 33.—Apparatus for formalin sterilization. (*W. T.*—Water tank. *F. T.*—Formalin tank. *G.*—Water-glass gauge to show quantity of formalin. *A.*—Air cock. *V.*—Valve. *F.*—Funnel. *E.*—Air pipe to maintain same pressure in both tanks. *D.*—Drain-off cock. *H.* and *R.*—Supports. *B.*—Base. *O.*—Outlet. *S.*—Glass tube through which the formalin drops to tank below.)

gallons, but the weaker solutions do not seem to be effective against many other diseases.

Application.—There is universal agreement that one gallon of the solution should be applied to each cubic foot of soil in order to thoroughly saturate every particle. It may be applied by means of watering cans, sprayers, barrels with hose attachments, overhead system of watering, special devices and through the regular water pipes of the house, and at different times, if the soil does not absorb the solution promptly.

The watering-can method is slow and tedious and should not be used except in small houses. Sometimes barrels are supported on trellises 5 or 6 feet above ground and bibs inserted for hose attachment. A frame 10 feet square may be shifted from place to place, and this will mark each area which should receive a barrel of the solution. In soils that do not absorb water rapidly it will be necessary to return to the same areas two or three times in order to apply the full amount and to avoid puddling the surface.

The pipes used in the overhead system of watering have been employed sometimes, but the lack of uniform distribution is an objection to this plan.

B. H. Thorne, in the 1909 Report of the Vegetable Growers' Association of America, gives the following description of the formalin tank which is shown in Fig. 33:

"In order to get the right proportions, run clear water through the tank into a barrel of known capacity and time it, then run water through the formalin tank under the same pressure as the water, regulating it by the valve at *S* until the formalin tank runs one pint of formalin to 25 gallons of water. The water tank should be at least ten times the capacity of the formalin tank in order to furnish air to take the place of the formalin used.

"The apparatus should be pumped full of air before it is used. A bicycle pump attached at *A* will do it nicely. The mixture will be as thoroughly done as in ordinary spraying. Be sure to have the outlet at the faucet end from the formalin entrance at *S*."

Mr. Thorne also gives in the same report the following description of a formalin mixer, making it possible to apply the solution through the regular water pipes:

"The formalin mixer is made of two ordinary kitchen range tanks, one above and at one side of the other. The upper one holds the formalin and the lower one is the mixer. The tops of both are connected by a small pipe with a valve in it. This pipe is to equalize the pressure in both tanks by the passage of air back and forth.

"The formalin tank has a glass water gauge at the bottom to show when the formalin gets too low, and the lower tank a gauge at the top to show when the water gets too high. From the bottom of the formalin tank a ¼-inch pipe goes down to meet the pipe from the waterworks running into the bottom of the lower tank. Connecting the end of the ¼-inch pipe with the water-works pipe are a needle valve to regulate the flow of formalin, and another glass gauge to show that the formalin is running properly.

"The formalin and water are mixed in the lower part of the lower tank by the moving water coming in continuously and the mixture runs out about one-third of the way up back into the water-works system. The apparatus is connected to the regular watering system through a by-pass.

"In order to get the right proportions of formalin and water, run 50 gallons of water through the apparatus and time it, and then regulate the needle valve to run out two pounds in the same time. An air-pump is needed to force air into the upper tank to force back the water in the lower tank when it gets too full. With this apparatus one man can apply the mixture as fast as the water runs."

It is also important to spray walks, benches, flats and tools with formalin.

After sterilizing with formalin, planting should be deferred 10 days to two weeks because the plants will be injured if set too soon.

Cost.—So many factors enter into the expense of sterilizing with formalin that it is difficult to give definite cost figures. When a mixer was used, Thorne claimed that the solution and its application cost about two-fifths of a cent a cubic foot, provided the formalin was bought in barrel lots at wholesale prices. A later circular (No. 151) of the Ohio station places the cost of material for only one house of 3,000 square feet at $21. This is much above the required expenditure for steam sterilization as estimated by the same station, viz., by perforated pipe method $15.40 for 3,000 square feet, and inverted pan method $12.20 for 3,000 square feet. A prominent Cleveland grower, who has about four acres of glass, states that two men with four pans will sterilize 3,000 square feet in two days, the labor costing $8, and fuel $6, or $14 for this area. An account was kept in a well-managed house at Irondequoit, N. Y., where perforated pipes were used, and the actual cost in a 30 by 180 foot house—5,400 square feet of space—was $22.50.

Hot Water Sterilization

This method of sterilization has been attracting attention for several years. Waid, in a recent issue of the *Market Growers' Journal*, writes as follows on this subject:

"Recent accumulative evidence has demonstrated the value of hot water as a treatment for greenhouse soil, especially when the soil is infested with nematodes. To be effective, however, it is necessary that it be forced into the soil to a considerable depth, 6 or 8 inches, and at a very high temperature. A grower at Grand Rapids, Mich., used hot water on most of his greenhouse soil this season with very satisfactory results. He heated the water in one boiler, then forced it into a second boiler in which the water was kept at a temperature of 238 to 240 degrees, under a pressure of 15 pounds. It required two days for five men to treat one house 275 by 34 feet. About five tons of soft coal was consumed per house. The total cost of treating one house was about $50. One bed of the same size was treated with $100 worth of formaldehyde. The hot water treated beds gave the best and heaviest crops. The soil was a light sand. It would seem that so much water might 'puddle' a heavy soil."

Tompson, in the same issue of the *Market Growers'*

Journal, comments as follows about the use of hot water in sterilizing soils:

"We have some progressive growers who have done good work with hot water and are becoming advocates of this method when properly used. The plan is to force the water into the soil under pressure, with more or less live steam combined with the water. A gas pipe about 4 feet long is placed on the end of a hose and the pipe is forced into the soil to a depth of 6 or 8 inches. This puts the water down quite deep where the heat is held and warms the soil downward as well as upward. This necessitates very thorough work, the pipes being forced into the soil every inch or two back and forth across the beds and thus thoroughly saturating the soil with boiling water. The ground seems to be heated to a depth of 10 or 12 inches and cucumber growers have succeeded in eliminating trouble from nematodes very much more successfully by this method than by any other. Sterilizing for other common diseases of lettuce, cucumbers and tomatoes is easy compared with nematode destruction."

CHAPTER VII

INSECT ENEMIES AND THEIR CONTROL

The insect problem demands the most careful consideration of greenhouse vegetable growers. Practically every greenhouse crop has one or more insect enemies. Some of these pests are parasites on the roots, and others feed on parts of the plant above ground. They cause enormous losses annually. The various means of control are better understood than they were a few years ago, and for that reason future losses should gradually diminish. Success in each instance depends primarily on timeliness and thoroughness of application of the proper method of control.

Preventive measures.—Cleanliness in the greenhouses and adjoining workrooms is exceedingly important in preventing insect depredations. The entire establishment should have a thorough cleaning annually, and more frequently if possible. The most propitious time for a complete renovation is during the summer, usually in August, when there are no growing crops in the houses. It is then possible to remove all rubbish, repaint the wood work, take out decayed parts of benches, and to thoroughly clean every part of the range, packing room and furnace rooms.

Not only should a thorough cleaning be made annually, but rubbish which is likely to harbor insect pests should not be allowed to accumulate at any time under the benches or about the workrooms. Weeds in the houses, especially during the summer months, are almost certain to become the hosts of pests which later may develop into enemies of the forcing crops. It is almost equally important to keep the premises about the greenhouses free from weeds and debris which may harbor foes of the vegetables grown under glass.

Steam sterilization (Chapter VI) is universally admitted to be the most effective preventive measure in controlling many of the insect foes of forcing crops. Fumigation with hydrocyanic gas, at the rate of five ounces of cyanide of potassium to 1,000 cubic feet of space, is destructive to all animal and plant life, but it should not be used when there are any crops in the houses.

Care should be exercised to select for greenhouse purposes soil which is free from white grubs, cutworms and wireworms. If they are known to exist in the soil, thorough steam sterilization before the beds are planted will be a certain method of destroying them. Insect enemies may be introduced through manure, and it is therefore important to apply it to the beds before they are sterilized.

Red spiders and various insects, like thrips, aphids, white fly and nematodes, may be transferred to the houses on plants. When this happens, the plants should be dipped, fumigated or perhaps destroyed, if they are badly infested.

The rotation of crops is always helpful in avoiding losses from insect depredations. For example, it is much more difficult to control the white fly on tomatoes if the crop is grown throughout the year than it is if lettuce is produced a part of the year.

Insect ravages are generally less harmful to crops that are making a vigorous growth. It is important, therefore, to employ every possible means to promote rapid growth, avoiding at the same time the development of soft, tender plant tissues, which are preferred by insects and very susceptible to the attack of fungi.

Steam sterilization is extensively used for the control of insects and diseases affecting greenhouse crops. See Chapter VI.

Tobacco fumigation.—It is undesirable to use spray materials as generally in the greenhouse as in the management of crops grown out of doors. It is possible to employ in inclosed structures methods that are impracticable in the open ground. Fumigation has been practiced for many years in controlling the ravages of certain insects, especially aphids and the white fly. The poisonous alkaloids of tobacco are especially destructive to the various species of aphids or plant lice.

Fumigation by the burning of tobacco stems is the most common method of combating plant lice in the large vegetable-forcing estabishments. The stems, which are mostly the mid-veins of tobacco leaves, should be as fresh as possible in order to make an effective smudge. They can often be obtained at slight cost from local cigar factories. They vary considerably in strength, due to age and possibly to different varieties, and this factor should be kept in mind when stems are procured from different sources.

The stems should be dipped in water or sprinkled, so that they will be moist when the smudge is started. A convenient way is to place the stems in old burlap bags, kept for the purpose, and to plunge them into a tub or a tank of water. After the surplus water has been drained off, the stems are ready for the fire and the bags will be found convenient for carrying them through the houses. Many greenhouse men simply sprinkle the stems a few hours before they are wanted for use. It is possible to make them too wet to burn, especially if they have been stored in a moist place.

Some growers make the smudge immediately after daylight, but the most common practice is to attend to this operation in the evening, when it will not interfere with regular work in the houses.

No general rule can be given relating to the frequency of fumigations. This will depend on the crops under cultivation and the prevalence of aphids. It is important to start with plants apparently free from lice. If this is done, once a week may be sufficient. When there are evidences of serious trouble, it will be best to fumigate lightly on three successive nights. This is regarded as more effective than one strong treatment, which may injure the plants. If the three treatments are successful, no further attention may be needed for a week or ten days.

The danger of injury to the crops will depend upon the plants that are under cultivation; cucumbers are more easily affected than tomatoes, but tomatoes are more susceptible to injury than lettuce. If the plants have been grown too rapidly and the tissues are soft and tender, injury is likely to occur. High temperatures are largely responsible for injuries from tobacco fumigation. Gourley made the following interesting experiment:

"A small test was run on the effect of smoke on lettuce in the following manner: A rectangular box 32½ inches by 13¼ inches by 15¾ inches (inside dimensions) with a capacity of 753.6 cubic inches was placed over four lettuce plants of a size ready to be marketed. The temperature within the box before starting the smudge was 54 degrees. A dense smudge was created in one end of the box with dried tobacco leaves. When the box was raised after an exposure of 15 minutes the temperature was 115 degrees, and the plants covered with a viscid, brownish precipitation of nicotine compounds which was intensely bitter and sickening to the taste. The leaves were mostly limp and brown.

"Again the box was placed over four fresh plants of the same size as the former; the temperature was standing at 60 degrees within the box. Two sections of stove pipe were secured; the lower one had a false bottom of wire on which we could build the smudge and pass it up into the box through the second piece of pipe. The dimensions of the pipe were 4 feet long and 7 inches in diameter. The smoke was thus cooled somewhat before it came in contact with the lettuce. The exposure as before was 15 minutes. When the box was raised the temperature was 90 degrees, being 15 degrees lower than in the previous trial. The leaves were not injured nearly as much, but in the same manner, indicating that the injury was proportional to the amount of heat accompanying the smudge. This injury occurs rarely in practice."

A practical grower has observed that lettuce is easily injured by tobacco fumigation at a temperature of 60 degrees, that light treatments may be made at 55 degrees without injury, that strong fumigations may occur at 50 degrees without injury, and that it is almost impossible to damage the crop at a temperature of 45 degrees.

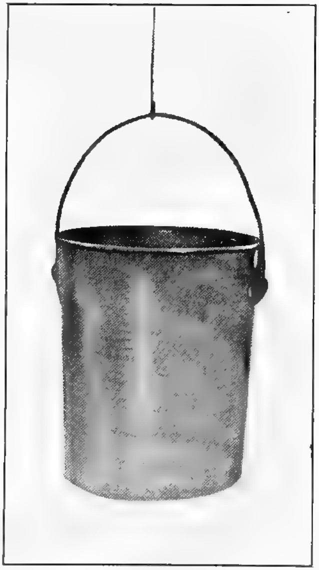

Fig. 34.—Garbage can suspended to wire, used in fumigating with tobacco stems.

The danger of injury will be very much less if the plants are dry during the smudging. It is necessary, of course, to have the house well filled with the smudge in order to make the treatment fully efficacious.

The stems are sometimes placed on the walks, but it is better to put them in kettles, cans, wire cages or other metal utensils. Some of the Toledo growers use a special wire cage in which the dry stems are placed and then soaked with water. Garbage cans (Fig. 34) are employed sometimes.

The fires are always started in the lower part of the house, as on the walks, because the smudge rises slowly and gradually fills the house. The stems create a considerable degree of heat and, therefore, the fires should not be started close to wood or other inflammable material. One fire for each 50-foot unit of house 25 by 40 feet wide will give satisfactory results. A little experience will soon enable the operator to use the required amount of stems to make a good smudge. Some dry material, such as paper, small pieces of wood, corn cobs, etc, are placed in the bottom of the container, and the moist tobacco stems above. A common practice is to use a little kerosene to start the fires.

Tobacco preparations in various proprietary forms may be purchased from nurserymen, seedsmen and other dealers. Most of them are excellent and some are considered more efficacious than the burning of tobacco stems. They are also more convenient to use and the expense may be no greater, especially if the stems must be bought from a middleman instead of a factory, and shipped, perhaps, a long distance, thus incurring a heavy freight bill.

Fumigating powders are in common use. These may be placed on shallow pans in the greenhouse walks, and a few drops of kerosene added to facilitate ignition. The powders burn slowly and gradually fill the house with fumes which are poisonous to all forms of aphids.

Liquid extracts of tobacco are popular among florists, and they are used to some extent by vegetable growers. These concentrated forms may be vaporized by pouring them on hot pipes, plunging hot irons into kettles of the extracts, or by the use of hot steam admitted through a steam hose into the extract. Special vaporizing lamps may be purchased which are highly satisfactory. The liquid extracts may also be diluted and applied as a spray. This plan is not regarded as satisfactory for lettuce, because it is not desirable for any kind of a tobacco solution to come into contact with the leaves.

Sheets of paper, impregnated with concentrated tobacco extracts, are popular with some gardeners, and especially with frame vegetable growers. The papers are easily ignited and convenient to use.

Ordinary tobacco powder is often dusted on cucumber plants and sometimes on lettuce, but it is only moderately effective, because it serves mainly as a repellent. It also acts as a preventive when placed on top of the soil when the lettuce is planted.

Hydrocyanic gas fumigation.—This method of destroying insects which feed on greenhouse vegetable crops is now employed by most of the large commercial growers. It made slow progress for many years, mainly for two reasons—the danger to the fumigator and to others likely to be about the establishment, and the possibility of injuring the plants.

Numerous experiments, however, made by scientists as well as by practical growers, have demonstrated that hydrocyanic gas, when properly used, is a cheap, safe and effective fumigant. By its use insects may be destroyed which are extremely difficult to exterminate by any other method. Among such pests is the white fly, a most serious enemy of greenhouse tomatoes and cucumbers. This gas is a deadly poison also to thrips, plant lice and mealy bugs, but it does not kill the red spider or scale insects unless used sufficiently strong to kill the plants.

The equipment needed for fumigation with hydrocyanic gas is stone or earthenware jars or crocks, which should be of gallon size and fairly narrow. Wrapping paper or preferably small paper bags will be needed for the crystals of cyanide of potassium or cyanide of sodium, which should be 98 to 99 per cent pure. Ordinary commercial sulphuric acid will be needed to produce the gas, and a glass or porcelain measure or dipper should be provided to handle the sulphuric acid. Metal dippers are quickly destroyed by this acid. A suitable basket will be required to carry the packages of cyanide through the greenhouses.

Numerous experiments have been made to determine the amount of cyanide of potassium which will prove effective in destroying the white fly and yet cause no injury to the plants. So many factors are involved that no general rule can be given. Much depends on the condition of the houses. Poorly constructed and old houses with many small openings between the panes of glass and wooden parts will require more cyanide than new, tightly built ranges. Young, tender plants are much more easily injured than older plants with tougher tissues. If it is necessary to fumigate on a windy night much of the gas will escape. Again, if the plants are wet or if the humidity of the house is very high the plants will be susceptible to injury.

The earlier writers on this subject advocated one ounce of cyanide of potassium to 5,000 cubic feet of space. Later, when fumigators became more skillful, one ounce to 3,000 cubic feet was often employed. More recently some of the most extensive and successful growers find that when proper conditions exist the plants are not injured if an ounce of cyanide is used to 1,000 cubic feet. This amount, however, is probably the maximum quantity which should be used under the most favorable conditions. Some of the most cautious growers prefer to make lighter treatments of one ounce to 2,000 to 2,500 cubic feet, and to fumigate more frequently. Ordinarily, the treatment should be repeated at intervals of ten days until no insects can be found. As a preventive measure some greenhouse men fumigate at intervals of two weeks, regardless of whether insects can be found or not. For those who have not had experience in this method of fumigating, it will be safer for them to begin with light treatments, note results and increase the amount of cyanide if necessary and also the frequency of the applications. Five ounces of cyanide to 1,000 cubic feet may be used when there are no crops in the houses and it is desired to kill red spiders and all other animal life.

Daylight fumigations have not been successful. It is always important to attend to this operation at night, when there is no wind. The workmen, too, are then out of the houses and visitors are not likely to be in the establishment.

Dry plants and low humidity are exceedingly important in order to avoid injury to the crops. The losses sustained by those who first tried cyanide fumigation were often due to excessive moisture conditions. Any accumulation of moisture on the plants is certain to absorb the gas and thus damage the plants, and high humidity causes the gas to settle quickly to the beds and walks. There should be no watering or spraying on the days when the houses are to be fumigated.

There is some difference of opinion regarding the effect of the gas at different temperatures of the greenhouses, though most growers believe that the plants are more susceptible to injury when the temperature is high. There is probably little if any difference in the effect of the gas at temperatures ranging from 50 to 60 degrees.

Trials made in a tomato house at The Pennsylvania State College indicate that tobacco and cyanide fumigations may be made to advantage at the same time. Pans of tobacco powders were ignited and immediately thereafter the bags of cyanide, at the rate of only one-third of an ounce to each 1,000 cubic feet of space, were placed in the crocks. This double treatment was found to be highly satisfactory in combating the white fly. It is believed that the tobacco fumes serve to disturb and dislodge the flies, and that the hydrocyanic gas is then more effective in killing them.

There should be sufficient acid to react with all of the cyanide crystals, and sufficient water to dissolve the potassium acid sulphate which results from the reaction. A common formula is one ounce of cyanide of potassium, two ounces of sulphuric acid and four ounces of water. A more recent formula, which is wholly satisfactory and less expensive, is 1-1-3, which provides sufficient acid for chemical reaction. Sodium cyanide, apparently, is just as effective as potassium cyanide. When this is used the formula should be 3-4-6. Sodium cyanide will produce more gas, and only three-fourths as much is required per 1,000 cubic feet as when potassium cyanide is used.

The jars are usually placed 20 to 30 feet apart in the central walk of the greenhouse. Their distance apart depends on the width of the houses. A successful grower of cucumbers uses 12 jars in a 25 by 300 foot house. He places six ounces of water, six ounces of sulphuric acid and 1½ ounces of cyanide of potassium in each jar. A good plan is to have three jars for a house 20 by 100 feet in size, four jars for a house 25 by 100 feet and five jars for a house 30 by 100 feet in size. In very wide houses or in ridge and furrow ranges there may be a number of rows of crocks or vessels.

Preparations for the use of hydrocyanic gas are made before dark. The ventilators and all openings of the house are closed as tightly as possible. The valves regulating the heating pipes are adjusted so that they will require no further attention until morning. Care is exercised to keep all workmen, visitors, children and animals out of the houses. The jars are then properly distributed along the walks, and water is placed in them. The sulphuric acid is added about half an hour before the cyanide is to be used. Violent heat is caused by the chemical reaction of the sulphuric acid and water and it is important for the liquid to cool considerably before the cyanide is added in order to prevent too rapid generation of the gas.

Some growers drop the cyanide into jars without the use of paper bags or packages. It is much safer, however, to use paper containers, for these will resist the action of the acid for a few seconds and make it a safer operation for the fumigator. The proper amounts of cyanide may be weighed on suitable scales or it may be more convenient to have them prepared in proper amounts by the druggist.

When everything is in readiness, all doors are closed and locked except the ones through which the operator is to pass. If there are several rows of crocks there must be a man for each row. The packages are carried in a basket or a convenient receptacle, and the operator usually starts at the end of the house farthest from the packing or service rooms. He passes rapidly from vessel to vessel, carefully placing a packet in each crock so as to avoid splashing the contents or breathing the gas that might escape before he proceeds to the next crock. After the last crock is passed, he leaves the house and locks the door which has been left open for his exit. The house should be carefully guarded for a few hours. There is absolutely no danger in this operation if proper care is exercised.

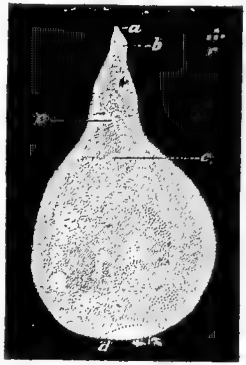

Fig. 35.—Female nematode (Heterodera radicicola) magnified 85 diameters: *a*, mouth; *b*, spherical sucking bulb; *c*, ovaries as seen through the body wall; *d*, anus; *e*, small white spots showing approximately the natural size of these worms. They are usually white. It is generally not difficult to isolate them in water by breaking open the galls containing them. *(After N. A. Cobb.)*

Some growers prefer to raise the ventilation in two or three hours after fumigation is begun, but the more common practice is to wait until the next morning. The houses may then be entered for a few minutes with safety and the ventilators opened as wide as the weather will permit. It is better not to stay in the houses until the ventilators have been opened for at least one-half hour. The odor of the gas will be noticeable the next morning, but this need cause no concern.

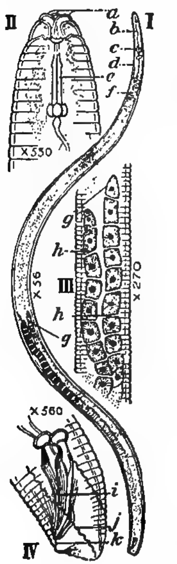

Fig. 36.—Male nematode: I, worm in profile view; II, head of the same, more highly magnified; III, middle region of worm showing blind ends of the sexual organs; IV, posterior extremity. The drawings were prepared from stained specimens, examined in carbolic acid solution. *a*, lips; *b*, œsophageal tube; *c*, median bulb; *d*, excretory pore; *e*, spear; *f*, intestine; *g*, blind ends of testicles; *h*, testicles; *i*, specula; *j*, rudimentary bursa; *k*, anus. *(After N. A. Cobb.)*

Sulphuric acid should also be handled with care. It is destructive to clothing and it burns the flesh. Flesh burns should immediately be washed with water, and oil or vaseline applied.

Inasmuch as cyanide of potassium is a most dangerous poison, it should be kept under lock and key, away from children. The smallest granule taken internally will be almost certain to cause death.

It is a simple matter to determine the number of cubic feet in a greenhouse. For instance, suppose the house is even span and 30 by 100 feet in size, 6 feet from ground to eaves and 9 feet from eaves to ridge. The cubic contents below the eaves would be 30 by 6 by 100 or 18,000 cubic feet. The space above the eaves would be 30 by 9 by 100 divided by two, or 13,500 cubic feet, a total of 31,500 cubic feet for the house. To determine the space above the eaves in an uneven-span house, draw a perpendicular line from the ridge to the level of the eaves, thus making two triangles. The contents of each triangle may be ascertained by multiplying the height of the perpendicular side of the triangle by the length of the base line and that product by the length of the house. This total divided by two will give the capacity of the triangle. If the eaves are not on a level, the space may be divided into rectangles and triangles and the cubic contents of the house calculated similarly to the foregoing method.

Miscellaneous insecticides, in addition to those previously described in this chapter, are sometimes employed in the treatment of greenhouse vegetable crops. Kerosene emulsion is a standard spray for the control of aphids, though the liquid tobacco preparations are generally preferred for use in the greenhouse. Arsenate of lead, when an arsenical poison is needed, is most satisfactory for greenhouse purposes. Various soaps and soap preparations, some of them proprietary, are useful in checking the ravages of certain insect pests. It will seldom be necessary, however, to use any of these materials if the major treatments previously described are thorough and timely.

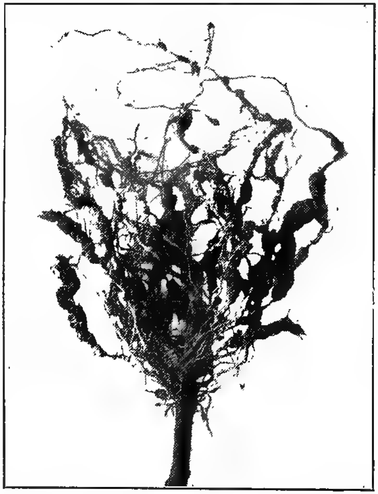

Fig. 37.—Galls on cucumber roots produced by nematodes.

The spraying apparatus for greenhouse use should be light and convenient to operate. The various forms of knapsack sprayers are sometimes employed. Automatic tank pressure sprayers are becoming popular. Some growers prefer bucket pumps, but they are not the most convenient forms for greenhouse sprayers. Hand atomizers are very useful for treating small lots of plants. An extensive Ohio grower uses a pressure tank mounted on a cart. A very long half-inch hose enables him to spray the houses with only an occasional moving of the cart. The plan is entirely satisfactory.

Nematodes (Heterodera radicicola).—These little pests, which are nearly microscopic in size, are variously known as gall worms, eelworms and thread worms. The trouble which they cause is often referred to as root knot and root gall, and sometimes as big root. The last term should not be confused with the malady "big root" and "club root" of cabbage and other brassica, caused by a slime mold. Nematodes are widely distributed throughout the temperate and tropical parts of the world. High temperatures and long summer seasons are most favorable for their existence, and for these reasons they are most troublesome in southern sections.

Greenhouse conditions are naturally ideal for nematodes. They are especially destructive to the cucumber and tomato, and they sometimes infest asparagus, muskmelon, pea, bean, beet, celery, carrot, eggplant, pepper, onion, spinach and radish. More than 500 kinds of plants are said to be subject to the attack of nematodes. Roots with soft, tender tissues, such as the cucumber, provide favorable conditions for this enemy.

Fig. 38.—Roots of tomato plant completely invaded by gall worms. *(After George F. Atkinson.)*

The two sexes of the nematode are shown in Figs. 35 and 36. These worms are so minute that it is necessary to use enlarged illustrations in order to show their various features. Fig. 35 represents the mature female, which is nearly pear-shaped and less than a millimeter in length. The body cavity of the female is occupied by eggs and larvæ. Fig. 36 shows the slender, threadlike male, which is 1 to 1.5 millimeters in length, with enlarged parts. Scofield, of the U. S. Department of Agriculture, gives the following life history of the nematode in Circular 91, U. S. Bureau of Plant Industry:

"The larvæ of the gall worm upon hatching from the egg, which hatching sometimes occurs within the body of the parent, ultimately escape from the host plant and live for a period in the surrounding soil. These larvæ, although very active, have but little power of progressive locomotion, and the spread of infection from place to place must depend upon the transportation of infested soil or infested plants. Soon after emerging from the parent and the tissue of the host plant these larvæ seek other roots and bore their way into the plant tissues by means of a spearlike structure, which is protruded from the mouth. They feed upon the cell sap of the host plants.

"After fertilization takes place the females begin reproduction by forming eggs within the body. These eggs are laid at the rate of from 10 to 15 a day, and it is estimated that one female may lay as many as 500 eggs. After completing the egg-laying process the female dies, the male having died soon after fertilizing the female.

"The worm lives from one season to the next, either in the egg stage or in the larval stage within the host plant. The life of the individual worm is short (only a few weeks), when temperature and moisture conditions are such as to favor growth.* It is possible, therefore, to greatly reduce the numbers, if not to exterminate the worm entirely, by keeping the infested land free from plants upon which the worm can feed."

The characteristic root galls of the cucumber, produced by this parasite are shown in Fig. 37, of the

* Additional information concerning the life history of this parasite, with a list of susceptible plants and details of experiments in controlling the nematode in the southeastern United States, may be found in Bulletin 217 of the Bureau of Plant Industry, entitled "Root-Knot and Its Control," by Dr. Ernest A. Bessey.

tomato in Fig. 38, of lettuce in Fig. 39. Serious derangement of the normal life functions is caused by the worms, which results in the development of irregular galls and the imperfect nutrition of the plant. Evidence of infested roots may be indicated by the leaves becoming sickly or yellowish or by the stunted and dwarfed appearance of the entire plant. If the attack is serious, yields will be greatly diminished or the plants may die before any crop is harvested. The fleshy enlargements are watery and tender, and they provide ready entrance for fungi and bacteria, which may cause rapid decay and additional interference with the nutrition of the host plant.

Fig. 39.—Galls on lettuce roots caused by nematodes.

Nematodes migrate very slowly, not more than a few feet a year, but they may be introduced or distributed in the greenhouse by means of infested soil, manure and plants. They may be conveyed about the establishment on the shoes of the workmen and on the various tools which are used for tillage operations.

Numerous preventive measures have been advocated. Chemicals of various kinds have not proved practical. Lime is probably of no value, for the worms will live for several days in a saturated solution of lime. Formalin has been used with slight success. Freezing, desiccation and inundation are valuable to some extent, but they are not regarded favorably by greenhouse growers. The only means which have been found to be economical and satisfactory in destroying the pests are thorough sterilization with steam and hot water. (See Chapter VI.) After the beds have been planted and the crop is found to be infested, nothing can be done until the plants are removed and the soil sterilized.

Aphis.—Various species of the aphis feed on the different vegetable forcing crops. They are commonly called plant lice and green and black flies. While there is considerable variation in the structure of the different species as well as in their life histories, all have sucking mouth

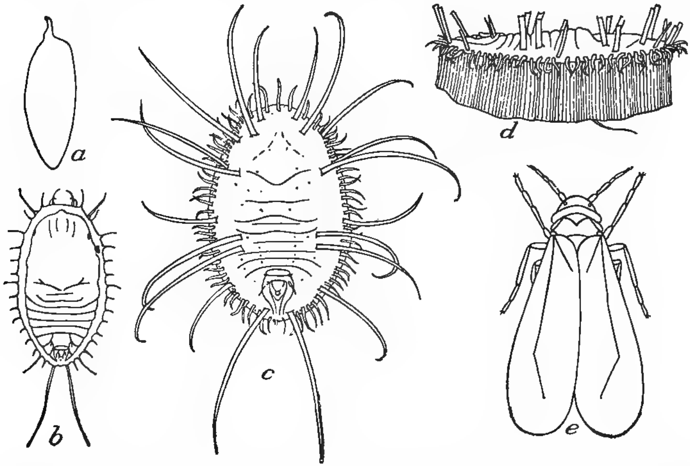

Fig. 40.—White fly *(Aleyrodes vaporariorum)*; *a*, egg; *b*, young larva; *c*, pupa, top view; *d*, pupa, side view; *e*, adult—*c*, *d*, *e*, about 25 times natural size; *a*, *b*, still more enlarged; (*a*—*d*, after Morrill, Tech. Bul., Mass. Exp. Sta.; *e*, original.)

parts. They are extremely persistent on some crops, such, for example, as the green fly on lettuce. The young are brought forth alive, and they reach maturity in seven to ten days and begin to produce young, so that innumerable insects may appear from a few parents within a remarkably short time, unless preventive measures are taken.

Inasmuch as plant lice have sucking instead of biting mouth parts, they cannot be killed by stomach poisons such as arsenate of lead, but must be destroyed by contact insecticides or by suffocating fumigants. Tobacco extract and soap solutions are the most commonly applied of the liquids, and tobacco fumigation is universally regarded as the most desirable means of controlling the green fly, especially on lettuce. See page 224.

White fly (Aleyrodes vaporariorum).—The greenhouse white fly is widely distributed among establishments devoted to vegetable forcing. It is universally regarded as one of the worst foes of greenhouse crops, and must be combated in an intelligent and vigorous manner in order to prevent the most serious ravages. Tomatoes and cucumbers suffer most from the depredations of the white fly. Lettuce, eggplant, bean, melon and many floral crops are subject to attack.

A complete description and life history of the white fly (Fig. 40), and remarks on the appearance of infested plants are given as follows in Circular 57, U. S. Bureau of Entomology:

"The mature white flies of both sexes are four-winged insects scarcely more than 1½ millimeters or three-fiftieths of an inch in length. The adult white flies, as well as the scalelike larvæ, are provided with sucking mouth parts. In a short time after the emergence of the adult from the pupa case, the body, legs and wings become covered with a white, waxy substance which gives this, as well as other species of the genus, a characteristic floury appearance. The adults feed nearly continuously during their existence. If deprived of food, they will rarely live for a longer period than three days under ordinary temperature conditions. The longest recorded length of life of one of these insects in the adult condition is 36 days, but it seems probable that the average length of adult life is much greater than this would indicate. The largest number of eggs which an adult white fly is positively known to have deposited is 129, but this number is probably below the average. Indeed, the specimen which produced this number of eggs with little doubt deposited over 50 others which were not recorded. The number of eggs deposited per day by an adult female white fly in a laboratory has been found to average very nearly four. Probably in the warmer temperature of a greenhouse this number is greater by one or two eggs per day. These observations, even though falling short of showing the normal increase in numbers of this species, emphasize the importance of a remedy which will, above all, destroy the adults and check at once the rapid deposition of eggs. A peculiarity of the egg-laying habits of this and some other species of white fly is the tendency to deposit the eggs in a circle while feeding, using the beak as a pivot. These circles, when completed, are about 1½ mm. in diameter and usually contain from 10 to 20 eggs each. On the more hairy leaves groups of eggs of this kind are less frequently met with than on those which are more nearly smooth. The majority of the adults are found upon the upper and newer leaves of the food plant. They are almost invariably found upon the underside of the leaves, and it is here that nearly all the eggs are deposited, although many are found upon the tender stems and leaf petioles and a very few scattering ones on the upper surfaces of the leaves.

"The eggs are distinguishable with difficulty by the naked eye, being but one-fifth of a millimeter, or one one hundred and twenty-fifth of an inch, in length. They are more or less ovoid in form and suspended from the leaf by a short, slender stalk. With ordinary greenhouse temperatures the eggs hatch in from 10 to 12 days. The newly hatched insect is flat, oval in outline, and provided with active legs and antennæ. It rarely crawls farther than one-half inch from the empty eggshell before settling down and inserting into the tissue of the leaf its threadlike beak. After feeding for five or six days, the insect is ready to molt its skin. The second and third stages are much alike, except in size, and differ principally from the first stage in that the legs and antennæ are vestigial and apparently functionless. These two stages occupy from four to six days each.

"The so-called pupal stage, up to the time when growth ceases, is in reality the fourth larval stage, the fourth larval skin enveloping the true pupa. The pupæ and empty pupa skins are quite conspicuous when the insects are abundant. Their outline is similar to that of the larvæ, but they are thicker and boxlike, about three-fourths of a millimeter, or three hundredths of an inch in length, and provided with long, slender wax rods or secretions which are useful in distinguishing this from nearly allied species of the white fly.

"The entire stage from the insect's third molt to the emergence of the adult form lasts from 12 to 16 days in the laboratory and greenhouse. The adult emerges from a T-like opening, leaving the glistening white pupa case attached to the leaf. At first the wings of the adult are crumpled close to the body, giving them a peculiar appearance. In the course of a few hours the wings unfold and the insect has then completed its development, which has extended over nearly five weeks, if under the ordinary temperature conditions of a greenhouse.

"*Appearance of infested plants.*—As already stated, the upper leaves of a plant are preferred by the adult females for the deposition of their eggs. Thus there is a slow but continuous migration of adults upward to keep pace with the unfolding of the leaf buds. On thoroughly infested plants we find on the uppermost leaves only adults and freshlv laid eggs; a little lower on the plants we find eggs in the process of hatching; and, finally on the lowermost parts of the plants we find discolored, shriveled leaves with many pupæ and emerging adults and few, if any, unhatched eggs or young larvæ. The larvæ and pupæ secrete little globules of honey-dew, so named after the material of a like nature secreted by plant lice. These globules usually either drop or are forcibly ejected, and falling on the upper surface of leaves directly below, give them a glazed appearance. This is frequently followed by the growth of a sooty fungus which hastens the complete destruction of the leaf.

"When overcrowding of the young occurs, this fungous growth finds favorable conditions for its development on the under surface of the leaf, resulting in the destruction of many of the immature insects. Owing to the interference with the respiratory processes of the leaf, both by the bodies of the insects themselves and by the fungous growths due to them, badly infested plants have a tendency to wilt when exposed to the sun's rays. In seriously infested greenhouses the leaves of the plants gradually die, the lower leaves first, and if unchecked the insects greatly impair the value and vitality of the plants, even though they do not actually cause their total destruction."

In the control of the white fly in greenhouses, preventive measures should be taken as much as possible. The pests are so minute that they may easily be introduced into a house without being observed until considerable damage has been caused. When plants are transferred from frames or other houses they should be in inspected with extreme care, and if even a few white flies are found the plants should be fumigated before they are set in the permanent beds. Special boxes or small beds may be employed for this purpose, where hydrocyanic gas may be used with safety. Fumigation with this gas is recognized as the most effective means of controlling the white fly on tomatoes and cucumbers. See Page 109 for directions.

Nicotine solutions are applied to some extent to kill the white fly. These sprays are not effective unless they come in contact with the insects. The same may be said of various soap solutions. Fumigation involves much less labor and it is not so expensive as spraying, whatever may be the character of the solution.

Red spider (Tetranychus telarius, Linn.) is a common pest of the greenhouse cucumber and tomato, and it also feeds on the melon, bean, eggplant and many ornamental plants which are grown under glass. If unchecked in its ravages serious losses may result.

Though commonly known as the red spider, it is a mite instead of a true spider, and for this reason Ewing of the Oregon Agricultural College has suggested the name "spider mite." The fact that the body is seldom red is an additional reason for dropping the old name. Ewing has made a very thorough study of the spider mite, and we are indebted to him for most of the information which is given here in regard to its life history. Those who are especially interested in the spider mite should read Bulletin 121 of the Oregon Agricultural College.

According to Ewing and other workers, a single female may deposit from 51 to 94 eggs, and she may lay as many as 15 in a day. If a mite is feeding on soft, tender parts of favored host plants, and the temperature is high, the greatest number of eggs will be laid. In other words, low temperature and poor food are unfavorable to egg production, and suitable conditions maintained in the greenhouse for plants requiring high temperatures are favorable for the rapid multiplication of this pest. The incubation period ranges from three to eight days, the length depending on temperature. All of the eggs noted by Ewing hatched, unless the temperature was too low or they were destroyed by predaceous insects. The spider mite is parthenogenetic; that is, fertilization is not necessary in order that the eggs may hatch.

The new almost flesh-colored larva begins to feed soon after it is hatched, and remains near the plant where it emerged from the shell. While the larva does not spin a web it is frequently found on webs spun by adults. A trifle more than three days is the average period of the larva stage, and about the same time is required to pass the first nymph stage, when the mites are also active feeders. The second nymphs have the ability to spin webs, and the duration of this period is practically the same as for the first stage. There is an active and a quiescent period in each of the three stages explained. The average duration of the adult stage is over 21 days, and eggs are laid throughout the period, except about the first five days.

The eggs are nearly spherical, covered with a tough shell, pearly in appearance and 0.09 millimeter in size. They are deposited singly, but generally close together. The larva is almost spherical, flesh-colored and has but six legs. It averages 0.19 millimeter in length. The first nymph is very similar to the larva, except that it possesses an extra pair of legs and is larger, being 0.27 millimeter in length. The second nymph is very similiar in shape to the first, but averages 0.36 millimeter in length.

The adults vary greatly in color. They may be green, yellowish, greenish yellow or bright orange. Females average 0.42 millimeter in length and the males 0.32

millimeter in length. The mite is provided with suctorial mouth parts, requiring for its extermination contact insecticides rather than stomach poisons.

Numerous measures are recommended for the control of spider mites in greenhouses. The destruction of all weeds in the greenhouse during the summer season is a valuable precaution. Weeds near the houses may also be a source of infestation. Plants which are purchased or transferred to other houses should be carefully examined, and sprayed if found to be infested. Infested individual plants may be found from time to time. Such plants should receive prompt attention, to prevent the distribution of the pests. Plants should be promptly removed from the houses after crops have been harvested, so as to prevent further breeding of the mites. Rotation of crops is always helpful in controlling the ravages of the red spider. Fumigation with tobacco and ordinary strengths of hydrocyanic gas is not effective, because the mite, not being a true insect, does not possess spiracles or breathing spores, hence killing by suffocation is extremely difficult. An experiment was made by Ewing, in which he used approximately one ounce of potassium cyanide to 1,000 cubic feet of space; 50 larvæ, 40 nymphs and 30 adults were placed on plants, and results noted. The ventilators were not raised for 15 hours. At the end of this period, 32 larvæ, 25 nymphs and 27 adults were found to be alive, thus proving the inefficiency of this gas in killing spider mites.

Various sprays are used successfully in combating this enemy of greenhouse crops. Water has long been known as an enemy of the red spider, though the use of water alone does not always prove fully effective. There are abundant evidences that the force of the spray, whether of water or some other solution, is an important factor in destroying mites. A fine spray applied with force knocks the mites from the leaves, thus injuring them so that few return. Special nozzles have been devised for this purpose.

Soap solutions are often employed, but there is a difference of opinion regarding their value. One ounce of laundry soap to five gallons of water is an approved formula for this purpose. Whale oil soap, two pounds to 50 gallons of water, is also used.

Sulphur in various forms is used extensively in combating red spiders. Dry sulphur may be applied to the plants with a dust gun. Sulphur as a liquid spray has not been very effective against the red spider on cucumbers. Sulphur is sometimes painted on hot greenhouse pipes, where it slowly volatilizes, thus becoming a fumigant. For many years florists considered this practice of value in suppressing red spiders. Experiments made by Ewing show the futility of it. He says: "Eleven days of this treatment had not the slightest effect upon the spider mites. The practice may be considered as foolish and useless as the equally old and time-honored custom of throwing handfuls of powdered sulphur in the crotches of trees in order to eradicate mites in an orchard."

Tobacco sprays are employed by many greenhouse growers. The Ohio Experiment Station obtained excellent results in the greenhouse by using one-half pint of a proprietary tobacco extract, two quarts of lime sulphur and 25 gallons of water.

Oil emulsions are effective sprays against the red spider. Ewing recommends two gallons of distillate, four pounds of whale oil soap and 100 gallons of water. Dissolve the soap in a few gallons of hot water by heating. Add the oil and agitate in the usual way with a force pump until the solution is well emulsified, and then dilute to 100 gallons.

Miscellaneous pests, such as white ants, white grubs, sow bugs, snails, millipedes, wireworms and cutworms, which may cause injury to greenhouse vegetable crops, may be eradicated by thorough soil steam sterilization before the crops are started in the permanent beds.

CHAPTER VIII

DISEASES AND THEIR CONTROL

An important factor.—Anyone who engages in vegetable forcing will be compelled to give consideration to the disease factor. If a new house is constructed and the utmost care exercised in the selection of soil and in the management of the crops, diseases may not appear for several years. But they will ultimately be found and if not checked they will soon cause serious losses..

If the grower is to cope with the disease factor in a satisfactory manner, he should be familiar with the parasites which are most likely to appear. He should know their life histories and how the crops become infected. A knowledge of the conditions, which are most favorable to the development and dissemination of the diseases is highly important. The several means of prevention and control should be studied and the utmost care exercised in the selection and execution of the plans which are most promising. In many instances success depends more upon timeliness and thoroughness than upon any particular plan.

Sanitation.—All that has been said in Chapter VII pertaining to greenhouse sanitation, and its importance in avoiding insect depredations, applies even more directly to the disease problem. The utmost cleanliness at all times in and about the greenhouses and service rooms will be valuable as a preventive measure. The use of disinfectants during the summer or at other times when there are no crops in the beds will prove effective in guarding against possible attacks. There are times when it pays to disinfect pots, flats, dibbers and all soil tillage tools used in the beds. Refuse and all old plants should be promptly removed after the harvesting of every crop, so as to immediately stop the further progress of any disease that may be present.

Soil selection.—Unless the most thorough steam sterilization is practiced, too much care cannot be exercised in the selection of soil which is not infected with disease germs of the crops to be grown. For example, it will be folly to select a garden soil in which lettuce, tomatoes and cucumbers have been grown for many years when these same crops are to be grown under glass. When new ranges are constructed, it may be possible to select soils so free from infection that radical measures of control, such as steam sterilization, may not be necessary for several years.

Manure selection.—Infection of greenhouse vegetable crops may easily occur through stable manures. For this reason, soil sterilization, whether steam or formalin, is used, should be practiced after the manure is applied.

Infected plants.—Diseases are often introduced when infected plants are purchased or transferred from other houses. In new establishments, where there may be no evidence of fungous or bacterial troubles of any kind, it is highly undesirable to take chances in buying plants from any district, even under the assurance that infection does not exist on the premises of the grower who offers the plants for sale.

Influence of light.—Practically no experiments have been made upon the influence of light in relation to the development of parasitic fungi. It has been observed that shading or the reduction of light hinders the progress of certain diseases of plants grown in the open. For example, Duggar calls attention to the fact that ginseng growers have found that lath screens are valuable in preventing sun scald on the margin of the leaves, and, inasmuch as a serious blight is supposed to gain entrance through the tissues thus affected, shading actually diminishes the infection from this disease. It is possible that shading is sometimes beneficial in the control of parasitic fungi of greenhouse vegetable crops, though the opposite view is universally held by successful growers.

Various diseases of greenhouse cucumbers and tomatoes are much more troublesome during the fall and winter months than during the spring and early summer. The success of the spring crops is attributed almost wholly to more light and more sunshine. The days are longer, and there is a larger proportion of bright, sunny weather to cloudy days than there is from November to March. This fact should be fully considered when making cropping plans. Some crops, such as lettuce, do better with the minimum amount of light than other crops like the tomato and cucumber. For this reason lettuce is most generally grown as a fall crop in preference to cucumbers and tomatoes. And this decision, too, is usually based on the fact that cucumbers and tomatoes are far more susceptible to disease during the fall and winter than from March 1 to August 1. Sunlight not only favors the most rapid growth of plants, but it also prevents the germination of certain disease spores. Shading, however, has a place in greenhouse management. The subject is discussed on page 36.

The influence of moisture.—Excessive watering in the greenhouse invariably results in soft, tender plant tissues which permit the easy entrance and rapid development of parasitic diseases.

The constant maintenance of high humidity in the greenhouses is just as dangerous as an excessive amount of moisture in the soil. It also encourages the growth of succulent tissues and is most favorable to the production and germination of spores. Growers who do not ventilate the houses freely and regularly, to reduce humidity as well as temperatures, are almost certain to experience heavy losses from the attacks of various diseases.

While constant high humidity in the houses should be avoided, it is thought by some that moisture on the leaves is an advantage when bordeaux mixture is to be used.

In this connection it is stated, in the *Market Growers' Journal*, that by merely watering bed surfaces with a hose, little moisture reaches the foliage, and thus the bordeaux mixture does not become effective. To the writer the explanation lies in the need of atmospheric moisture to make the copper compounds soluble in bordeaux mixture. Wherever, therefore, there is in greenhouse practice no moistening of the foliage, bordeaux mixture will not become available for fungicidal effect to any considerable extent.

It is important, therefore, to maintain a supply of soil moisture sufficient to cause normal growth. It also seems that inadequate soil moisture, which may cause a slow, weak growth, makes the plant more susceptible to certain diseases.

The influence of temperature.—Very high temperature in the greenhouse may render the plants susceptible to disease. No harm will result from high temperature if there is sunshine, normal soil moisture conditions and proper ventilation. But excessive heat and high humidity in the absence of sunshine are certain to cause very rapid growth and soft, tender tissues which are most sensitive to diseases. High temperatures and abundant moisture also provide the most favorable conditions for the germination of spores and the further progress of diseases. Great extremes in temperature should be avoided because they are not conducive to the strongest growth of the plant.

Vigor of growth.—It is universally conceded that greenhouse plants which are making a normal, vigorous growth are the least susceptible to disease. It behooves the grower, then, to maintain soil and atmospheric conditions which are most favorable to the plants under cultivation. This involves careful and intelligent fertilizing, watering and ventilating. There must be no neglect in firing the boilers or in any other operation that is essential to the growth of disease-resistant plants.

Crop rotation is an important means of avoiding troublesome diseases of vegetable forcing crops. If a three or more crop system of rotation can be adopted, the chances of serious losses from diseases are much less than if but one crop is grown.

Resistant varieties or strains.—Some progress has been made in the development of varieties and strains of vegetables for outdoor culture which are largely resistant to diseases. Very little progress, however, has been made in this direction with vegetables which are profitable for forcing purposes. There is no reason why strains or even varieties should not be found or produced which would be highly or quite resistant to fungous and bacterial infections.

Steam sterilization.—This is one of the most important means of preventing numerous fungous diseases of greenhouse crops. See Chapter VI.

Formalin sterilization is effective as a preventive measure, where it is impracticable to use steam. See Chapter VI and page 98.

Summer mulch.—It has been found that mulches of manure or other vegetable matter, applied during the summer and watered often enough to keep the soil moist, are effective in destroying disease germs of greenhouse forcing crops. See page 78.

Spraying to control diseases affecting greenhouse vegetables is just as unpopular as spraying to check the ravages of insect pests. It is a slow, tedious operation, that should be avoided if possible. But however thorough has been the work of sterilization and fumigation, and the observance of the various precautions previously discussed, the grower sometimes finds it an advantage to employ fungicidal sprays. Their effectiveness depends upon the selection of the proper mixture for each disease and applications that will be both timely and thorough.

Bordeaux mixture is unquestionably the most important fungicide for the treatment of vegetables grown under glass. The chief objection to its use is the discoloration of the fruits or products, and this is a serious objection if the mixture is applied to the crops a short time before they are to be marketed. The strength of the proportions of the mixture may vary from two pounds of copper sulphate and two pounds of stone lime to 50 gallons of water, to five pounds of copper sulphate and five pounds of stone lime to 50 gallons of water. Ordinarily, plants like the cucumber and tomato are not injured if the 5-5-50 formula is employed.

Various directions are given for making bordeaux mixture, but a simple plan is to dissolve the copper sulphate in a few gallons of hot water in a wooden pail. Slowly slake the lime in another vessel and add enough water to make a thick milk solution. The dissolved copper sulphate is then poured into the barrel or tank containing about 40 gallons of water, the lime milk added and the solution stirred. Additional water may be used if necessary to make the total volume 50 gallons. Separate stock solutions of copper sulphate and of lime milk may be kept on hand, but the prepared mixture deteriorates when left standing. It is important that unslaked stone lime rather than air-slaked lime be employed. Air-slaking may be prevented by keeping the stone lime in tightly covered vessels. The Ohio Station reports that bordeaux mixture is most effective when the atmosphere of the house is so highly humid that the leaf surfaces are moist.

Ammoniacal copper carbonate.—As previously indicated, bordeaux mixture leaves a deposit on the plants and fruits which is objectionable if the products are soon to be marketed. For this reason, some growers prefer to use ammoniacal copper carbonate—which leaves only a slight deposit—previous to harvesting and marketing certain crops, though this fungicide is not so effective as bordeaux mixture. The mixture contains the following constituents:

Copper carbonate	5 ounces
Ammonia (26° Baumé)	3 pints
Water	50 gallons

Dilute the ammonia with water to about five times its volume. Make a thin paste of the copper carbonate with a small quantity of water, and add this to the ammonia by constant stirring. After diluting to 50 gallons of water the mixture is ready for application. It should be used as promptly as possible because the ammonia evaporates rapidly.

Potassium sulphide or liver of sulphur is sometimes employed in the greenhouse, especially when it is desirable to avoid the discoloration of the foliage. From three to five ounces of potassium sulphide is used to 10 gallons of water.

Sulphur is sometimes applied as a dust over the plants for the treatment of mildews.

CHAPTER IX

STARTING PLANTS

Plants of high quality are essential to success in the production of any greenhouse crop. Profits are often diminished because inferior plants are used in setting the beds. They should be of the proper size, not too large nor too small, and ready for the beds the very day any space becomes vacant. They should be strong, stocky and vigorous rather than weak, spindling and succulent. The color of the leaves should be dark green rather than pale green. It is especially important that they have a well-developed root system. The management of the young plants should be so skillful that there will be no evidence of diseases and insects when they are transferred to the permanent beds.

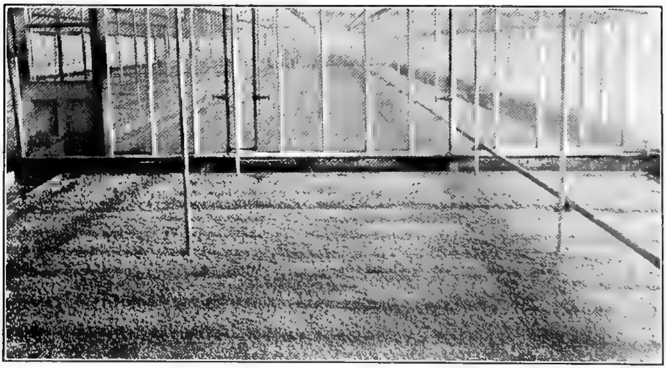

Fig. 41.—Two nurseries in a four-acre Boston range. Note lettuce seedlings of different sizes.

Seed of high quality.—Failures are often due to poor seed. The greenhouse grower, who usually makes successive sowings at short intervals, is not likely to be disappointed in the seed not germinating. This matter, however, should not be overlooked. Germination tests, made in advance of the usual dates for sowing, may be the means of avoiding loss and disappointment. Very little time is required to make such tests, and the results may much more than compensate for the slight expense.

The term "high quality" as applied to seeds has a much broader meaning than the mere matter of germination. It relates primarily to the quality of the crop produced from tne seed selected and planted. Unfortunately, many greenhouse men do not seem to fully appreciate the value of high-grade seeds. They fail to grasp the fact that planting the best seed may materially increase their profits. Chances are taken, year after year, in using seed of unknown quality, until they discover, accidentally, perhaps, that the superior quality of the produce sold by their competitors is largely due to the planting of better seed.

We should bear in mind that greenhouse space is precious, that the area with its glass roof and artificial heat is worth many times an area of equal size in the open. It is folly ever to use seed that we do not know will produce satisfactory crops.

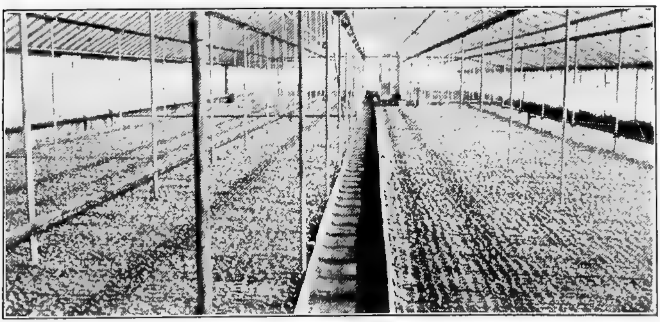

Fig. 42.—Nursery in large range near Boston. Head lettuce plants.

High-quality seed for greenhouse purposes may be obtained by two methods. The usual one is to purchase the seed from reputable dealers. If this plan is followed, it is important for each grower to make small plantings in order to determine the merits of the seed in producing a satisfactory crop, and in meeting definite market conditions.

It is gratifying to note in this connection that a fairly large number of seedsmen specialize more or less in the development of strains of vegetables adapted to greenhouse culture. This is the ideal system and with the growth of the vegetable-forcing industry it will become more attractive to commercial seed growers.

It is interesting to observe, however, that nearly all of the extensive and the most successful growers of greenhouse vegetables breed their own seed. This statement does not apply to lettuce growers, though some of them save their own seed, but it does to the men who are producing cucumbers and tomatoes under glass. These master growers claim that the practice enables them to make larger profits because of the superiority of their products.

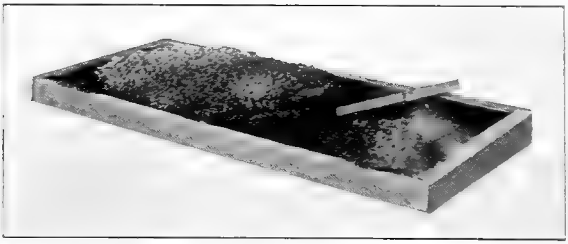

Fig. 43.—Flat of Grand Rapids lettuce seedlings.

When seed is saved from home-grown plants a few principles should be carefully observed. In the first place, no progress whatever will be made if fine specimens are selected from the picking baskets. It is not unusual for a small, weak plant to produce an extra fine tomato, cucumber, pepper or eggplant. Not individual specimens, but the plant must be regarded as the unit of selection.

To begin with, the grower should have a very definite idea of what he wants. The market demands should also be known before a given type is decided upon. After a definite conclusion is reached concerning the most desirable size, shape, color and quality of the product to be grown, the most careful observation is made when the crops are harvested. Here and there will be found plants which approach the ideals of the grower, and they are also vigorous, productive and perhaps free from disease. Such plants are marked and the seed saved in separate packages. The packets are then numbered and small plantings of each made for the next crop. It will be found that some of the selections do not perpetuate their good qualities, while others do. Selections are again

Fig. 44.—Flat of lettuce plants ready for transplanting into the beds.

made from the best plants of the best lots, and in the course of a few generations a strain of special merit should be developed if the work has been done intelligently. Some of the leading greenhouse growers are developing a trade for special strains, though this is seldom, if ever, their motive in breeding better seeds.

Separate plant houses (Figs. 41 and 42), are almost indispensable in large establishments. They make it possible to maintain temperatures which are most suitable for the various classes of plants at different stages of growth without interfering with the crops in the main houses.

It is well known that the temperature for lettuce immediately after the first transplanting should average 5 to 10 degrees higher than that for lettuce which is approaching maturity. It is impossible to provide the proper temperature for both lots of plants if they are in the same house. Again, the main houses may be filled with a winter crop of lettuce when it is time to start tomatoes or cucumbers for spring planting. While it is possible, with skillful management, to accomplish this, it is not a simple undertaking.

The humidity of the houses can also be better regulated if there are separate nurseries for starting the plants. Fumigation, too, may be necessary in the plant compartment when not in the main houses, or vice versa. If separate houses are provided growth may be forced or retarded, as may be required to prepare the plants for the beds at the proper time. The advantages of separate plant houses are apparent.

Fig. 45.—Lettuce plants in flats.

The nursery should be conveniently located with reference to the various units of the entire range of houses. Numerous valves should be placed in the heating pipes so that the most exact regulation of temperature will be possible. Not less than two compartments, and preferably three or four, should be provided for large ranges of houses. Level, water-tight beds or benches for the sub-irrigation of plants in flats will be found an advantage, especially if the soil is silty or clayey and inclined to bake.

Flats vs. beds.—While many greenhouse men prefer to start and grow their plants in beds (Figs. 41 and 42) there are special advantages in using flats. (Figs. 43, 44 and 45.) If solid ground beds are employed it is a tiresome task to bend for hours over them sowing and covering the seed.

Plant boxes may be placed on tables of convenient height and the sowing done in greater comfort. The same statement may be made in regard to the first trans planting of the seedlings. High stools may be used, if desired, when the work of sowing and transplanting is

Fig. 46.—Utilizing shelf space in an overcrowded house. Unfair to the plants in the beds underneath.

done at tables, and the tables may be shifted as desired in the potting room or greenhouses.

Flats are a great convenience in shifting the plants about the premises and in utilizing space. (Fig. 46.) They may be easily carried or carted here and there, to provide the best conditions for growth, or to supply young plants to the workmen as they transplant into the permanent beds. It is possible to control soil moisture conditions more perfectly in flats than in beds, which is a most important factor in growing good plants.

Finally, plants grown in flats, especially if an inch of rotten manure has been placed in the bottom of the boxes before they are filled, may be shifted and transplanted with more soil adhering to the roots than is usually possible with bed-grown plants.

Flats should be made in such dimensions that they may be placed on beds or benches without the loss of any space. Their exact depth does not seem to be of special importance. It has been demonstrated that just as good

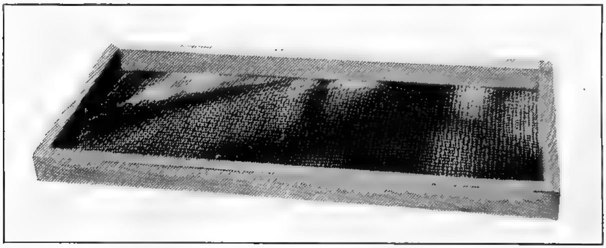

Fig. 47.—Flat with wire-mesh bottom.

plants can be grown in boxes only 2 inches deep as in those of twice that depth. Deep boxes require more soil and they are heavier to handle. It is more difficult, too, to remove plants from them with a large quantity of soil adhering to the roots. Perhaps the only important advantage in favor of deep flats is that they do not require such close attention in watering as do boxes that are only 2 inches deep. Some growers use flats with bottoms made of wire netting, as seen in Fig. 47.

Use of pots.—Both earthen and paper pots are used in vegetable-forcing establishments. Although they add to the operating expenses by requiring a larger investment of capital, and transplanting cannot be done so rapidly from pots as from flats and beds, their advantages are so obvious that the subject deserves special consideration.

The greatest advantage in using pots is that there is absolutely no check in growth when the plants are shifted from pot to pot, or from the pots to the beds where the crop is to mature. With each shift there is no root disturbance of any kind, and the additional soil provided at each transplanting makes possible the continuous growth of the plant. Uninterrupted growth is particularly important for plants like the cucumber, tomato, pepper and

Fig. 48.—Cucumber plants growing in pots and in an adjacent bed.

eggplant. Again, some plants, like the cucumber, do not transplant so readily as others. In such instances, pots are practically indispensable.

Sometimes it is impossible to make the final shift to the beds at the time decided upon when the seed was sown. There may be lack of sunshine or other interferences to retard the growth of the plants in the permanent beds. Then, too, market demands are variable, and it becomes necessary at times to defer harvesting for a week or more after the time when the grower thought the beds would be cleared ready for another lot of plants.

If the plants are growing in pots, they may be held for a longer period than is possible when they are in flats or beds, because the pots are easily separated, more space being thus allowed for each plant. The crowding of the tops of plants is much more injurious than restriction of the root growth.

If separate compartments (Fig. 48) are available, the potted plants may be placed by themselves and cultural conditions provided which will retard their growth. Even if the plants should become larger than is desired, they can be shifted to the beds without difficulty, and a satisfactory crop may be obtained.

Pots enable the grower to utilize every square foot of space in the greenhouse. (See Fig. 49.) If a plant here and there dies, or fails to make satisfactory growth, the pot can be removed and the vacancy filled with a good plant. It is also possible to place them in different parts of the house, wherever there may be unused space. Many growers find that it is economy to stand or plunge potted vegetables for short periods between plants in the permanent beds, thus making the space do double duty.

If insects or diseases appear at any time, the potted plants may be removed and sprayed, fumigated or perhaps destroyed.

Most greenhouse growers prefer to use earthen pots. With good care they will last for many years. Additions to the supply may be made from year to year until the required number has been purchased. Paper pots of various descriptions appeal to others, largely because they are less expensive than earthen pots. Berry baskets

FIG. 49.—POTTED CUCUMBER PLANTS IN A BED OF GLADIOLI.

of quart size are used by some growers for the starting of tomato and cucumber plants. Sometimes the plants are not removed from the baskets, but the plant is left intact and thus basket and all are set in the bed.

Soil selection and preparation.—Any soil which is properly prepared for use in the permanent beds will be satisfactory for starting the plants. It should be open and porous, so that water will be promptly absorbed and the surface of the ground will dry off quickly. As previously indicated, the soil should be free from insect pests and disease parasites; to avoid trouble from such sources, it may be necessary to resort to steam sterilization.

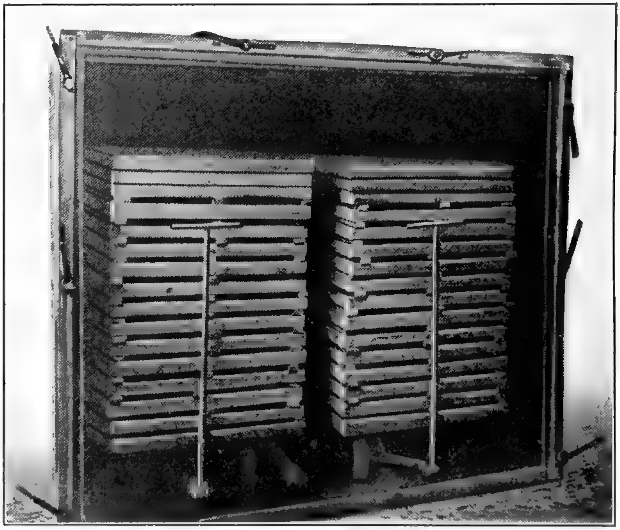

Fig. 50.—Chamber used for the steam sterilization of soil in flats. (Note that the flats are on carts.)

(Fig. 50.) Some growers prefer to use soil that is not quite so fertile as the soil used in the beds. The tendency of plants in very rich soil is to make excessive leaf growth and poor root development, while the opposite of this is desirable in the starting of all classes of plants. This tendency, however, is not marked, if proper moisture and temperature conditions are maintained. See Chapter V for details of soil preparation.

Seed sowing.—The time of sowing should be determined with extreme care. This will depend to some extent on the variety selected, for some varieties require more time to mature than others. Seasonal conditions, with special reference to the amount of sunshine and the rate of growth depending thereon, should also have consideration. But the most important factor is the demand of the market to be supplied. When will it pay the best prices for the various crops and when can they be grown most profitably, are questions which should be answered if possible before the seed is sown.

Experience will soon teach the greenhouse gardener when each sowing should be made, so that he may have the seedlings ready for transplanting at the proper time. Experience will also enable him to determine rather definitely the quantity of seed to sow each time in order to produce the required number of plants. There should be no uncertainty, however, about this matter. It is often difficult, if not impossible, to make up the shortage by purchasing plants that may introduce insect or disease parasites. The safe policy is to sow an ample quantity of seed, even if thousands of plants must be discarded. With a larger number of plants than is actually needed, only the strongest may be used, and this will count for uniformity in size of plants during the entire period of growth.

The soil should be fairly moist before the seeds are sown. This is important for two reasons: First, the soil works better; second, it receives water more rapidly, and the seeds are not so likely to be washed out of the ground by watering.

Whether the seed is sown broadcast or in drills is largely a matter of preference. The work may be done quicker by broadcasting. This method also results in a more even distribution of plants, a factor considered important by some growers. On the other hand, the drill method makes possible the application of water between the rows without wetting the plants. The plants are easily and quickly pulled at the time of transplanting, and remain in better order for this operation, thus saving more time perhaps than the extra labor caused by sowing in drills rather than by broadcasting.

When drills are used, the furrows for lettuce, tomatoes and seeds of similar size are usually about one-fourth of an inch deep. The furrows are made with thin, narrow strips of wood, such as a piece of plastering lath. The seed may be sown with the thumb and finger or by the use of an envelope.

Whatever plan is used, it is exceedingly important to sow the seed thin enough to prevent crowding. Ordinarily, eight to ten plants to each linear inch of the furrow are as many as will produce a stocky growth. If the plants are to be pricked out very soon after they are up, there is no objection to growing probably 15 to the inch. The furrows are quickly closed by the use of the fingers or by drawing a pot label along each side of the rows. After the furrows are closed the soil should be firmed with a block of wood, and the beds thoroughly watered. Lettuce is generally sown broadcast.

Transplanting.—Most growers prefer to make the first shift when the rough or true leaves are partly formed, which will be in three or four weeks from the date of sowing. Others prick the plants out in 10 to 15 days, and believe that this practice is favorable to the growth of stocky plants. It is certain that there should be no crowding of the plants in the flats or seed bed, and this may be prevented by thinning or early transplanting.

From the standpoint of economy of space, early transplanting is a disadvantage, but it is unquestionably best from the standpoint of growing strong, stocky plants. Lettuce is often transplanted before the true leaves are formed.

There is the greatest diversity of practice in methods of transplanting. Spotting boards of different kinds are made to mark the soil in the flats or beds. They may be

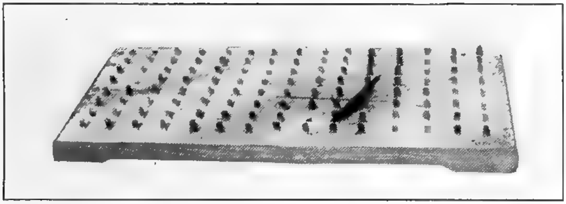

Fig. 51.—Spotting board used in transplanting lettuce.

provided with slight projections which merely indicate the places where the plants are to be set or they may contain pegs (Fig. 51) which when forced into the soil and withdrawn make holes for the roots of the plants. The latter plan saves time and, properly executed, results in straight rows uniformly spaced.

The soil may be pressed firmly to the roots of the plants with the fingers, or a small dibber may be found convenient for this purpose. The plan should be used which is most convenient to the gardener. Soil of the proper moisture content is even more important for transplanting than for seed sowing. Some water is generally applied after the plants are shifted, though this is unnecessary if the soil is as moist as it can be made without being too wet. When plants are shifted from pots of one size to those of a larger size, a little earth is first placed in the bottom of the pot, and soil is then packed between the ball of earth and the side of the pot. A common practice with many vegetables is to make the first shift into flats, and the second and perhaps additional shifts into pots. A 2-inch pot may be used the first time, a 3 or 4-inch the second, and if desired for tomatoes a 5 or 6-inch the third. More explicit directions for transplanting each crop will be given in later chapters.

Care of plants.—One of the greatest dangers in the starting of plants is over-watering. No more water should be used than is necessary to keep the boxes or beds moist. Too frequent as well as too profuse watering should be avoided. A fine lot of plants may be ruined by a single careless watering. High temperatures are also disastrous, especially if there is an excessive supply of soil moisture. Proper ventilation is of the greatest importance. See Chapter X on Watering, Heating, Ventilating and Shading.

Damping-off is caused by fungous diseases which sometimes play havoc among young vegetable plants. It usually attacks the stems of the plants at or near the surface of the ground. If the infection is severe, it may spread rapidly over the beds and cause many plants to rot off and die. The trouble may be avoided by the use of clean soil, by steam sterilization, and by proper ventilation and watering. When the disease is known to be present, watering only between the rows will be found to be a valuable preventive measure. In other words, if the plants are kept dry there will be less danger of the fungus entering the tissues.

CHAPTER X

WATERING, HEATING, VENTILATING AND SHADING

Success in the management of greenhouse crops depends more upon the maintenance of proper moisture and temperature conditions in both soil and air than upon any other factors. Watering, heating, ventilating and sometimes shading are most vital operations in the growing of plants under glass.

Importance of water.—Most of our greenhouse vegetables contain over 90 per cent of water. The amount of water, however, which enters into the composition of plants is insignificant compared with that which transpires from the surfaces of the leaves. The nutrient solution in a properly prepared soil is very dilute, and an enormous quantity is absorbed by the plant in order to meet its food requirements. Water is the vehicle by means of which the nutrients are conveyed to different parts of the plant, and while some of it enters into the composition of the tissues, most of it transpires from the leaves. It is likely that the amount of water which daily transpires from the leaves of a vegetable plant in a greenhouse, during the bright sunny weather in May or June, more than equals the weight of the plant.

Water also performs various other functions, as rendering plant foods soluble, giving rigidity to plant structures and reducing the temperature of plants. Aside from these functions relating to plant growth, the humidity of the greenhouse, which may be regulated by the grower, will depend largely on the use of water. Extremely low humidity may be just as harmful under certain conditions as extremely high humidity.

Amount of water required.—An enormous amount of water is required to grow good greenhouse crops. As previously stated, it enters into the composition of the plants, but most of the water which enters the roots escapes by transpiration from the leaves. There is also rapid evaporation from the soil. Wright, after making a survey of this question in nearly 75 commercial greenhouse establishments, estimates that the average daily requirement of water during the months of May and June is 280 gallons per 1,000 square feet of bed surface in crops, or over 12,000 gallons to the acre. Expressed in different terms, 243 gallons of water would be required daily per acre during the months of May and June, and under certain conditions more than that amount might be needed, to meet the requirements of the crops.

Much more water is required during the late spring and early summer months than through the winter. The heat rays of the sun are then intense, and with the ventilators and doors open there is the most rapid escape of water from both the plants and the soil. Again, at this season of the year the days are longer and there is much more sunshine than during the winter months.

The character of the weather at any particular season of the year is also an important factor. It is readily understood that less water will be required on cloudy days than in bright, sunny weather, and this matter should have the most careful consideration of the grower.

The kind of crop under cultivation is also an important factor to be considered. Generally speaking, tomatoes and cucumbers require more water than does lettuce.

Crops which are well advanced or approaching maturity, necessarily require more water than young plants, though there may be diminished evaporation from the surface of the beds because they are shaded by the crops.

Soils which are very open and porous, due to a large percentage of coarse sand, require more water because of loss by percolation and evaporation.

The location of the beds and heating pipes should be considered with reference to the water requirement of the plants. If solid beds are used and the heating pipes are remote, less water will be needed than when raised benches are employed with the heating pipes under them.

No rules can be given regarding the amount of water which should be applied. Enough water should be used to keep the soil moist, but over-watering should be carefully avoided, for this makes soft, tender tissues, and with crops like tomatoes and cucumbers may cause excessive stem and leaf growth with a poor setting of undersized fruit. It is possible to apply so much water that the plants become stunted and refuse to make satisfactory growth. The dangers of over-watering in relation to diseases have been indicated in previous chapters.

Insufficient watering may be just as harmful as over-watering. It necessarily results in small plants and poor crops.

It is important to be thorough in watering. The water should be uniformly applied over the entire bed surface. Sometimes dry areas appear here and there, and it is often an advantage to water these before time for the next general watering. Enough water should be applied each time to moisten the soil to the entire depth of the beds. A few careful examinations of the beds, made several hours after each application of water, will enable the grower to determine whether a sufficient amount has been used to moisten the beds to their full depths.

When to water.—The frequency of watering will depend on several factors. As previously stated, transpiration of water from the leaves and evaporation from the soil are much more rapid when there is warm, sunny weather, and at such times it is necessary to apply water more frequently than during cool, dull, cloudy weather. In the winter, when the days are short and there is little sunshine, it may be unnecessary to water oftener than once a week, or even at longer intervals under certain conditions. On the other hand, in the summer it is usually necessary to water every day and sometimes twice daily. Whether it is summer or winter, much less water is required on cloudy days.

It is always better to water when the temperature of the greenhouse is rising rather than falling. Unless the water is applied in a fine spray, it will make the soil cooler, which, of course, is undesirable, but there need be no anxiety about this matter if the temperature of the houses, due to the rays of the sun or the heat from the boiler, is gradually rising. Then, too, in order to prevent injuries from various fungous diseases, the foliage of the plants should be dry or free from excessive moisture during the night. For the two reasons just given it is preferable to water the beds in the forenoon, and that is the general practice among greenhouse growers of vegetables and flowers.

The pollination factor should also have consideration. Pollination is most active when neither the atmosphere of the house nor the plants themselves contain much moisture. This matter should be watched closely in tomato and cucumber houses, especially when there is dull, cloudy weather. Under such conditions an abundance of water should be used each time so that it will be unnecessary to water more frequently than is absolutely required. If the fruits are not setting well, it will be an advantage sometimes to use less water than is actually needed for the plants, in order to maintain lower humidity, which is favorable to the pollination of the flowers.

If additional humidity is needed for any purpose, and the beds should not be watered, the walks may be wet down several times a day, if necessary.

It will be seen from the foregoing remarks that no rules can be made relating either to the amount of water which should be used or the frequency of its application. This operation calls for the exercise of good judgment. The plants themselves tell the experienced grower when they are in need of water. If they wilt or even appear to droop, there is no question about their requirement, unless the heat of the house is excessive and the humidity unusually low. The color of the leaves is a valuable guide to the right amount of water. Light green foliage, if temperatures are normal, indicates the use of too much water, while a dark green color shows that this factor is being properly regulated. Examination of the soil is also valuable in determining when water should be applied.

Temperature of water.—Much has been said in favor of warming the water during the winter, before it is applied to the beds. It is doubtful, however, whether instances can be cited in which the use of cold water has actually caused serious injury of any kind. Difficulties may arise after the use of cold water, but the probabilities are that they are due to cloudy weather or other causes rather than to cold water. The fact is, if water is applied in a fine spray, every globule will take on the temperature of the air before it reaches the soil or foliage of the plants. In sub-irrigation, where a stream of water is turned into the tile, there may be some objection to using cold water, but even in this case the water would soon acquire the temperature of the soil. However, there is some evidence that the use of warm water in sub-irrigation tile is an advantage to crops requiring especially warm soils.

Methods of watering.—Various factors should be taken into account in the consideration of different methods of watering. Among them may be mentioned:

(1) Cost of installation. The cost of installing a given system may be slight, but if it is unsatisfactory there is no justification for its use.

(2) Effect on plant growth. One system may be better

than another, as shown by larger and better crops.

(3) Uniform distribution of water. A system which does not distribute the water evenly over the entire area of the beds cannot give the best results.

(4) Effect on soil. Some systems of watering compact the soil, and cause the formation of hard incrustations on the surface of the beds. This effect is objectionable because it prevents the proper aeration of the soil and necessitates frequent tillage to break up the crust.

(5) Mechanical injury to the plant. This may occur if a stream of water is forced against the plants through a nozzle which is not properly adjusted.

(6) Labor cost. This factor should have special consideration. It is inefficiency to devote hours or days to work which might be accomplished by means of mechanical devices that require very little attention.

Watering can and hose.—In the early days of greenhouse cropping, all of the water was applied with watering cans. It is a slow, laborious method that should not be used in any commercial establishment, except in starting small lots of plants. A step in advance was made when the hose was attached to the spigot, and water applied direct to the beds. Some growers use the hose without any nozzle, and this may be desirable if profuse watering is necessary, as during the summer months when cucumber plants have attained full development

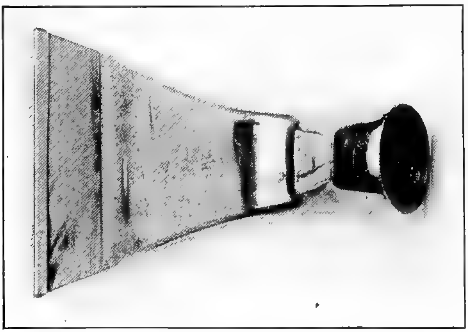

Fig. 52.—A convenient form of nozzle for greenhouse watering.

and the crop is being harvested. Ordinarily, it is preferable to apply water in a fine spray or mist, and this is not possible without the use of a special nozzle which may be attached to the hose. Fig. 52 shows a most serviceable nozzle for the watering of small plants, and it is also convenient for watering limited areas here and there which may need water before the time of the next general watering. Some form of hose watering is used more or less in all commercial establishments. A combination of two systems is ideal. For example, sub-irrigation is highly satisfactory for lettuce, but many growers prefer the hose or perhaps the overhead system for cucumbers, partly because they are valuable in controlling the red spider. The hose and overhead watering also make a desirable combination. Though the expense of installing two systems of watering may seem excessive, the advantages thereof may more than justify the additional expenditure.

Watering with a hose, unless carefully managed, may result in the incrustation of the surface of the soil. To avoid this difficulty, the spray should be as fine as possible and the hose should not be held too long at one place.

Sub-irrigation.—Several agricultural experiment stations have conducted experiments in the watering of greenhouse vegetable crops by means of sub-irrigation. The work of the Ohio station has attracted most attention. In the institutions where sub-watering has been tried, the results have generally been favorable to this system. For reasons, however, which cannot be satisfactorily explained, sub-irrigation has not become popular among commercial greenhouse men. A grower here and there is using the system, but the rank and file of the gardeners who produce crops under glass have not adopted this plan of watering. It is presumably due to the cost of installation. There is also some objection to having the tile in the beds where they interfere more or less with the soil preparation. An experienced grower states that three to five times as much water is required for sub-irrigation in beds that are not water-tight as with surface watering, and this is a serious objection when the supply of water is limited or expensive.

There seems to be no difference of opinion concerning the advantages of sub-irrigation, which may be enumerated as follows:

(1) The surface of the beds remains dry. This lessens the dangers of fungous diseases, especially of lettuce, and obviates the necessity of frequent tillage.

(2) The surface of the bed remains open and porous, thus providing perfect soil aeration without the use of tillage implements. From this standpoint, sub-irrigation possesses special advantages for heavy soils.

(3) Less labor is required to water the houses than when a hose is used.

(4) With sub-irrigation it is possible to maintain lower humidity than with any form of surface watering. This is a special advantage in controlling certain diseases and in providing the most favorable atmospheric conditions for pollination.

(5) The tile may be used for steam sterilization as well as for watering, and thus the expense avoided of special sterilizing equipment, and the labor of shifting pans, pipes and perhaps moving the soil whenever the beds are sterilized.

(6) The tile may also be used for heating the beds by admitting steam at low pressure. Some good results have been reported relating to this practice.

(7) Sub-irrigation is the means of avoiding any mechanical injury to the plants, which sometimes occurs when nearly mature lettuce is weighted down by water applied above the beds.

(8) It is unnecessary to water so frequently when sub-irrigation is used.

(9) According to growers who have had considerable experience with this system, over-watering is impossible when water is applied through tiles laid in beds that are not water-tight. This unquestionably is one of the greatest advantages of sub-irrigation.

(10) Larger yields are often obtained with sub-irrigation.

This method of watering, as seen in Fig. 53, may be used on raised benches as well as in beds on the ground. It is necessary, of course, for the benches to be water-

Fig. 53.—Tile laid in bed for sub-irrigation.

tight, which involves an additional expense that must be charged to the cost of installing the system. Inasmuch as benches are not generally used in extensive vegetable-forcing establishments, it is seldom that we find benches constructed for sub-irrigation. Aside from the expense, it is a simple matter to make reinforced benches with concrete bottoms and sides which will be entirely water-tight. Such beds should be not less than 6 inches deep.

B. H. Thorne, who had 12 years of experience in the use of this system, claimed that it is not desirable to have the ground beds water-tight, because there is then no danger of over-watering. There are two main points to be considered: First, the tile lines must be laid level, and, second, there must be water-tight walls around the beds, which may be of any convenient size. Beds need not be more than 6 inches deep, though 8 to 10 inches will give better results, and some growers prefer them even deeper than 10 inches.

Pipes of various sizes may be used, but tile are more satisfactory as well as more economical. Tile 2½ inches in diameter are preferred if they must be laid near the surface of the beds, and 3-inch size is best if they are to be placed 4 or 5 inches or more below the surface of the ground. In shallow beds the tile need not be covered with more than an inch or two of soil. If the soil is light, open and porous, it is better to place the tile near the surface of the beds rather than at a depth of 10 inches or more, because less water will be required. In shallow beds of light soil, the first line of tile should be 10 inches from the wall of the bed, and the interior lines should be about 2½ feet apart, though 3 feet is permissible. In the deeper beds it is customary to place tile 18 inches to 2 feet apart. The concrete walls, if well made, need not be more than 2½ inches thick.

A little mud mortar placed at each joint will hold the tile in place while they are being laid and until the beds have been filled with soil. Deep beds require more water than shallow ones, but applications need not be so frequent. There does not seem to be any uniform practice in regard to the length of the lines of tile. If they are carefully placed, with the joints as close together as possible, and there is an abundant flow of water, the lines may be 50 feet long. At the ends of such lines, elbows are used to provide outlets above the surface of the ground, and pipe headers may be used to connect with several lines of tile. It is then possible to water a 9 x 50 bed in five hours or less, the time depending upon the

FIG. 54.—OVERHEAD IRRIGATION IN A LETTUCE HOUSE.

volume of water available as well as upon the rate of flow, depth of bed and character of soil.

During the winter months, one watering may last for five weeks or longer, and in the summer it may not be necessary to water oftener than once a week or every 10 days. In newly planted beds, especially if the plants are small, it is necessary to make one or two surface waterings until the plants have become established.

Thorne recommends that the tile be cleaned and relaid every third year.

Sub-irrigation is considered especially desirable for lettuce and tomatoes.

Overhead irrigation.—Of the various systems of watering greenhouse vegetable crops, overhead irrigation (Fig. 54) is the most generally used in large commercial establishments. Wright, in a recent survey of extensive ranges used for the forcing of vegetables, found that 78 growers out of 100 were employing the overhead system. The advantages of this system are as follows:

(1) Comparatively small cost of installation. It is estimated by the manufacturers that the cost will usually be about $300 an acre. This is very much less than the expense involved in preparing the beds for sub-irrigation.

(2) The water is applied more uniformly than is possible with any other system except sub-irrigation. There should be no wet spots anywhere in the house when the overhead system of watering is employed.

(3) The labor of watering is very slight. Only a few moments are required to open the valves and to turn the nozzle lines as may be necessary to water the entire house. An automatic turning device has been invented recently which should further reduce the attention required by this system in the watering of greenhouse crops.

(4) The patented nozzles diffuse the water into an extremely fine mist, which then descends gently upon the

plants and beds. In effect it is like a very fine rain. If the beds have been properly prepared, the water will not stand on them and there will be practically no incrustation on the surface of the beds, nor will the fine mist compact the soil. Again, there need be no fear of the fine mist causing mechanical injuries to the plants.

(5) With the overhead system the hot, dry atmosphere of the greenhouse may be changed in a few minutes. This is often a great advantage in the summer for a crop like cucumbers.

(6) It is also possible to apply fungicides, insecticides and liquid fertilizers through the overhead system of pipes and nozzles.

The main flow or feeder line should run across the house, and it is usually most convenient to have it at the end near the boiler room or packing room. It should be amply large, to meet the demands of the houses. The following table, furnished by the manufacturers of a popular system, may be followed in determining the proper size of the main supply line:

	LENGTH OF LINE							
	50 ft	100 ft	200 ft	300 ft	400 ft	500 ft	600 ft	700 ft
30 gal. per min.	1½	2	2	2	2½	2½	2½	2½
75 gal. per min.	2	2½	2½	2½	3	3	3	3
100 gal. per min.	2½	2½	3	3	3	3½	3½	3½
150 gal. per min.	2½	3	3	3½	3½	3½	4	4
200 gal. per min.	3	3½	3½	4	4	4	4	4
300 gal. per min.	3½	3½	4	4	4	4	5	5
400 gal. per min.	4	4	4	5	5	5	5	6
500 gal. per min.	4	5	5	5	6	6	6	6

Nozzles or distributing lines connect at right angles with the supply line. The connection is made with a patented swivel union, which makes it possible to turn the line with a lever, in order that all of the ground may be evenly watered. The nozzle lines are placed 16 feet apart, so that two lines would meet the requirements of a house 32 feet wide, three lines for a house 48 feet wide, etc. The nozzle lines may be 500 feet long if necessary. The size of the pipe will depend on the length of the line, the pressure of the water and the nozzle to be used. It is better not to have too great a length of pipe of any one size.

The following table, prepared by the manufacturers of an approved system, will be found valuable in estimating the pipe requirements:

SIZES OF PIPE FOR GREENHOUSE NOZZLE LINES

Calculated on greenhouse nozzles placed 3 feet apart in the line. If the nozzles are closer together larger pipe must be used

Nozzle No.	Total length of line in feet	No. feet ¾" pipe	No. feet 1" pipe	No. feet 1¼" pipe	No. feet 1½" pipe	No. feet 2" pipe
Greenhouse No. 2	100	100	—	—	—	—
	150	75	75	—	—	—
	250	75	75	100	—	—
	300	75	75	100	50	—
	500	75	75	100	125	125
Greenhouse No. 3	75	75	—	—	—	—
	100	60	40	—	—	—
	150	60	60	30	—	—
	250	40	60	75	75	—
	300	40	60	75	75	50
	400	40	60	75	75	150
Greenhouse No. 4	50	50	—	—	—	—
	100	40	60	—	—	—
	150	40	50	60	—	—
	250	35	40	75	100	—
Greenhouse No. 5	30	30	—	—	—	—
	70	20	50	—	—	—
	100	20	50	30	—	—
	150	20	50	40	40	—
	250	20	30	60	60	80

The nozzles on the greenhouse lines are generally placed 3 feet apart. The theoretical discharge from 100 No. 2 or No. 3 greenhouse nozzles, according to estimates of the manufacturers, is shown in the following table:

THEORETICAL DISCHARGE OF 100 NOZZLES IN U. S. GALLONS PER MINUTE

The No. 1 outdoor nozzles and the No. 3 greenhouse nozzles are the sizes most generally used

Head		Type nozzles	
Pounds	Feet	Greenhouse No. 2	Greenhouse No. 3
5	11.55	11.5	17 6
10	23.1	16.3	25.1
15	34.7	19.9	30.8
20	46.2	23.1	35.4
25	57.8	25.8	38.6
30	69.3	28.4	43.3
35	80.9	30.6	46.9
40	92.4	32.6	50.2

The nozzle lines in the greenhouse may be supported by special hangers provided for the purpose. Holes in the pipe for the brass nozzles are made by a special drilling machine. It is not a difficult matter to install an overhead system of watering, and the manufacturers are always pleased to give instructions on any point which may not be fully understood. Whenever a pressure of 10 pounds or more can be obtained, it is possible to operate the overhead system of watering, though a higher pressure makes a finer spray. In fact, practical growers prefer a pressure of not less than 25 pounds, and 40 pounds is better.

Temperature.—The proper temperatures for the various greenhouse crops will be discussed in later chapters. It should be said here, however, that a uniform temperature is important, unless sunshine should cause a wide range in temperature, which will do no harm if free ventilation is given. An inadequate heating plant may be responsible for low temperatures that are disastrous to the crops. Ordinarily, excessively high temperatures with poor ventilation do more harm than insufficient heat.

Ventilation.—The necessity of ventilation was discussed in Chapter VIII on Diseases and Their Control. Every practical grower knows that plants in houses improperly ventilated soon become tender and spindling, and they are then especially subject to the attack of fungous diseases. Abundant ventilation is necessary in order to grow strong, vigorous plants. The direct effects of ventilation are to reduce the humidity, to lower the temperature and to increase transpiration of water from the leaves and evaporation from the soil. Good judgment must be exercised in ventilating. Too much ventilation under certain conditions may be just as harmful as too little. Admitting fresh air increases the circulation of air in the houses, and this may be of special value in reducing humidity and in preventing or checking fungous diseases. Too much ventilation is impossible during the summer months. In the winter time care should be taken to prevent cold drafts from coming into direct contact with the plants.

The usual custom is to open the ridge ventilators as much as may be possible in the forenoon, when the temperature in the houses is rising, and to close them sometime in the afternoon. If the weather is fairly mild, they should be opened early in the morning and closed late in the afternoon. In the summer they are left open day and night, except on the approach of severe storms, when they should be closed to protect both crops and houses from possible damage.

Shading the houses is sometimes an advantage or even a necessity. Whitewash made from air-slaked lime is generally used. Cucumbers seem to be most benefited by shading.

CHAPTER XI

MARKETING

The growing of vegetable crops under glass is an expensive proposition. Land of high value, usually near a city, is selected for the establishment. If a considerable area is covered, large sums of money must be spent for construction, maintenance, heating, labor, equipment, water, manure, etc. Depreciation, interest on the investment, fire and hail insurance and probable losses must also be taken into consideration. Production costs under glass are necessarily much higher than out of doors. This fact should be kept in mind by the greenhouse market man. If a profit is to be realized, much better prices must be obtained for the forced products than for vegetables grown in the open. In other words, modern methods of marketing must be employed if the venture is to prove a satisfactory business proposition.

The most skillful marketing, however, cannot do everything toward making the business a financial success. So much is being said about better marketing that there is danger of losing sight of the equally important factor of successful production, especially in regard to quality. The high cost of production makes it imperative to grow the best, and the most approved methods of marketing will fail to make the business yield satisfactory dividends unless vegetables of the highest quality are available from day to day. High quality, economic production and skillful marketing are the factors that win large profits.

Psychology of successful salesmanship.—The appearance of an article when offered for sale, more than any other factor of marketing, determines the price that can be obtained for it. This statement applies to food products just as well as to clothing, household furnishings or automobiles. If an article is not attractive it is not likely to sell well. Vision must be appealed to if we wish to make prompt sales at good prices. When the eye is pleased, the mind usually decides quickly and favorably as to the value of the article. This is practical psychology applied to salesmanship.

Now, various factors are involved in the art of making greenhouse vegetables attractive when offered for sale. The variety grown is an important consideration. For example, curly-leaf lettuce is much more pleasing in appearance than plain sorts, and bright red tomatoes are preferable to dull red specimens. The form of the product is also important. No one would claim that an ill-shaped cucumber is as attractive as one that is uniformly cylindrical except at the ends.

Numerous illustrations might be given to show that both color and form are important factors in relation to the attractiveness of vegetables. The choicest and finest ones will fail to fully please the eye of the prospective purchaser unless they are graded and packed in the proper manner. Packages which are small, neat, clean and convenient appeal to the vision, and if they are filled with superior vegetables, tastefully arranged, they will not fail to command attention.

Mention should also be made in this connection of tying materials, oiled paper, labels, trademarks, etc., which not only attract attention, but convey the impression that the vegetables are of special quality. The appearance of the market wagon and team, or of the delivery truck, as well as the neatness and personality of the salesman, should also have consideration.

Harvesting.—Each crop should be harvested at the proper time to obtain the highest yield without sacrificing quality. Over-ripeness should be carefully avoided, for such a condition always impairs quality.

Various kinds of baskets and crates are used in gathering the crops. If the houses are small the products are usually carried to the packing room. In large establishments, wheelbarrows or special carts (Figs. 55, 56 and 57) are employed, and wide alleys and corridors may be provided for their use. It is not a light task to harvest the crops under several acres of glass, and growers will do well to consider conveniences which will make the work less expensive as well as pleasanter.

Packing room.—The packing room (Fig. 58) should be easily accessible from all parts of the range. It is an advantage to have it close to the boiler room for the convenience of laborers who might be required in both places. It should be of ample size, to avoid crowding and to promote the work by proper organization and system. The floor should be of concrete, with a gentle slope to one or more drains. A wooden or metal wash tank with a drain board at each end should be placed in the central part of the room. Ordinary bath tubs are excellent for this purpose. An abundance of clean, running water is essential. Tables or benches of convenient height are placed around the walls of the room. There should be a sufficient number of windows to light the room well by day, and, since it is sometimes necessary to work at night, good artificial lights should be provided.

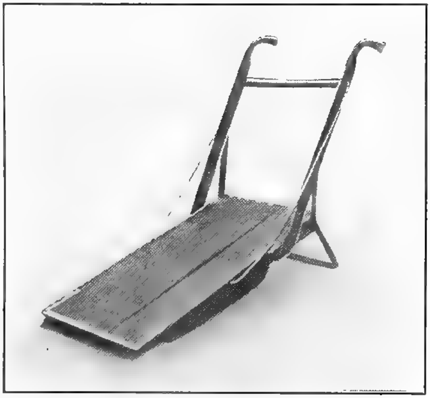

Fig. 55.—A convenient homemade cart for handling two barrels at a time.

The greenhouse packing room should be large enough to accommodate the market wagons or delivery trucks necessary to handle the crop. It is an advantage to have a driveway at one side of the room so that the floors of the wagons or trucks will be on the same level as the floor of the packing room. Provision must also be made, usually above the packing room, for a liberal supply of crates or baskets.

Packages.—The greatest care should be exercised in the selection of packages for the handling of greenhouse products. Baskets or crates used for products grown in the open may not be satisfactory for the higher quality vegetables grown under glass. Small packages are gain-

Fig. 56.—A handy cart for greenhouse use.

ing in popularity. Vegetables generally sustain less injury in transportation in small packages, and the small package is usually more attractive. There is nothing especially attractive about a barrel, but a neat little box or basket, filled with choice vegetables, naturally appeals to the consumer, and in most instances to the dealer. The small package is of greater advantage also to both producer and dealer than most of them realize.

Suppose, for example, that lettuce is shipped in barrels. The retailer who obtains a barrel, and whose trade is limited, may not sell more than one-third of the lettuce the first day. The remaining heads are more or less wilted by the second day, and they do not appeal to the buyers, so that fewer sales are made on that day. The lettuce is in much worse condition the third day, and the day closes with a remnant so inferior that it cannot be sold at all. The dealer, of course, is reluctant to buy another barrel of lettuce until disposition has been made of the previous lot. His sales and profits are diminished, the consumer is disappointed, and the producer wonders why his lettuce does not sell better. Had the small grocer bought a bushel box or perhaps two half bushel baskets of lettuce, there would have been no dissatisfaction at any point from producer to consumer, because a fresh lot of lettuce would be offered for sale every day. There are good reasons, sometimes, for using barrels for the shipment of lettuce, but the illustration applies to thousands of stores where various kinds of greenhouse products are handled in packages that are too bulky for the best results.

The style or form of the package should have consideration. Small baskets with handles always appeal to buyers. Variously designed carriers are in use, which seem to meet the demands of dealers. This subject will be more fully discussed in connection with notes on the marketing of each crop.

The bushel box and other smaller wooden and paper boxes and rectangular crates of various descriptions are popular because they can be loaded solidly on wagons, trucks and cars without any loss of space. It is a great advantage to use uniform and standard types and sizes in each community, and uniformity in this matter throughout the country would be of inestimable benefit to the vegetable-forcing industry.

Preparation for market.—Inasmuch as greenhouse products are usually of special quality and in many instances easily bruised or damaged, it is necessary to handle them with extreme care. They are taken promptly to the packing room, where they are prepared for market. Cleanliness is essential. In many instances very little attention will be needed to remove any soil or dirt that may adhere to the vegetables. The use of a moist cloth may be sufficient to secure proper cleanliness, though it is sometimes necessary to wash the vegetables.

Fig. 57.—Harvesting a crop of cucumbers in a large range.

Special emphasis should be placed on the importance of careful grading. It is a good business proposition to practice rigid grading. A reputation for uniformity in the vegetables offered for sale cannot be established without rigid grading. With most greenhouse products it is desirable to make three grades. Size, color, shape, markings, degree of ripeness and defects of various kinds should be taken into account.

Packing.—Not only must the vegetables be clean and properly graded, but they should be arranged or packed in the most attractive manner. A pleasing appearance secured in packing may be obtained by the careful place-ment of every specimen, so that the arrangement of layers and rows of individual specimens will be orderly and systematic. Lining the inside of packages with white or perhaps colored paper produces a pleasing effect. Attractiveness is often secured by wrapping each specimen with soft paper, which may bear the name and address of the grower. The use of paper in this way also helps to insure the safe transportation of the vegetables without bruises or other mechanical injuries. Radishes, rhubarb, etc., tied with blue or red tape always present a pleasing appearance.

Honest packing is absolutely essential. The vegetables at the bottom of the package should be just as good as those on the top. If there is any difference in this respect, it is better to have the specimens of less merit on the top. This will not only be an agreeable surprise to the dealer or to the consumer as the package is emptied, but it may cause him to place another order with the grower who has not deceived him. However, it is always better to have the produce run uniform throughout the package.

It is also important to give full measure. Partly filled packages, though the vegetables may be of the highest

Fig. 58.—Corner of packing room in a well-managed establishment.

quality, do not appeal to buyers. They invariably give the impression that the grower is endeavoring to get full prices for packages of vegetables which do not represent full value. It is a mistake to follow such a practice. In the long run the grower will gain by showing liberality and generosity in giving full or even heaped-up measure wherever covers are not required for shipment.

Methods of selling.—Hundreds of vegetable-forcing establishments are located near good markets that may be reached by wagon or auto delivery trucks. Whenever this is possible, the problem of marketing is comparatively simple. Other large establishments are located so far from market that practically the entire crop must be transported by rail.

A great many different methods are employed in selling greenhouse crops. Where the business is conducted on a large scale, it is customary to sell through commission and wholesale houses. In other cases wagons and trucks deliver the products to retail stores and hucksters, and this is the most common plan whenever two acres or less of glass is employed. Parcel post shipments are made to a very limited extent. It is apparent that our growers, as a rule, do not care to look up a trade which might be supplied by parcel post, nor do they want to attend to the multitude of details demanded by this system of marketing. Theoretically, it seems practicable, but it has not appealed to greenhouse growers. The extra labor required may be the greatest barrier to the adoption of the system.

Delivery trucks and wagons.—Auto delivery trucks are in common use among greenhouse growers. They have largely superseded wagons. The chief advantages of an auto delivery truck may be enumerated as follows:

(1) It enables a gardener to engage in vegetable forcing at a remote distance from the city. He may have unusually favorable conditions for vegetable forcing, such as a

sandy soil, protected location, abundant supply of pure water, cheap fuel, accessible labor and a good road to the city. Under such conditions, an auto truck may make vegetable forcing an attractive business proposition.

(2) The truck makes it possible to deliver produce promptly and speedily. This is a great advantage when a rush order is received, or when the market is unusually brisk and it is important to move the crop as rapidly as possible. There may be a shortage of labor in the greenhouses, and a motor truck enables the salesman to spend more hours in production instead of in marketing. It is also desirable for the vegetables to be placed on the market as soon as possible after they are packed. They should not be unnecessarily exposed to either excessively hot or very cold weather.

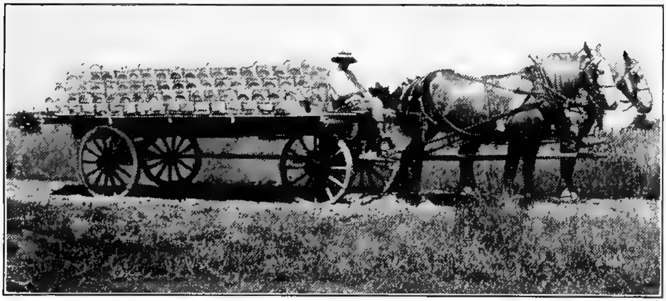

Fig. 59.—A load of cucumbers en route to shipping station.

As a source of power, gasoline may be cheaper than oats. In other words, many growers find that it is more economical to deliver with auto trucks than with horses and wagons. Furthermore, the auto truck may be kept on the road constantly, if necessary, and made to take the place of several teams.

Whether a motor truck or a wagon is used, it should be constructed so as to protect the vegetables from extreme cold while the vegetables are being transported to market.

Refrigeration.—When carloads of greenhouse vegetables are shipped to distant markets during the months of June and July it is necessary to ice the cars.

Pre-cooling.—Sometimes it is an advantage to pre-cool vegetables before they are sent to market. An Ohio grower has found a cold storage room adjoining the packing room a great advantage. It is commodious, and the large double doors permit the entrance of a loaded truck. During hot weather a picking of tomatoes may be made, if desired, on Saturday afternoon and held in prime condition for the Monday morning market. This cooler is also valuable for the temporary storage and cooling of crops grown out of doors.

Advertising—There are numerous ways of advertising greenhouse vegetables. The vegetables themselves, if high in quality, are the best advertisement. A neatly painted and lettered wagon or auto truck will gain publicity for the grower. Attractive brands and trademarks, placed on the packages or wrapping papers, are always effective. It sometimes pays to place advertisements in newspapers which circulate in towns or cities where the vegetables are sold. Gate bulletins, if vegetables are sold at the greenhouse, will attract patrons. Circulars or letters sent to the homes of prospective buyers, giving information relating to the quality and wholesomeness of the vegetables, should increase the volume of business.

Co-operative associations are not as common as they should be among gardeners who are growing vegetables under glass. Some of the Cleveland, Ohio, growers have found it an advantage to conduct a co-operative sale store. A strong organization has been formed at Ashtabula, Ohio.

An interesting organization has been formed at Grand Rapids, Mich. The organization consists of about 30 greenhouse men who have their goods sold for them collectively. The selling is done by a produce company which is also a member of the association, and whose members are, in addition, general merchants. The company receives for its services a certain fixed price. The greenhouse men that are in this association raise practically nothing but lettuce and tomatoes. The lettuce is cut at the greenhouses, and placed in boxes especially prepared for same and brought to the company's store, where it is inspected, washed, packed and prepared for shipment. This is done under the supervision of the association and at the association's expense, 2 per cent ot the gross sales being taken out to cover these expenses. The tomatoes are handled in practically the same manner, and the aim of the association is to pack its stuff uniformly, and to see that only vegetables of good quality are put on the market. It has also been the aim of the association through its selling agents to obtain as wide a distribution of its products as possible. The association has been remarkably successful. While the members have full power through their officers and committees to pass upon all questions concerning their goods, they have always left the selling of them entirely to their regularly appointed agents. The lettuce returns are prorated weekly and all who bring the lettuce in one week receive the same price. The tomato sales, on account of more rapid fluctuation of the market, are pro-rated twice weekly.

There is a unique organization of eight to ten frame growers at Norfolk, Va., known as the "Hotbed Growers' Association." Each member of this association is also a member and stockholder of the Southern Produce Company, and secures affiliation in this way with the larger and stronger organization. The members of the Hotbed Association plant, harvest and market the same crops at the same time. This insures large shipments, and eliminates, as far as possible, competition among the members.

There is one reliable house in each important city that receives consignments of the Hotbed Association. In return for the privilege of receiving all of the consignments, each commission house sends and pays for a private telegram reporting prices obtained for each shipment. In addition to this information, a daily market wire from each of these houses is sent during the shipping season to the Hotbed Growers' Association through the Southern Produce Company. The members of the Hotbed Growers' Association are very enthusiastic concerning the benefits of the organization.

Market slumps of greenhouse products sometimes occur because of inefficient distribution. Many small towns, and occasionally cities, are meagerly supplied with greenhouse vegetables, while other centers of population have a surplus. It is extremely difficult to avoid such congestion without co-operation among growers. Progress in this direction, for various reasons, has not been very encouraging.

CHAPTER XII

ASPARAGUS

Importance.—The forcing of asparagus has appealed to comparatively few American gardeners. It is generally believed that it does not offer special inducements as a forcing crop, and undoubtedly there are good reasons for this opinion. Statements may be found here and there, in the literature relating to the subject, that the forcing of asparagus is profitable, but it is seldom one hears of a grower who claims that he has made the venture a financial success, or that he considers the crop especially promising for forcing. However, we must recognize the fact that asparagus is forced in a very limited way by market gardeners and private gardeners, and occasionally by the more extensive greenhouse growers, so that the subject deserves careful consideration.

The forcing of asparagus in European countries, especially in France and England, is an important commercial proposition. But climatic and economic conditions there are quite different, and it is most improbable that the same methods employed in the United States would yield satisfactory profits. The cost of labor in this country would likely be more than the gross returns would justify. Excellent transportation facilities from the South and from California enable those sections to place an early crop on eastern markets at prices which can scarcely be met when artificial heat must be used to force the shoots. However, many private gardeners are always interested in the forcing of asparagus, and there is no reason why thousands of people should not force the crop for the home table. It is also probable that commercial growers may become more interested in the crop, especially if we learn how to force it more economically so that it could be sold at lower prices.

Principles involved.—The large fleshy roots and crowns of asparagus are shown in Fig. 60. These contain sufficient nourishment to make a good cutting of shoots without receiving any additional plant food from the soil. That is, if sufficient heat and moisture are provided, shoots will be produced for a period of four to six weeks when the food supply of the thick roots will be exhausted and they will be of no further value for forcing or planting in the open. When the roots are forced in the beds where they stand, this does not necessarily occur, for cutting may be discontinued before the crowns are completely exhausted, and they will then recuperate in a season, ready to produce another crop. Roots which have been dug and moved to other locations for forcing are invariably discarded at the close of the forcing period.

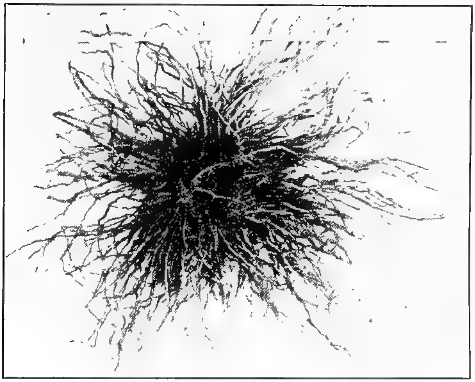

Fig. 60.—A large root of asparagus suitable for forcing purposes.

There is a difference of opinion among growers concerning the value of fertilizers applied to the forcing beds. Without any leaves or chlorophyll it would seem that the shoots would be unable to utilize any nutrients other than those stored in the roots, but some of the largest and most successful growers claim that positive benefits are derived from the application of commercial fertilizers and also stable manures. Voorhees held the same opinion. When the roots are forced in beds which have full light, perhaps there is sufficient chlorophyll development on the shoots to be of some value in the elaboration of plant food.

Light is not essential. The beds may be in total darkness, though subdued or diffused light is usually admitted to the beds. If white shoots are desired there should be practically no light unless the shoots are blanched by means of a 6 to 8-inch covering of soil or sand over the beds.

Varieties.—Any variety which produces large shoots is suitable for forcing. Inasmuch as the roots should be grown for four years before they are large enough for forcing, it is important to select a variety practically immune from rust. Much has been said about the merits of old varieties, such as Palmetto, Conover Colossal and Barr Mammoth, but recently Reading Giant, introduced by the Asparagus Experiment Station of Concord, Mass., is receiving much attention because of its freedom from rust and its vigorous habit of growth. There is no reason why this superb variety, or other equally good or superior, disease-resistant varieties, developed at Concord or elsewhere, should not ultimately replace the old, well-known kinds, both for field culture and forcing.

Growing the roots or crowns.—Anyone who undertakes the forcing of asparagus should grow his own roots, whether they are to be forced in permanent field beds or removed to other locations where artificial heat can be provided. It is probable that the forcing of this crop would prove more renumerative if greater care were exercised in growing the roots. In too many instances they are dug from field plantations which are no longer profitable because of their age or other unfavorable conditions. As a rule, the field plantations fail to return satisfactory profits because the roots were perhaps inferior when planted and they have become largely exhausted by cutting year after year. In all such cases the roots lack vigor, and when planted in the forcing bed produce small shoots and light crops. The planting of a few such roots to meet the demand of the home table is not objectionable, but when choice shoots are wanted for market the strong, vigorous roots must be employed for forcing.

Good roots, such as the one shown in Fig. 60, cannot be grown except from good seed selected from strong, rust-resistant plants. Such seed is now obtainable from specialists. A rich plot of ground should be selected to start the plants, well supplied with fine, rotten manure and available plant food. The seed should be sown as early in the spring as the ground can be worked. If very strong plants are to be grown, it is desirable to be liberal in the space allowed for each plant. A seed dropped every 3 inches in the row, and the rows 16 to 18 inches apart, will give each plant room for its best development. A few radish seeds sown with the asparagus will germinate promptly and mark the rows, and thus facilitate cultivation. The asparagus seeds are slow to germinate and the plants will not appear for about four weeks. There should be frequent tillage throughout the summer. An excellent plan is to cultivate the nursery until midsummer and then apply a 3-inch mulch of horse manure which has been aerated a few days by spreading it in a loose pile not more than 18 inches deep. The manure will prevent weed growth and conserve soil moisture more perfectly than tillage, and liquid plant food will be furnished the asparagus after every rain. Overhead irrigation and manure mulching can be used to advantage in growing strong roots. Top-dressing a few times during the summer with nitrate of soda at the rate of 100 pounds to the acre will prove beneficial unless the soil is very fertile. No effort should be spared to grow unusually strong roots.

An interesting experiment has been made by Myers of The Pennsylvania State College to determine the value of crowns of different sizes. While the investigation was made primarily for the benefit of the trucker and market gardener, it also contains valuable lessons for growers who are engaged in the forcing of this vegetable. In the spring of 1908, one-year roots of Palmetto were purchased and divided into three grades or sizes, No. 1 being the largest, No. 2 medium size, and No. 3 the smallest. Two rows 340 feet long were planted with each grade. The following graph (Fig. 61) shows in a striking manner the returns of each size over a period of six years.

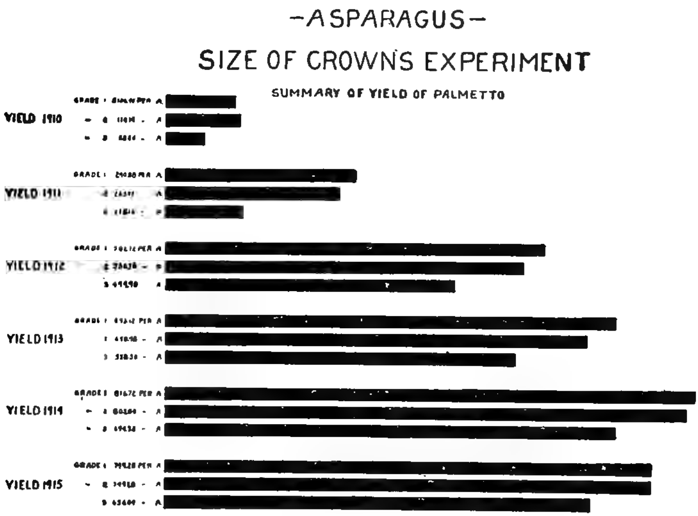

Fig. 61.—Graph showing returns from asparagus roots of different sizes.

It will be seen that the smallest roots give the smallest returns for every year, though the difference is not so marked after the second year of cutting. The difference between returns of roots of first and second size is worth considering but is not so striking. The experiment shows that it is a poor business proposition to plant small roots, whether they are to be used for field culture or for forcing. Average annual receipts per acre, during six seasons of cutting, from No. 1 roots were $539; from No. 2, $521; and from No. 3, $418.

There is absolutely nothing to be gained by planting more than one-year-old asparagus roots in field plantations. If roots are to be grown primarily for forcing, it would seem that the most profitable plan would be to transplant the yearling roots early in the spring, and to set them closer together than would be desirable if the beds were to be cut over a term of six years or more. Good plants and strong roots may be grown when they are set in rows only 3 feet apart and the plants 1 foot apart in the rows. Such close planting is unnecessary, of course, if plenty of land is available. Somewhat stronger roots will probably be grown if they are planted 2 by 4 feet apart. Whatever planting distances are adopted, the plantation should have thorough tillage until the roots are dug for forcing. Some gardeners prefer to begin cutting in the field the second season from planting. It will be seen by Fig. 61 that No. 1 roots, planted in 1908, produced $106 worth of asparagus to the acre in 1910. In four years of cutting, No. 1 roots produced a total of $1,673 worth to the acre, after which they were in prime condition for digging and forcing. Most growers who have had experience in forcing asparagus prefer to dig roots that are four years old from transplanting. In this event, No. 1 roots would have returned gross receipts amounting to only $397 to the acre. When roots are to be used for forcing it is questionable whether the most profitable practice is to dig them so early. It will be seen by referring again to Fig. 61 that maximum returns were not reached until 1914, which was the fifth cutting season.

Digging and storing roots.—Unless the crop is to be forced in the field where the roots stand, it will be necessary to dig the crowns late in the fall before the ground freezes. In most sections of the North this work should be done not later than November 10. There should be as little mutilation of the roots and buds as possible, for any damage to them will necessarily reduce their value for forcing purposes. The grower, however, must not be alarmed if he finds that it is impossible to remove old plants from beds without breaking off many of the long, fleshy roots. It was a difficult task to dig the large root shown in Fig. 60, and this is one of the chief reasons for using younger roots. Four and five-year-old roots may be removed by plowing along both sides of the row and then loosening the roots with a spading fork. The expense of this method of harvesting the roots is much less than that of digging them. Any soil that naturally adheres to the roots is allowed to remain.

The crowns should not be unnecessarily exposed to the wind and air, but should be promptly stored where they will not dry out. A shed, cool cellar, cave or pit may be used for this purpose. Sufficient soil should be thrown over the roots to keep them moist.

Forcing in permanent beds.—Numerous plans have been used for forcing asparagus in permanent beds without removing the roots to other quarters. It is claimed by some growers that this method produces larger shoots of better quality than can be obtained from transplanted roots. An additional advantage, as previously stated, is that the roots are not completely exhausted and may be used again, perhaps several times, for forcing. While the arguments seem to be in favor of forcing the roots where they have been grown, we do not know of any extensive growers, though there may be some, who are following this method.

The simplest plan of field forcing, sometimes practiced by amateur gardeners, is to pile hot manure around barrels or small frames placed over the asparagus crowns. The top of the barrel may be covered with canvas or boards to conserve the heat.

Ordinary coldframes placed over the beds and covered with glass sash will advance the crop much earlier and more rapidly in the spring than if it is left without covering. This method is used to some extent by market gardeners. Additional heat may be furnished by banking the frames with hot manure, or a coil of steam or hot water pipes may be placed in the frame.

Hot manure is sometimes placed over the beds early in the spring and allowed to remain until the shoots start, after which it is removed. This method cannot be used too early in the spring without taking risks of losses from freezing.

European gardeners and perhaps a few American growers force asparagus by plowing or digging a trench midway between two rows. The soil is thrown over the rows of asparagus and the trenches are filled with hot manure. Sometimes such trenches are lined with brick, with passageways to the asparagus rows, thus making them permanent. Steam pipes may be placed in the tunnels, with or without manure. This plan does not appeal to American gardeners.

Whitten, of the Missouri Station, conducted an interesting experiment in forcing permanent beds by steaming. Trenches were made between the rows and covered with 12-inch boards which rested on 4-inch blocks placed along either side of the trenches. This formed tunnels between the rows through which hot steam was conducted. To guard against the escaping of steam, 2 or 3 inches of soil was placed over the boards and the entire plantation was covered with 5 or 6 inches of horse manure. The following data regarding the experiment are quoted from Bulletin 43 of the Missouri Station:

"To conduct the steam a 1½-inch pipe was carried above ground from the boiler to one end of the central tunnel, a distance of 185 feet. A steam hose long enough to reach each tunnel was attached to this pipe through which to blow steam into the tunnels. It was not the idea to give a constant supply of steam, but to discharge a little into the tunnels each afternoon, or as often as was necessary to maintain sufficient warmth. A piece of tile was inserted into the mouth of each tunnel to prevent the discharging steam from tearing away the earth.

"The first steam was turned into the tunnels on November 14, 1896. Steam was discharged into each tunnel, not to exceed five minutes at a time, in order not to heat the earth too hot in any single place. It required about one hour of steaming the first day to bring the bed up to the required temperature of sixty degrees. The distribution of heat throughout the bed was very uniform and satisfactory. The moist steam seemed to permeate the soil equally in all directions.

"After the first day, very little steaming was necessary until the asparagus began to be produced. On an average the bed was steamed about twice in three days, and then only for about five minutes for each tunnel. The soil and horse manure mulch seemed to hold the heat very well, the frequent steamings keeping up fermentation in the mulch.

"The first asparagus was cut November 24, 10 days after the first steam was applied. The stems were cut just before they got through the soil and were perfectly bleached. They were as large as those ordinarily produced during the normal period of growth in spring, and were far more crisp and delicious.

"Cuttings of asparagus were made almost daily for about a month, when the growth became somewhat weak. The last cutting was made on December 22. During the month 141 bunches of the ordinary market size and weighing about one-half pound each were cut from this bed of 25 by 50 feet. This was equivalent to 300 feet of row or 100 hills of asparagus.

"The second asparagus bed was managed the same as the first. It was steamed on December 16, 1896, and the first asparagus was cut on December 30. The weather was much colder at this time and a little more steam was required. At times, however, no steam was applied for two or three days, and the temperature of the bed did not fall much below sixty degrees. The finest asparagus was produced during the coldest weather. The time of cutting, however, was slightly more irregular than in the previous bed, and was prolonged until February 26, 1897. The bed was 25 by 75 feet, or equivalent to a row 450 feet long. It produced 234 market bunches besides considerable that was taken for exhibition purposes.

"At this writing, May 2, 1898, the spring growth of asparagus from the beds forced during the winter of 1896-97 shows that one season's growth, after forcing is sufficient for the plants to regain their normal vigor.

"By blowing steam directly into the tunnels the soil is kept moist; the steam has a penetrating effect, and permeates all parts of the bed, giving a uniform heat throughout; this moist steam keeps up a continual fermentation of the manure mulch, thus giving heat and only occasional brief steamings are necessary.

"Care must be taken not to use too much steam at one time, or the plants may be ruined by over-heating. Our asparagus rows were 4 feet part, the tunnels midway between them were only 8 inches wide, and yet we found that five minutes at a time was as long as was safe to force steam into a single tunnel.

"These experiments have been so successful as to indicate that anyone provided with a steam heating plant, could successfully force asparagus for the markets in this manner."

Ordinary drain tiles were also used at the Missouri Experiment Station, but they did not give satisfactory results. Cornell Station forced asparagus in a portable pipe-frame house covered with canvas. It was 20 by 50 feet in size. The sides or walls were 18 inches high and the frame consisted of a ridge and three pairs of rafters. With five lines of steam pipe, one under the ridge and two at each side of the house, no difficulty was experienced in forcing asparagus during the winter months. At the close of the forcing period, the canvas is removed and the beds are cultivated for a season, and they may then be used again for forcing.

Forcing transplanted roots.—Roots may be removed from the field beds and forced wherever suitable conditions can be provided. Perhaps the most common plan is to use the space under greenhouse benches for this purpose. Side boards may be placed along the walks to retain the soil, or, if preferred, shallow trenches may be dug to receive the roots.

Sometimes the beds or benches of the greenhouse are used for forcing asparagus. If there is a good market for the product, it may pay as well as lettuce or other more commonly grown greenhouse crops.

A Pennsylvania grower has been highly successful in forcing asparagus in a house which is about 20 by 50 feet in size. Almost the entire structure is below the surface of the ground. That is, the brick walls which are about 8 feet high extend less than a foot above the ground. The roof, which slopes slightly, is made of glass and sash-bars which extend across the entire width of the house. There are three tiers of beds in this structure arranged in the same manner as for the culture of mushrooms. It is seen at once that the house is economical in construction as well as in heating. The few heating pipes needed are connected with the furnace of the residence. Several crops may be grown in this house during the winter. The owner is well pleased with the results.

Sheds in connection with greenhouses or potting rooms are often used for the forcing of asparagus. It may also be grown in cellars which are warm enough. A common plan in this country and in Europe is to use either manure or steam-heated frames or hotbeds. When manure is used, the roots must not be planted until the violent heat has subsided, or small, spindling shoots will be produced. If the climate is severe and the roots are forced during the winter months, there should be a depth in the hotbed of not less than 30 inches of manure.

Soil.—Any fine soil that contains a large proportion of organic matter will be suitable for forcing this crop. It is possible that nearly as good results might be obtained by planting in sand or coal ashes. If the roots obtain even a small percentage of nutrients from the earth during the period of forcing, then it would be desirable, of course, to use rich soil. Inasmuch as this seems to be a debatable question, the safe practice is to use fertile soil that will absorb water promptly after its application.

Planting.—Freezing the roots for a few days before they are planted is thought to be an advantage. Preparatory to planting, regardless of the location, about 2 inches of earth should be placed in the bottom of the beds. The roots, which should not be less than four years of age, are then placed on this layer of soil as close together as possible and the spaces around and between them filled with soil. An inch or two of earth is placed over the tops of the crowns, and 6 to 8 inches of soil is used in this way if blanched shoots are to be grown. In order to have a succession of shoots it is necessary to make new plantings at intervals of three to four weeks.

There is a better market for forced asparagus during the late fall and winter than in the spring, when there is more competition from California and the South. There are probably no better seasons to have it ready for market than at Thanksgiving and Christmas. Less heat is required, too, early in the winter than during January and February.

Temperature.—There is some difference of opinion concerning the most suitable temperatures for the forcing of asparagus. Growers and writers all agree that the crop should be started at a low temperature. It will begin to force at 45 degrees or even below that point. If the temperature does not exceed 50 degrees for a week the results will be better. High temperatures at first apparently produce weak, spindling shoots. After strong shoots have started, a temperature of 55 to 60 degrees will be satisfactory, though some practical growers prefer 75 degrees or even higher temperatures.

Watering.—Immediately after the beds are planted they should be given a thorough watering. Enough water should be applied to penetrate the entire depth of the beds. They should then be kept constantly moist, and this may require two or three waterings a week. Rather profuse watering is regarded as necessary for high yields of large shoots.

Marketing.—The spears should be removed from the crowns with care, to avoid injury to buds or shoots that may be starting. In loose soil it is an easy matter to break them off with the thumb and fingers. In deep beds, which are required to blanch the spears, an asparagus knife will be found to be an advantage.

Half-pound bunches rather than larger sizes are in most demand. The price varies from 20 cents to 75 cents a bunch. It is probable that satisfactory returns cannot be realized at a price which is much less than 75 cents a bunch.

Well-managed beds will yield for a period of four to six weeks. If excessively high temperatures are maintained the crowns become exhausted in four weeks or less.

CHAPTER XIII

RHUBARB

The forcing of rhubarb is similar in many respects to the forcing of asparagus, which has been treated in Chapter XII. There are essential differences, however, that make a separate discussion necessary.

Importance.—The forcing of rhubarb is much more general and extensive than the forcing of asparagus. There are many large houses devoted to this purpose, and hundreds of truckers, market gardeners and even farmers find it profitable to grow more or less rhubarb when out-of-door plants are not producing.

The growing of rhubarb in cellars and basements for the home table and perhaps a small surplus for market is particularly satisfactory. Just a little nook or corner will grow all that a family can use. The plants themselves, grown in subdued light, are very beautiful and their æsthetic value appeals to the amateur.

Quality.—The city consumer as well as the gardener who supplies his own table soon discovers that forced rhubarb is superior in quality to that grown in the open where the plants receive full light. The forcing of this crop is nearly always conducted in partial darkness, but sometimes all light is excluded. Whether grown in total darkness or in partial light, the quality is materially affected. In texture the forced stalks are unusually crisp and tender on account of the development of less woody fiber. The skin is very thin and tender and does not separate readily from the stems. Rhubarb forced in partial light contains 8 to 10 per cent more water than that grown out of doors in full light, so that the proportion of acid is less than when the stalks are grown in the open, consequently less sugar is required to sweeten the sauce, which is a beautiful, nearly transparent pink.

Light.—Formerly it was the customary practice to force rhubarb in total darkness. Total darkness prevents the development of chlorophyll; consequently the stalks are whitish and the leaf blades mere rudiments. The markets show a preference for a little color in the stalks and for leaf blades that are slightly developed (Fig. 62). When grown in diffused light, the stalks vary in shades of pink, and some leaf-blade development adds to the attractiveness of the product. The stems average longer than those grown in total darkness, and some light is an advantage in caring for the beds and in harvesting the crop.

The importance of diffused light should be emphasized. Results will not be satisfactory if some windows are covered and others admit full light. Under such conditions the growth will be unequal and crooked stems will be developed by the tops of the plants bending toward the light. Diffused light may be obtained by placing brown paper over all of the cellar windows, or burlap along the sides of the beds, if the crop is being forced under greenhouse benches.

Principles.—The large, fleshy leaves of the rhubarb, which is a perennial, elaborate more food than can be utilized by the parts of the plant above ground, with the result that there is an unusual accumulation of nutrients in the fleshy roots. An old root of a single plant may weigh several pounds. When the crowns are forced under favorable conditions of heat and moisture, the supply of food in the roots is transformed and extended into new growth. In other words, it is transferred to the leaf stalks and small leaf blades. As the stalks are harvested, additional shoots appear and grow until the supply of plant food in the roots is exhausted, when, of course, no further growth can take place. If the roots which are being forced are wanted for propagation, as is sometimes the case, they must be lifted from the beds before they are completely exhausted, and stored in a cool, moist place until wanted for planting in the field or garden.

Forcing in permanent beds.—Rhubarb may be forced in the beds where the plants stand by using practically the same methods as those used for asparagus, explained in Chapter XII.

The placing of barrels over hills is a favorite practice among home gardeners, and this plan is used to some extent by commercial growers. Sometimes a shallow trench is dug around the hill so that the barrel will stand a few inches below the surface of the ground. No other protection may be given the plant, but if rapid growth is desired, hot manure must be piled and packed around the outside of the barrel, and the latter covered with boards if maximum heat is required. Barrels are used in this way in the spring of the year when there is no further danger of hard, freezing weather. The method is most suitable for home gardens.

Fig. 62.—Rhubarb stalks grown from roots planted in coal ashes.

Market gardeners sometimes grow special beds of rhubarb to be used for forcing, and deep coldframes are then placed over them. The planting distances must be such as to best utilize space in the frames. If the frames are 6 feet wide, there may be three rows of plants running lengthwise in them, and the plants may be 2 feet apart or even less than that if the beds are given special care previous to the forcing period, so that they will grow strong roots.

Trenches heated by steam or hot manure, as explained on page 184, may also be used, but it is doubtful whether the plan is practicable when labor costs as much as it does in the United States.

In the Boston district, cheap permanent benches are built over the rhubarb plantations, where the plants are set about 2 feet apart each way. Such houses ordinarily contain board walls. There are wooden rafters to support hotbed sash, placed to make either an even-span or a shed form of roof. For use in winter, a few coils of steam or hot water pipes are installed for the maintenance of proper temperature. For use early in the spring, no heat will be required in addition to that supplied by the rays of the sun on the glass sash. At the close of the period

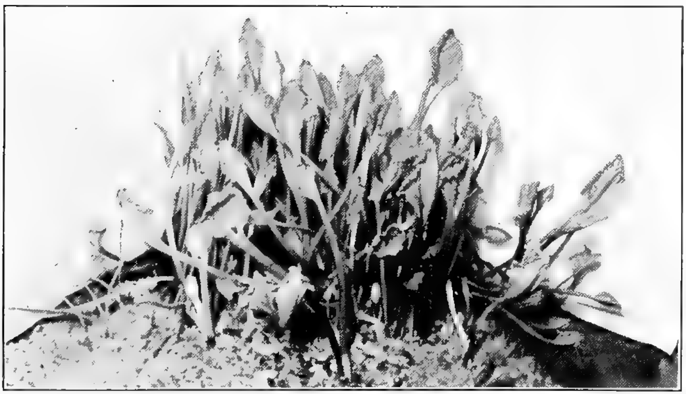

Fig. 63.—Rhubarb growing in coal ashes in an ordinary cellar.

of forcing, the sash are removed and the plantation is fertilized and cultivated so that the roots will become large enough to be forced again the following season.

Portable, cheaply constructed houses are sometimes used in the forcing of rhubarb. Such houses may be moved from place to place in the field, whenever the roots fail to yield satisfactory cuttings.

Forcing transplanted roots.—The more general practice is to transplant the roots to suitable places for forcing.

A common plan is to use the cellar or basement of the residence. Fig. 63 shows a small bed which the writer grew near the hot water furnace in the cellar. It required very little attention and produced more rhubarb during the period of production than could be used on the home table. There is no reason why thousands of cellars should not produce, with scarcely any trouble, a delicious supply of rhubarb that would be available from November until April or May, when cuttings can be made from plants in the field or garden.

It is a simple matter to grow rhubarb in deep coldframes (as seen in Fig. 64). They should be excavated to a depth of about 2 feet in order to allow ample space for the growth of the stems. The roots are planted close together in the bottom of the pits and glass is placed on the frames. This method of forcing is satisfactory when the beds are started any time after the first of March, or perhaps earlier in some parts of the North. More rapid growth will be secured if hot manure is banked around the outside of the frame, or a coil of pipe for the use of steam or hot water is placed inside of the frame. Sometimes the roots are planted in the fall inside of high frames placed on the surface of the ground. The roots freeze when the weather gets cold, and later they are forced by placing sash on the frames and banking them with horse manure. This is a practical commercial proposition.

As previously stated, a common plan is to utilize space under greenhouse benches for the forcing of rhubarb. The success of this plan will be determined largely by the temperature which must be maintained for other crops in the house. See page 163. Occasionally the beds or benches are used for rhubarb, but that space is regarded as more valuable for other crops which require more exacting conditions of heat, light and moisture.

Manure hotbeds are largely employed by market gardeners for this purpose. It is not necessary to have a

Fig. 64.—Rhubarb growing in coldframe.

depth of more than 18 inches to 2 feet of manure, unless the climate is very severe. In mild sections a foot of hot manure will be adequate to force the crop. Pits, caves and cellars of various descriptions are used. Small pits and cellars are sometimes heated with lamps or stoves. Steam or hot water, however, is always preferable, though good results may be had with stoves.

There are many cheaply constructed, commercial rhubarb houses. (Fig. 66.) Sometimes these structures are several hundred feet long and 15 feet or more in width. They may be built as sheds along the side of a greenhouse or other building. Economy in construction and heating is important. Paper roofs will be satisfactory and second-grade lumber may be used for the walls. Small windows should be well distributed in order that all parts of the house may be equally lighted. Such houses are sometimes used for the storage of celery and root crops until Thanksgiving or later, and the rhubarb may be planted any time after this, though it is seldom forced before January 1.

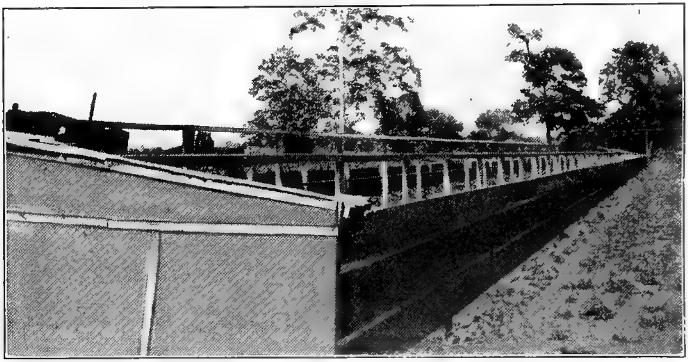

Fig. 65.—An inexpensive rhubarb house near Boston. Sash are placed on the frame whenever it is desired to force the crop.

Varieties.—Several varieties, such as Linnæus, Strawberry, Victoria, Paragon and Mammoth, are mentioned in connection with the forcing of rhubarb. Varietal distinctions are not marked or well defined, so that it is impossible to give specific information on this subject. The Linnæus type is earlier and smaller than the Victoria, which seems to be regarded as the most vigorous of the varieties, excepting, perhaps, the Mammoth. Both Linnæus and Victoria are extensively used for forcing. There is so much variation, however, in strains of different varieties that the whole matter is in a state of confusion. Whatever strain or variety is used, the ideal plant for forcing is one which is vigorous in growth and which produces a moderate number of large, pink stalks rather than many small ones. Plants grown from seed of the same plant are extremely variable. If the best plants from a large number of seedlings were selected and multiplied from year to year by the division of the roots, superior plants would soon be available for forcing purposes.

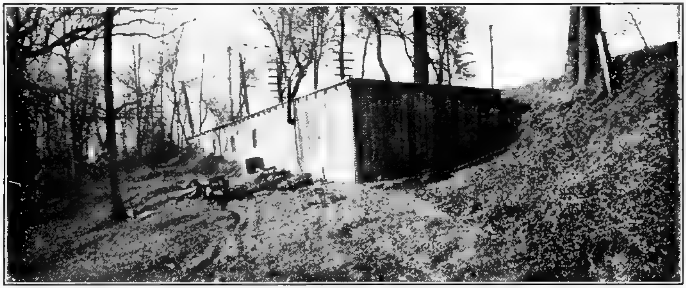

Fig. 66.—A simple house in Maryland for the forcing of rhubarb.

Growing roots.—Rhubarb is generally forced from roots taken from plantations which have produced several crops. The stems of plants which are four or five years old are much smaller than those on two and three-year roots. When old roots are used for forcing, the stems are necessarily smaller than is preferred by the market, but inasmuch as the old plantation is no longer satisfactory the gardener concludes that it is better to force the crown, and thus make an additional profit, than to plow the field and not attempt to save the roots. For example, while a superior forced product may be obtained from three-year-old roots (Fig. 67), the better business proposition may be to use the roots in the field until they fail to make a good financial showing and then force them, excepting, of course, the buds that are necessary to make a new planting. At any rate, this is the policy followed by most gardeners.

Some interesting experiments have been made on the growing of forcing roots from seed. The Wisconsin Experiment Station obtained good results from sowings made broadcast in August. The seedlings were transplanted into rich soil the following spring, when they made roots large enough for forcing in one year.

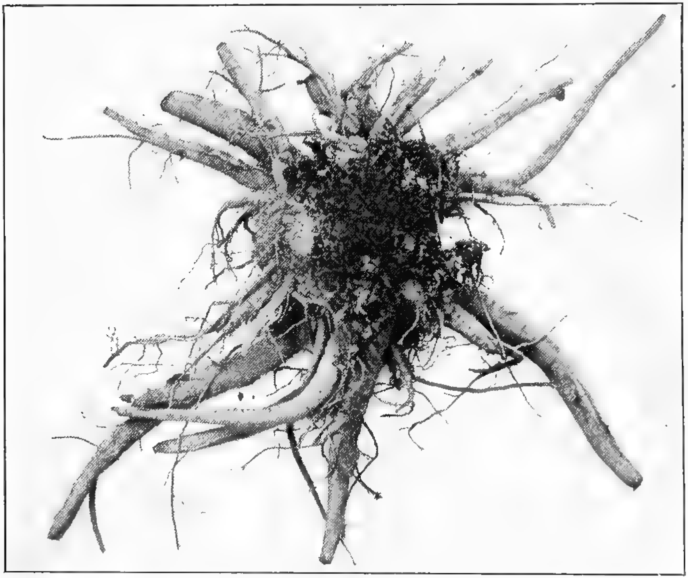

Fig. 67.—A large rhubarb root suitable for forcing.

Lazenby, of the Ohio State University, found that seed sown about April 1, in very rich, moist, sandy loam, produced plants of forcing size in one season. The rows were 2 feet apart and the plants thinned to 15 inches and given the most careful attention. By August 15 some of the stems were 20 inches long and the leaf blades a foot wide. Single roots, dug in the fall, weighed, with the little soil that naturally adhered, from two to five pounds and produced most excellent results in the forcing bed. See page 202 for notes on yields from these roots.

Seedlings may also be started under glass and planted in the open the latter part of April. If there is danger of frost, the young plants should be well hardened before they are set in the open ground. They stand transplanting well, and if started under glass the total period of growth the first year is very much lengthened, which is a great advantage in growing large roots. A soil of high fertility, and the most thorough tillage, are absolutely necessary for the growing of large roots in one season.

Digging and storing roots.—The roots are dug or plowed out and stored in the same manner as asparagus roots. See page 182.

Preparing beds.—Beds which are properly prepared for the forcing of asparagus are equally suitable for rhubarb. See pages 183, 186.

Freezing roots.—The growth of rhubarb under artificial conditions is accelerated by thoroughly freezing the roots and giving them a rest period before they are planted. Sometimes they are frozen in the field where they are plowed out, or they may be exposed to hard freezing at any time during the winter. They should be frozen solid throughout. There is no danger of injuring them by the lowest winter temperatures. It is undesirable, however, to leave the roots uncovered in the open ground more than several days, because their vitality will then be reduced by excessive loss of moisture. One to three days of freezing will have the desired effect. In mild climates where there is no hard freezing, drying the roots for a short time has much the same effect as freezing them, though drying should be avoided if possible because it reduces their vitality. An excellent plan is to dry the roots for a day and then pile them in an open shed, where they are covered with straw or other litter. When cold weather arrives, uncover the roots and freeze them preparatory to planting.

Planting.—The roots are placed close together on a bed of soil 2 or 3 inches deep. Care should be exercised that all spaces between the roots are filled and the roots themselves covered with 2 or 3 inches of soil. The small bed of plants shown in Fig. 63 was grown in hard coal ashes. We have had just as good results with small lots in soft coal ashes. It would seem that any medium, such as soil, ashes, moss or sawdust, which would hold moisture for the roots, would be satisfactory for forcing rhubarb. In large cellars or buildings, narrow passageways or walks should be left about every 5 feet for convenience in harvesting the crop. When a succession of stalks is desired, new roots should be started at intervals of about a month, depending on the rapidity with which the crop is forced. There is less breakage and mutilation of the roots if they are handled and planted while in a frozen condition.

Watering.—A thorough watering is given the beds immediately after they are planted. The amount and frequency of the applications, thereafter, will depend mainly on the method of heating and the location of the beds with regard to rapidity of evaporation. Ordinarily, the beds do not need to be watered oftener than once or twice a month. They should be kept moist, but over-watering may be harmful by causing decay and soft stems.

Temperature.—Rhubarb begins to grow at a temperature slightly above freezing. A crop may be matured when the temperature does not at any time rise above 45 degrees. Low temperatures are considered favorable to high yields. Growth is very slow when the temperature is under 50 degrees and a comparatively long time is required to mature the entire crop. A temperature ranging from 55 degrees to 60 degrees is ideal and that from 50 degrees to 55 degrees gives excellent results. If the temperature ranges from 55 degrees to 60 degrees, stalks will be large enough to cut in about 25 to 30 days from planting, and the beds will produce for at least four weeks. Excessively high temperatures not only cause rapid growth, but the stalks will be spindling.

Harvesting and marketing.—The brittle, tender stalks must be handled with extreme care to avoid injury. They are easily removed from the crowns by grasping the base of the stalk with the hand, and with the index finger of the same hand breaking and pulling the stalk from the crown without damaging those that may be starting. The stalks should be removed as soon as they have attained marketable size. If left too long they become soft, spongy and unsalable. Washing the stems is not considered desirable because they keep in better condition

Fig. 68.—Rhubarb forced in total darkness. Note small leaf blades.

for a longer period if no water is used. A cloth or brush will remove any soil that may adhere to the stalks.

The number of stems which should be tied in a bundle will depend on their size. If they are large, three or four (as shown in Fig. 68) will be sufficient. If small, twice that number may be required.

Forced rhubarb for market is usually tied with red tape. Some growers prefer white tape. A common practice is to tie a dozen bunches into one bundle and then sell by the dozen. Oiled paper can be used to advantage in wrapping the bundles or even the individual bunches.

Yields and returns are extremely variable. The small patch 2 feet square (shown in Fig. 63), grown in coal ashes, was planted January 9. The cellar was a little cool for rapid growth.

The bed of 4 square feet produced as follows:

February 24	33 ounces
March 1	42 ounces
March 4	39 ounces
March 9	129 ounces
March 25	50 ounces

This makes a total of about 18 pounds, or 4½ pounds to the square foot. The six stalks shown in Fig. 62 weighed 22 ounces. Their height ranged from 15 to 18 inches, and the largest were an inch in diameter. This bed was located about 4 feet from a hot water furnace.

The *Market Growers' Journal* reports the following weights and measures relating to 10 selected stalks grown by Lazenby from one-year roots at the Ohio State University:

	Inches
Average length of stem	17.3
Average length of leaf blade	4.4
Total length of leaf	21.7
Average length of leaf blade	3.0
Average weight of whole stalk	4.6

The crop sold from one lot of roots in an 8 by 10 foot bed in the cellar brought $10. Two crops from seedling roots grown on 185 square feet of space sold for $35.

In "The New Rhubarb Culture," Morse reports $144 as the winter returns from a cellar 36 by 54 feet in size, heated by two large lamps.

Perhaps an average return for 3 by 6 foot sash for rhubarb grown in coldframes is $1.50 each. Prices per dozen bunches range from 60 cents to $1.50. It is sometimes sold by the pound.

CHAPTER XIV

LETTUCE

Most of the forced lettuce sold in the city markets previous to 1888 was grown almost exclusively in hotbeds and coldframes. About this time greenhouse construction became active, and the development of the industry has surpassed the expectations of the most optimistic of the pioneer growers. W. W. Rawson of Boston, Mass., was the most conspicuous of the eastern horticulturists who were producing head lettuce in greenhouses for a number of years previous to 1890. Eugene Davis of Grand Rapids, Mich., is the pioneer western grower. He added to his range from year to year until he was one of the most extensive growers in the West. He is the originator of the Grand Rapids lettuce, and this accomplishment has won for him the distinction which he so well deserves, for it is practically the only variety grown in greenhouses from central Pennsylvania westward. The history of lettuce forcing in the United States has been closely associated with the growing of other crops under glass, particularly cucumbers and tomatoes. See Chapter I.

Importance.—Lettuce is unquestionably our most important vegetable forcing crop. It is seldom that a large commercial establishment attempts the forcing of other crops without planting lettuce at some period during the season. In hundreds of ranges the usual custom is to plant lettuce in the fall and continue its culture until the winter is well advanced, and then to grow tomatoes or cucumbers when weather conditions are more favorable. Profits can generally be realized from lettuce throughout the forcing season, but this cannot be said of either the tomato or cucumber, except when growers are unusually skillful and markets are highly satisfactory. Lettuce, too, can be grown and sold at prices which all classes of consumers are able to pay. It is sometimes called "the poor man's crop," in comparison with winter tomatoes and cucumbers, which, in order that a profit may be realized, must be sold at prices which class them as luxuries. This statement, of course, does not apply to late spring and early summer greenhouse vegetables. The demand for lettuce is at all times so large that it generally forms the backbone of greenhouse crop rotations.

Again, lettuce may be forced in a great variety of structures. It appeals not only to the greenhouse man who may be farming acres under glass, but it is equally popular with the smaller frame growers. Its habits of growth, temperature requirements, soil adaption and market demands give it first place among all the crops which are grown in greenhouses, hotbeds and coldframes.

Quality.—High quality in lettuce is essential to the grower as well as to the consumer. It increases demands, and larger demands mean better prices. It is urgently important for every commercial grower to do whatever is necessary to produce the highest quality. The success of the whole industry requires this if satisfactory profits are to be realized.

But what is quality and how is it to be obtained? There are differences of opinion as to what constitutes quality, but we are generally agreed on the following points: (1) The leaves should be crisp, tender and succulent; (2) the flavor should be sweet rather than bitter; (3) the heads should be firm, and this is especially important with compact heading varieties; (4) the heads should be clean and free from green aphis and injuries of insects and diseases; (5) the color should be light green rather than dark green.

High quality may be obtained by growing the best strains of the best varieties. Insufficient attention is given to this matter. Moderately rapid, continuous growth is a most important factor. Slow growth develops bitterness and woody tissues. The time of harvesting should have careful consideration. Head lettuce cut too soon lacks firmness as well as quality, and loose-heading sorts cut too late are coarser and they lack flavor. Cleanliness and proper methods of marketing have an important bearing on the quality of lettuce.

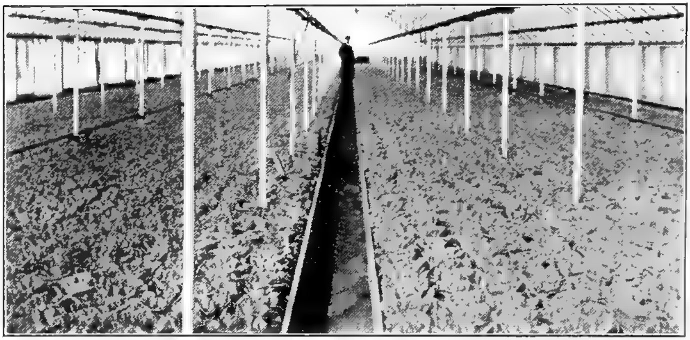

Fig. 69.—Head lettuce in the Boston district.

Beds vs. benches.—A general discussion of beds versus benches will be found on page 38. Probably 95 per cent of the lettuce produced in the United States is grown in beds on the ground instead of on raised benches. Just as good crops may be grown in ground beds and at much less expense, all factors considered, as on benches. Lettuce does not require bottom heat as much as do some other crops, though this is an advantage in hastening its maturity. Sub-irrigation on raised beds has proven highly satisfactory, but this method, for economic reasons, has not met with favor among commercial growers.

Ground beds may be of any convenient width. They are seldom less than 5 feet and sometimes they are 12 to 15 feet wide. Side boards or walls to the beds are sometimes provided, as shown in Fig. 69, or they may be absent, as shown in Fig. 70. This is largely a matter of preference. Narrow cement walks between the beds, for the convenience of the workmen, are of greater importance than walls.

Varieties.—Three general classes of lettuce are used for forcing purposes, namely, cabbage or compact-heading varieties, loose-heading varieties and Cos or Romaine.

Fig. 70.—Grand Rapids lettuce in a large Middle West range.

Of the solid-heading varieties, White-Seeded Tennis Ball or Boston Market (and its various selections) is the best known and most largely cultivated in greenhouses. It is grown almost exclusively in the large ranges of the Boston district. Its chief points of merit are early maturity, hardiness, fine quality and compact heads with a small proportion of outside leaves, thus making it possible to set the plants closer together than other larger varieties can be planted.

Improved Keene, also known as May King, is the leading variety in the Irondequoit district of New York. It is even smaller than Tennis Ball, but does not form such a compact head. It may be planted very closely together and still make heads large enough to sell by the dozen in the Rochester and Buffalo markets. Salamander or Black-Seeded Tennis Ball is grown to some extent in the greenhouses near Rochester.

Big Boston is the leading variety for planting in hotbeds and coldframes, but it does not give good results in greenhouse culture. It is much larger than White-Seeded Tennis Ball and must have a third more space to permit proper development. The leaves are coarser than those of Tennis Ball and the plants are hardier. It is universally selected for planting in muck soils and is generally grown in the extensive frame districts from New Jersey southward.

Hubbard Market is a hardy, vigorous variety, which is grown in frames to some extent.

There are many varieties of the loose-headed class, but Grand Rapids is practically the only variety now grown under glass. It is a cross of Hanson and an unknown, curly English variety developed by Eugene Davis, Grand Rapids, Mich. The plants are unusually vigorous in growth and not so susceptible to rot and other diseases as the compact heading varieties, such as Tennis Ball. The beautiful, curly leaves are used largely for garnishing purposes as well as for salads.

The Romaine or Cos lettuce does not resemble either of the other two classes. The leaves are longer and more

Fig. 71.—Cos lettuce on the right; head lettuce on the left.

erect, as shown in Fig. 71. When properly grown, they are crisp and tender, and possess a peculiar piquancy which is agreeable to most people. As people become better acquainted with Cos lettuce, the demand increases. When the heads are nearly mature, the leaves are tied together with raffia, which has the effect of blanching the interior leaves and making them more crisp and tender.

Several varieties of Cos lettuce are used for forcing. Trianon was found most satisfactory in a test at the New Hampshire Station. The heads were larger than those of other varieties and they were also excellent in quality.

Among other varieties which are grown to some extent under glass may be mentioned Bath, Express, Golden Yellow and Dwarf White Heart.

Cos lettuce does much better as a forcing crop during the fall and spring than at midwinter.

Seed of the highest quality is vital to success. Only the purest strains should be planted, and they should be maintained and improved if possible, by making careful selections. Some of the most successful greenhouse growers produce their own seed and sometimes a surplus to sell. When seed production is to be undertaken the plants should be set 12 to 15 inches apart in the row and there should be ample space between them—not less than 2 feet—to permit the use of wheel hoes without injuring the plants. The seed stalks should be tied to stakes so that they will not be blown over by the wind. As soon as the seeds are fully developed, the stalks are cut and hung in a building to dry. Threshing is easily accomplished by shaking and pounding the plants, and the seed is then cleaned by the use of a small windmill, or by throwing it up into the air, over a smooth floor or sheet, and allowing the wind to blow away the chaff.

Inasmuch as lettuce seed retains its vitality for three or four years, it is unnecessary to grow seed every year. When purchased, sufficient quantity should be obtained to last two years or more, and then preliminary tests may be made to determine the merits of the seed. Germination trials should be made from time to time, and the seed may be sown thicker, if necessary, in order to obtain a satisfactory stand of plants.

Soil.—Most of the large lettuce-forcing establishments are located where the soil contains considerable sand, and this is especially true regarding greenhouses devoted to the culture of head lettuce. Cos lettuce seems also to require soil that contains a fairly large percentage of sand. Grand Rapids lettuce is grown with entire success in practically all classes of soils, including the heaviest with the smallest proportion of sand. The general advantages of sand for greenhouse use have been discussed in Chapters III and V, and these should be fully considered in connection with the selection and preparation of soils for the forcing of lettuce. Greater weight of Grand Rapids may be obtained in heavy soils, but, notwithstanding this fact, growers prefer soils that are not too heavy.

For the production of head lettuce, the soil must be well aerated. This can be accomplished to a great extent by the liberal use of stable manure and sometimes by mixing muck with the soil. Experienced growers, however, claim that one or both of these materials cannot entirely take the place of sand. An open, porous soil is essential, though it is possible to make it too light and fluffy.

Beach made some interesting experiments at the New York Station; they were reported in Bulletin 146. Soils of various composition were used, but reference will be made to only two. What is referred to as the Geneva clay loam contained 3.32 per cent fine gravel, 5.20 per cent coarse sand, 20.71 per cent medium sand, 43.43 per cent fine sand, 0.94 per cent very fine sand, 7.96 per cent silt, 1.64 per cent fine silt and 9.86 per cent clay. The Geneva sandy loam contained 0.51 per cent fine gravel, 0.69 per cent coarse sand, 9.49 per cent medium sand, 77.50 per cent fine sand, 2.44 per cent very fine sand, 1.60 per cent silt, 1.23 per cent fine silt and 3.79 per cent clay. It will be noted that the soil which is called a clay loam contained over 70 per cent of sand of all sizes, and that the Geneva sandy loam contained over 90 per cent, which was a decidedly sandy soil. In discussing the results with head lettuce grown on these soils, Beach states:

"A comparison of the records of the four crops might at first give the impression that the different crops do not agree very closely as to their results, but a more careful study will show that in reality they conflict with each other very little, if at all. With the first crop there was no marked difference in the weight of the lettuce on the different soils. With the second crop the sand and manure gave decidedly heavier plants than did the soils which contained clay loam, but the latter really gave superior lettuce, for the plants on sand formed rather loose heads, actually less valuable for market than the more compact though somewhat smaller lettuce which was grown on the clay loam soils. With the third crop the results were quite similar to those which were found with the second crop. With the fourth crop the evidence was stronger than before in favor of the medium, heavy clay loam lightened with fairly well-rotted stable manure, as the best of the soil mixtures which were tried for forcing lettuce. The lettuce which it produced was not only superior to that which was grown on the sandy soil, in texture of leaf, firmness of head and general appearance, but it was also heavier."

Fertilizing.—Lettuce requires high fertility. Rapidity of growth and quality of the product are largely dependent upon an abundance of available plant food. There should be no doubt in the mind of the grower as to whether the soil is as fertile as necessary to produce a maximum crop of the best quality.

All are agreed that stable manure should constitute the chief fertilizing material for lettuce, because it not only supplies plant food, but creates favorable physical conditions in the soil. It is believed by many growers that if sufficient stable manure is used to maintain proper physical conditions in the soil, the food requirements of the plants will be fully met and there will be no necessity for adding other fertilizing materials. In fact, the results of hundreds of growers might be cited in support of this view.

It is claimed by some growers, especially by those who are cultivating light soils, that the free and continued use of stable manure ultimately makes the soil too open and porous for the best results with lettuce, and that it is preferable to use less manure, and to supplement it with commercial fertilizers. This class of growers, however, is in the minority, though there are some who obtain excellent results from the applications of commercial fertilizers in connection with manure. Rules cannot be made regarding the use of stable manures in greenhouses because conditions of soils, supply and kinds of manures available, treatment of previous crops, kind of crop to follow, etc., are so variable that no one treatment will suit all conditions.

The use of commercial fertilizer in growing lettuce under glass was advocated by Thorne of Wooster, Ohio. He found that a home mixture of 20 pounds of nitrate of soda, 60 pounds acid phosphate and 20 pounds muriate of potash, applied .in judicious amounts with moderate applications of manure, increased the yields.

Nitrate of soda is frequently applied to lettuce under glass. Sometimes the crop does not make as rapid growth as is desired; then a light application of nitrate of soda may have a very beneficial effect. As explained before, it may be used in liquid form, the plants even being sprayed with a dilute solution that will not burn them, the solution to be washed from the plants with a spray of pure water.

When nitrate of soda is mixed with the soil before the lettuce is planted, one pound to 100 square feet of space will be as much as can be used with safety to the plants.

A practice which is increasing among farmers, and there is no reason why it should not be just as valuable for greenhouse vegetable growers, is to mix acid phosphate or perhaps untreated phosphatic rock with stable manure at the barn or as it is thrown from the railroad cars.

Various forms of commercial fertilizers are sometimes used in the forcing of lettuce. Greenhouse plants are easily injured by excessive applications of chemicals, such as nitrate of soda, acid phosphate and muriate of potash, and large amounts should not be used at any time. Sayre draws the following conclusions from fertilizer experiments made at the Indiana Experiment Station:

"In regard to the experiments last year which were reported at the meeting of the Society of Horticultural Science, the items of principal interest were as follows: None of the fertilizer treatments except manure were beneficial, but the manure plots were greatly superior and indicated that manure was by far the best and most economical fertilizer. Our report was chiefly concerned with the effect of various fertilizers on the nitrogen content of the plant. An analysis of the plants shows that the chemical composition, at least in regard to nitrogen, was appreciably affected by the fertility of the soil, and could be modified by the addition of chemical fertilizers. The addition of phosphorus to the soil tended to decrease the percentage of nitrogen in the plant, and the application of nitrogen in addition to phosphorus tended to offset the phosphorous effect and raised the nitrogen content of the plant, but there is a definite limit to which the nitrogen content can be raised. Nitrogen alone slightly decreased the nitrogen content of the plant as might be expected from any element added in excess. Nitrogen unquestionably tended to promote leaf growth, while phosphorus tended to hasten maturity."

Most growers of lettuce apply lime to the beds about once a year. See Fig. 72.

Preparation of soil.—The preparation of greenhouse soils has been fully discussed in Chapters V and VI. Stable manure is generally applied for the first crop in the fall, and, if desired, additional amounts for subsequent crops. It may be well decayed, though some growers prefer fine manure that is comparatively fresh.

In the hard coal regions a favorite practice is to use mule manure from the mine stables. It is fine in texture and contains very little straw, hay or other bedding material.

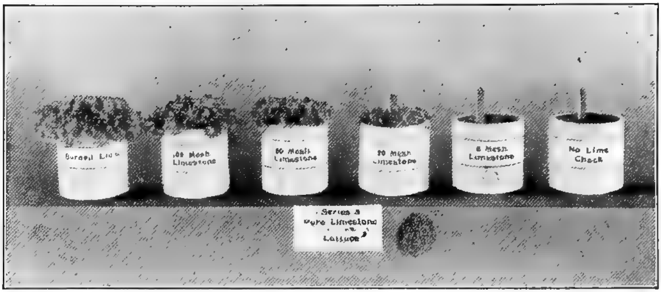

Fig. 72.—Pot experiment at The Pennsylvania State College showing the value of lime for lettuce.

In the Boston district, the manure is spaded into the soil to a depth of 12 to 15 inches or more. This rather laborious method is not regarded as necessary by the growers of Grand Rapids lettuce. A method which is becoming more common every year is to use plows and harrows, which may be drawn with one horse. Planting the houses in long narrow beds facilitates the use of horses in the preparation of the soil.

Starting plants.—The first sowing of lettuce for the fall crop is generally made early in August, though some of the largest growers do not sow until about August 20. Sowings made August 20 will produce marketable heads by the latter part of October or November 1. Lettuce maturing before that time does not generally sell readily because it must compete with lettuce grown in the open. In order to have a continuous succession of lettuce, sowings should be made at intervals of a week to ten days, and larger sowings should be made for the lots which will mature at times when there will be an unusual demand, as at Thanksgiving and Christmas.

The rate of growth of the plants should be carefully considered when making sowings. For example, the seedlings grow much more rapidly in the fall and spring than at midwinter. Ordinarily, the plants should not stand in the seed bed for a period longer than three weeks. In most instances it is better to prick them out in about ten days or less, and then they will be in no danger of becoming weak and spindling from being crowded, and there will be less danger of damping-off.

It is important to use no more soil than will barely cover the seed. Some growers prefer to use no soil over the seeds, but to keep them moist with burlap until they have germinated and then the covering is promptly removed. This practice saves time and produces excellent results. Others barely cover the seed and are careful to maintain uniform moisture conditions in the beds so that germination will be uniform. The seed beds dry out very rapidly during August and the early fall months, so that some shade is usually necessary.

Many growers sow in solid beds or on raised benches without the use of flats. A large number of growers, however, employ flats because they find them convenient and they believe better plants can be grown in them. If the transplanting is attended to promptly, 2,500 to 5,000 plants may be started in a flat 16 by 24 or 12 by 30 inches in size.

It is doubtful whether lettuce should ever be set closer than 2 by 2 inches apart at the first transplanting. At some seasons of the year and under the most favorable conditions the plants will begin to crowd each other in two to three weeks, when they should be transferred to the permanent beds. At each sowing and transplanting an estimate should be made of the number of plants that will be needed to fill the beds and to take the place of successive cuttings. It is better to err on the side of having too many than too few plants. When there is a surplus, the weaker may be discarded. This will count for greater uniformity for planting in the beds and also for marketing.

Space may be utilized more economically by using pots, to some extent at least, in the starting of plants. For example, instead of transferring plants from flats, in which they have been grown 2 by 2 inches apart, to permanent beds, another intermediate shift may be made to 2-inch or 2½-inch pots and the pots plunged between plants in the permanent beds, for about two weeks. This plan is most suitable for houses in which the lettuce is set not less than 8 inches apart each way in the permanent beds. The pots should be plunged in the soil up to their rims, and then they will not dry out to any considerable extent. They may be placed 4 inches apart one way, as shown in the following diagram, L denoting the lettuce plants just set and P the pots of smaller plants:

L	P	L	P	L	P	L
P	P	P	P	P	P	P
L	P	L	P	L	P	L
P	P	P	P	P	P	P
L	P	L	P	L	P	L

When this plan is followed, the potted plants, when removed to permanent beds in two weeks after the plunging, will produce marketable heads, under favorable conditions, in four to six weeks, the length of time depending on the amount of sunshine. With a week or two of a saving on each crop, it will be seen that this method means the gaining of an additional crop during the winter forcing season. It is some trouble, of course, and requires an outlay for pots and labor, but as a business proposition, it is worthy of careful consideration.

Planting distances.—There is the widest range in planting distances used by different growers. Tennis Ball is generally planted 8 by 8. Big Boston may be grown at these distances, but it should have more space for proper development. Improved Keene, when sold by the dozen heads, does not need more space than 6 by 6, but requires more liberal spacing if large heads are desired. Cos lettuce does very well planted 7 by 7.

Regarding Grand Rapids, a well-known Cleveland grower sets 7 by 9; the largest grower in Ohio, 9 by 9; most Ohio growers, 8 by 8; a Johnstown, Pa., grower, 7 by 8; an Erie, Pa., grower, 6 by 8. The Ohio station concluded from experiments that, all things considered, 7½ by 7½ is best. Occasionally a grower, who has a demand for small heads by the dozen, plants 6 by 6. When the plants are sold by number rather than by weight, the tendency is to plant close together. Liberal spacing is favorable to maximum weight of individual heads, but more time is required to mature the crop and thus obtain the maximum weight from a given area. When total weight for an entire season is considered, it is possible that 8 by 8 or 7 by 9 will give larger yields than any other spacing, though growers differ in their opinions about this matter.

Hexagonal planting is practiced in some greenhouses. This arrangement, as shown in the following diagram, gives each plant an equal amount of space on all sides, and more plants may be set in a given area than when placed in squares.

```
X       X       X       X       X
    X       X       X       X
X       X       X       X       X
```

The gain in this respect is considerable when a large range is planted. Close planting is a disadvantage in requiring a larger number of plants. It is surprising how many more plants are required to set a bed 7 by 7 than 8 by 8. More space one way, as when the plants are set

7 by 9, is a great advantage in facilitating tillage, either with a light wheel hoe, narrow rakes or special tools. Rot and other diseases are more likely to cause serious losses when the plants are set close together, because of poorer circulation of air.

Somewhat more time is required to harvest, trim, wash and pack closely set plants from a given area than if they were planted at greater distances. A special market, however, for small plants may more than justify close setting.

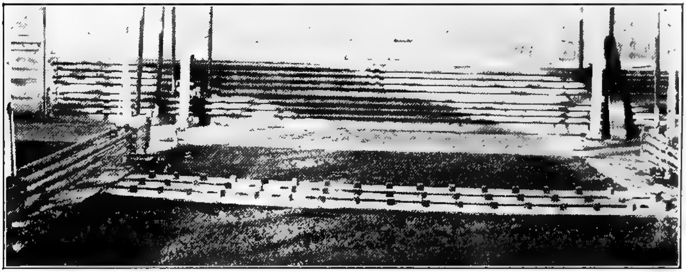

Fig. 73.—Transplanting board used for setting lettuce. Note large pegs.

Planting.—When a block of lettuce has been cut and marketed, the ground should be prepared and replanted at once. A delay of only one day, if the plants are ready, means some loss. Furthermore, the young plants should be transferred to the new beds before they have been checked or stunted in growth. Continuous growth from germination to harvest is essential to maximum yields of the highest quality.

Some kind of a marker should be used for spacing the plants accurately. Fig. 73 shows an inverted marker used in a very large establishment. It will be noted that there are three rows of pegs, and the pegs are about 2 inches in diameter. The workmen kneel on the boards while they are transplanting, and when the board marker is moved the holes are made ready for three more rows of plants, thus involving no extra labor for marking or making the holes.

As much soil as possible is retained on the roots of the plants, and they are set at about the same depth as they stood in the flats. It is important for the roots to be placed in an erect position, as shown by the right hand plant in Fig. 74. The left plant is dwarfed in growth because the taproot was bent when set in the bed. The soil is pressed firmly about the roots, and the beds are watered. A rapid workman will plant 500 or more plants an hour. Strong, stocky plants will stand erect after they have been set in the permanent beds.

Watering.—The merits of sub-irrigation for lettuce were discussed on page 155. Except for the cost of installing this system of watering, it is ideal for lettuce. Over-

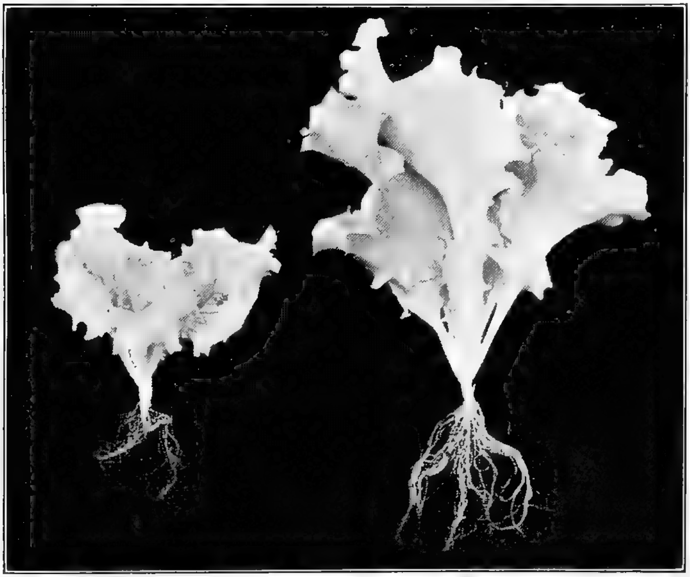

Fig. 74.—Plants of the same age. One on left dwarfed because the taproot was bent when the plant was set in the bed.

head irrigation for greenhouse lettuce is practiced by nearly all the large growers. The method is economical and efficient. Supplemental watering with a hose may be an advantage at times, but practically all watering should be done by means of overhead nozzle lines.

Lettuce requires a large amount of water. Probably the tendency with this crop is not to water enough rather than too much. The soil should be well supplied with moisture throughout the period of growth. When the crop is approaching maturity and making the most rapid gains in weight, an enormous amount of water is lost by transpiration from the leaves, especially during the spring months when there is so much sunshine. Heavy applications of water, just before the ground is covered with the plants, are usually of special value. Special care must be exercised in watering when the beds are well covered with plants, for there is then very little circulation of air among the plants and rot is more likely to appear than at any previous time. For this reason, the watering should be done early in the morning of bright days, if possible, and then, if the house is properly ventilated, the water will evaporate from the leaves before night.

Temperature.—High temperatures are favorable to rapid growth, but excessive heat for this crop, associated with high humidity, is certain to cause weak, spindling plants, and it greatly increases the possibility of loss from diseases, while low temperatures have the opposite effects. Low temperatures, especially as the crop approaches maturity, are favorable to maximum weight and compactness of heads. Nearly all growers allow 10 degrees higher temperature during the day than at night.

Grand Rapids lettuce may be successfully grown at a wider range of temperatures than either Cos or heading varieties. A higher night temperature than 45 degrees for head lettuce would not be permissible unless the houses were ventilated all night. Many growers of head lettuce prefer 40 to 45 degrees at night and 10 to 15 degrees higher by day.

Most growers of Grand Rapids lettuce maintain higher night temperatures than they did a few years ago. Formerly, 45 degrees at night and 55 to 60 degrees by day were standard temperatures among the best gardeners. Now, some of the largest growers prefer 48 to 50 degrees at night and 55 to 60 degrees by day. A night temperature of 45 degrees with high humidity and wet foliage is likely to cause much more damage than a temperature of 50 degrees with low humidity and dry foliage. On warm, sunny days during the spring, no harm will be caused by temperatures of 75 degrees or above, provided the houses are well ventilated. It is always important to have a definite understanding with the night fireman and watchman concerning the temperature that should be maintained.

Fig. 75.—The lettuce in this large range is cultivated with a 5-pronged weeder attached to a long handle.

Ventilation.—Much has been said on previous pages about the importance of ventilation. In lettuce culture it is one of the means of avoiding losses from the attacks of fungous diseases and of producing the best, most compact heads. On very cold or stormy days the ventilators are not opened at all, while in mild weather it is not uncommon to leave the ventilators open all night, to some extent at least. A safe practice is to ventilate every day as much as weather conditions will permit.

Cultivation in growing lettuce under glass may not be as important as when the crop is grown in the open, though it is unquestionably beneficial. One cultivation, in a few days after the beds are planted, to break the crust of the soil, may be sufficient, but additional tillage will be valuable, especially if the soil contains much clay or silt. The most common practice is to use hand weeders or pronged hoes in narrow beds. Iron rakes reduced to a width of 6 or 7 inches are satisfactory for the cultivation of wide beds. The tool shown in Fig. 75 consists of a five-prong hand weeder secured to the end of a long handle. Wheel hoes are employed in some houses where the rows are far enough apart to permit their use.

Intercropping is followed to some extent in the growing of lettuce under glass. The various systems employed are discussed in Chapter XXI.

Frame culture.—The forcing of lettuce in hotbeds and various types of frames is treated in Chapter XXII, page 403.

Pot culture.—Studies have been made at several agricultural experiment stations to determine the value and feasibility of maturing lettuce in pots. Seedlings which are three or four weeks old are set in 2-inch or 2½-inch pots, and the pots of large plants, as seen in Fig. 76, are then plunged at the usual distances for planting into the permanent beds. The rims of the pots should be at least half an inch below the surface of the bed.

The crop is watered and cared for in the usual manner until the heads are large enough to market. Then the potted plants (Fig. 77) are lifted and sent to market in the pots, or preferably the balls of earth and roots are wrapped in paper and a dozen plants placed in a flat or a market basket. The plants will hold up better if the balls of earth are soaked with water before they are sent to market.

Experiments at the Tennessee station resulted in a 15 per cent smaller yield by weight than was obtained by

Fig. 76.—Pot-grown plant ready to set in the bed

the usual method of setting in beds, but a higher price was obtained for the pot-grown lettuce on the Knoxville market. The lettuce was most attractive in appearance. It appealed to consumers who wanted several heads, and by watering the balls of earth they could keep the heads crisp and tender until the last leaf was consumed. This plan of marketing also enables the grocer to keep the plants for several days, if necessary, in a perfectly fresh condition. While there are some arguments in favor of pot culture, it has not appealed to commercial growers. This method necessarily involves more labor in growing

Fig. 77.—Pot grown plant ready for market.

the crop as well as in marketing it, and can be used only for local markets.

Insect enemies.—The green fly is recognized as the most serious insect enemy of lettuce. It is controlled almost exclusively by fumigating with tobacco or nicotine preparations, instructions for the use of which are given on page 105. Fumigations should be made at regular intervals so there will be no possibility of the insects becoming sufficiently numerous to damage the crop or to impair its selling quality.

The nematode sometimes attacks the roots of greenhouse lettuce, though it is not regarded as a serious enemy of this crop.

White grubs may be troublesome in soils which have not been steam sterilized. This is the larval stage of the June bug or May beetle. Old compost heaps and manure piles are favorite breeding places. The eggs or young larvæ may be introduced into the houses by infested soil and manure, and the grubs may cause considerable injury to the roots of fall lettuce. If the beds are sterilized with steam after manure has been applied, there should be no trouble from this enemy.

The white fly is found sometimes on lettuce, but seldom in numbers large enough to cause any considerable damage to the crop.

The green cabbage worm is sometimes a pest of the fall lettuce crop. When it appears in numbers large enough to cause concern, fresh pyrethrum, one part mixed with six parts of flour and dusted on the plants when they are moist, will be found effective in killing the larvæ. Pyrethrum when exposed to the air soon loses its poisonous principle and thus becomes harmless to human life.

Snails feed on lettuce and they may appear in soils which have not been steam sterilized. Air-slaked lime, dusted on the soil and plants, is recommended to check the ravages of snails.

Cutworms may also feed on lettuce growing in soil which has not been sterilized with steam. They feed at night and may be killed by placing paris green or other poison on lettuce leaves which are scattered over the ground where the crop has been cut and left for a few nights. In beds in which the plants are not ready to harvest, poisoned bran mash will prove effective. Paris green is mixed with dry bran until the latter is slightly tinted. A sweet solution is made by mixing one quart of molasses with ten quarts of water, and then mixed with enough of the poisoned bran to make a mash. A tablespoonful of the mash, which the cutworms prefer to lettuce, is placed at frequent intervals on the beds.

Diseases.—There are several diseases of greenhouse lettuce, but the most serious is known as the drop *(Sclerotinia libertiana Fckl.)*. It is most likely to appear during cloudy weather when the temperature of the house is too high, and insufficient attention is given to ventilation. The fungus first causes the wilting of the outside leaves of the plant, and finally the rotting of the stem at the surface of the ground. Head lettuce is most susceptible to attack, but the disease often appears on Grand Rapids and other loose-heading sorts, and may cause heavy losses in houses which are not properly sterilized. This fungus is both parasitic and saprophytic, living over by means of vegetative bodies called sclerotinia. Since this fungus may live over in the soil or in the old plant remains, it is necessary to apply some treatment which will kill the fungus. Formaldehyde or steam sterilization is usually effective. Thorough ventilation, careful watering and the maintenance of proper temperatures are also important factors in the control of this disease. There are other forms of rots, but this is the most important.

Lettuce mildew *(Bremia Lactucæ Reg.)* appears sometimes in houses where there is excessive moisture, and when there is little sunshine, but more particularly on frame lettuce in the fall. It is first seen on the upper surfaces of the outer leaves, as yellow spots, making the leaves paler in color and finally causing them to wilt. If proper sanitary conditions are maintained, mildew is not likely to cause serious losses.

Gray mold *(Botrytis vulgaris)* often accompanies lettuce drop. It is entirely saprophytic and does not spread so rapidly as lettuce drop. The edges of the leaves wilt and the leaves soon droop and die, their surfaces becoming covered with gray mycelium. Thorough sterilization with steam or formalin is effective as a preventive measure.

Dwarf, stunted heads or tufts of leaves, generally called rosettes, sometimes appear in beds of lettuce. They are most commonly caused by the fungus Rhizoctonia, which feeds on the roots of lettuce plants and thus interferes with their proper nutrition. As the old roots die, new ones form, but the plants do not thrive. Doubled or twisted roots (Fig. 74), due to careless transplanting, may result in dwarfed plants. Excessive applications of fertilizers, or unfavorable soil conditions, may cause the formation of rosettes. Gray mold or other diseases which attack and cause the loss of the outer leaves may have the same effect in causing the development of tufts of short leaves instead of fully developed heads. When a fungus is the direct cause of this abnormal growth, sterilization with steam or formaldehyde is effective as a preventive measure.

The excessive drying out of the soil frequently produces a "rosette" appearance of the plants.

Sometimes the margins of the leaves wilt and die, thus injuring the selling quality of the plants. This is a disease, the result of a physiological disturbance called "tip burn," that may occur on bright, clear days when the temperature of the houses is 70 degrees or above, following a season of cloudy weather. With good management in the regulation of soil and atmospheric conditions in the house, tip burn is not likely to occur.

Electro-culture.—Experiments made at several agricultural experiment stations show that electric light is beneficial to the growth of lettuce. The most extensive studies were made at the stations of Cornell University, West Virginia and Massachusetts. W. W. Rawson, a large commercial grower near Boston, was pleased with the results for a number of years, but he finally abandoned the use of electric lights for hastening the growth of lettuce. While reports of the stations are rather favorable, commercial growers have not regarded electro-culture as a practical business proposition.

Harvesting.—No general rule can be given concerning the proper time to harvest lettuce, because so many factors enter into the question. If the heads are to be sold by the dozen or hundred, they should be cut just as soon as they are large enough to satisfy the market requirements. The allowance of more time would necessarily lower profits for the year, unless the crop were held for higher prices. Some markets will handle by the dozen, plants which have been in the permanent beds only 4 to 5 weeks, and pay good prices for them. Under such conditions it would be folly to defer cutting for even a day.

The quality of the heads, as discussed on a previous page, should also have consideration. The quality of head and Romaine lettuce is particularly influenced by the time of cutting.

Prices should also be taken into account. For example, if lettuce is selling at 5 cents a pound and there are evidences of a stronger market, larger net earnings might be realized by holding the crop or at least not cutting in very large amounts for a few days or perhaps a longer period. Again, if the crop is moving at a high figure, and there are special reasons why a decline in price may occur, the crop should be moved more rapidly, though if many large growers who supply the same markets should do this at the same time, prices would be almost certain to be forced down. Organization of and co-operation among the growers, however, should result in uniform distribution and help to maintain remunerative prices.

The condition of the plants which are to take the place of the lot to be marketed is also a factor. If they are becoming spindling and overgrown, it may be better to sell the marketable heads at a sacrifice rather than to sacrifice the quality of the next lot of plants.

When the crop is sold by weight, the size of the plants should have the most careful consideration. The maximum weight of a plant, produced under favorable conditions, depends primarily upon the length of time it is allowed to grow in the permanent bed. If large plants are transplanted from pots to the permanent bed, fairly heavy plants may be produced in four or five weeks, provided there is considerable sunshine. It is seldom, however, that lettuce which is to be sold by weight is cut in less than six weeks from setting in the beds, and sometimes it is given 12 to 14 weeks in order that maximum weights may be obtained.

Records made at The Pennsylvania State College show how rapidly plants gain in weight after they have been in the beds about four weeks. For example, Grand Rapids lettuce, which had been growing in the beds for four weeks, was cut February 15, and the plants averaged three ounces each. February 22, another lot of plants

Fig. 78.—Grand Rapids lettuce.

of the same age, were cut from the same bed, and they averaged 4 5-6 ounces per plant. February 29, a third lot was harvested, and these averaged 7½ ounces per plant. There was much sunshine during the two-week period and, as the figures indicate, the growth was rapid. It will be observed, too, that the gain in weight was much greater during the second week. The lettuce was sold at 12 cents a pound. It was large enough at four weeks from planting to satisfy local markets, but a gain of 1.7 cents a plant per week was made by holding it for a longer period. The plants were set 8 by 8 inches apart and the weekly gain per 100 square feet was $3.83. On an acreage basis the gain per week would be over $1,500. It will be seen at once why most of the large growers who sell by weight are reluctant about harvesting the crop until nearly the maximum weight has been attained, and this requires a much longer period in the winter than during the fall or spring.

Three ounces to the head, of Grand Rapids, is considered light. Growers who ship in baskets and sell by weight average between four and five ounces to the plant. Six to eight-ounce plants are considered medium to heavy, and eight to ten or more, very heavy. A large grower of Grand Rapids, who ships in barrels, plants 9 by 9 inches apart and grows very large heads. It is not unusual for these plants to be in the beds from 10 to 12 weeks.

Lettuce is cut with knives and conveyed in baskets, crates or barrels to the packing shed where it is prepared for market.

Marketing.—Lettuce should be carefully trimmed of all defective outside leaves. Some growers do this at the beds, as the crop is cut, while others prefer to trim the plants in the packing room. The heads should then be washed to remove any soil or plant lice that may be on them. The most thorough cleanliness is obtained by holding the heads under a spigot of pure running water. Some growers dip the heads in tanks of water. Washing is also essential to insure the lettuce arriving at the market in a fresh, crisp condition. That is, the water which remains on the heads after they have been washed provides the necessary supply of moisture to prevent wilting for several days, if the packages are covered.

Various packages are used for the shipment of lettuce. Many of the large commercial growers who ship to distant points use barrels. Second-hand sugar barrels are used in large numbers for this purpose. They are especially desirable for winter shipments, on account of the thorough protection that can be given the lettuce. In cold weather the inside of the barrel should be lined with paper. In warm weather several ventilating holes should be cut in the barrel. Three or four holes are bored in the bottom of the barrel for drainage if the packed barrel is first immersed in water. A plan followed in a 10-acre Ohio range is to take the barrels on a cart (Fig. 55) to the beds, where the lettuce is cut, trimmed and packed

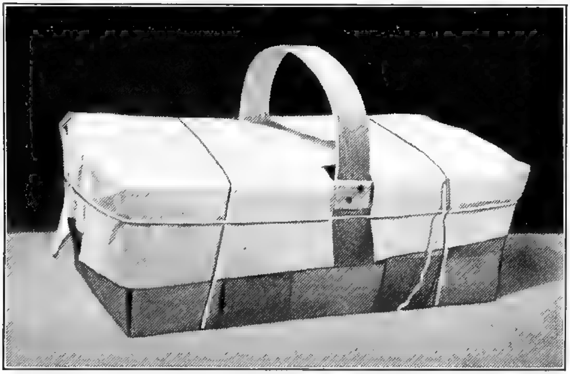

Fig. 79.—A basket of lettuce ready for market.

with the stems of the plants in the center of the barrel. The heads are pressed down gently as the packing proceeds, until the barrels are slightly more than full. They are then conveyed on the two-barrel cart to the packing house, weighed, and burlap covers placed over the lettuce, with paper underneath if additional protection is necessary for shipment during cold weather. The top hoop of the barrel is removed before the lettuce is packed, after which it is forced down over the burlap and secured with a few small nails. The packed barrel is forced under water with a special device and held there for about three minutes, when it is removed and allowed to drain.

A large percentage of the Grand Rapids variety is marketed in splint baskets (Fig. 79) of 14 quarts capacity. These may be bought in 1,000 lots at 3 cents or less apiece. From three to six pounds of lettuce can be packed in a basket, but some of the markets prefer only three pounds in each basket. The basket, after being filled, is wrapped with brown paper which protects the lettuce from cold weather and keeps it clean. This is considered a very satisfactory package.

Many growers in New York and throughout the New England States use bushel boxes for local markets, and they are popular packages with both producers and dealers. Larger boxes are used sometimes for distant shipments. Figure 80 shows trays of fancy head lettuce sold in the London market.

Fig. 80.—Choice head lettuce grown in England.

Various forms of crates are also used, especially for shipping head lettuce.

Yields and returns.—The yield from a given area that is well managed will depend mainly on the time of harvesting each crop. A successful grower of Grand Rapids considers 4,500 pounds a good yield for a fall crop from a 30 by 200-foot house; 3,000 for winter and 5,000 to 6,000 for spring. One pound per square foot is a good yield.

The price of lettuce when sold by the dozen heads varies from 20 cents to 75 cents, and occasionally more than 75 cents for large heads of high quality. Romaine lettuce may sell for $1 or more a dozen heads. The price a pound for Grand Rapids ranges from 4 cents to 20 cents. It is very doubtful whether any profit is made even in the best-managed houses when the price is 5 cents or less a pound, and most growers probably lose money at 6 cents. Ordinarily, the price ranges from 7 to 12 cents a pound. Prices average higher from January 1 to April 1 than at any other time.

Growers estimate that it costs from 2 to 3 cents a head to produce head lettuce in the late fall and winter and 15 to 20 per cent less in the spring.

CHAPTER XV

CAULIFLOWER

History.—Cauliflower has been grown in this country since the earliest days of vegetable forcing. At first its culture as a forcing crop was limited to frames. Sash were then used to construct low, cheap houses which were generally heated by means of flues. With the development of the greenhouse industry an occasional gardener, especially on Long Island, tried cauliflower. Today, cauliflower is grown under glass, to at least some extent, near most of the large centers of population.

Importance.—Cauliflower is not generally regarded as a very important forcing crop. It is shipped during the forcing season in large amounts from California and the South, so that prices now are not nearly so encouraging as they were years ago. The quality, however, is superior to that of cauliflower which is grown in the open ground, so that there will always be at least a fair demand for the greenhouse product. It is probable that cauliflower could often be profitably substituted for lettuce, and it would thus relieve or prevent market congestion. While it is now grown in small lots in hundreds of frames and greenhouses, and in large areas in a few houses, there is a feeling among greenhouse men that the crop ought to occupy a more important place in the forcing industry. The uncertainty of getting good seed has undoubtedly been a deterrent to many. We have reason to believe that the seed problem has been solved (see page 235), and that the industry will develop during the next few years. By using dependable seed and proper methods of intercropping, the forcing of cauliflower in greenhouses that are properly managed should pay satisfactory profits.

Beds vs. benches.—Experiments made by Bailey at

Fig. 81.—Cauliflower. Almost every plant produced a head.

Cornell University showed that ground beds (Fig. 81) were much superior to raised benches with bottom heat for the forcing of cauliflower. A smaller percentage of the plants on the benches produced marketable heads, which were also smaller and poorer in quality. It is more difficult, in the raised beds, to maintain proper soil moisture conditions, which is one of the most important factors in growing cauliflower. With proper care the crop can be grown successfully on raised beds, but it is a much more certain proposition in ground beds, to say nothing of the expense of constructing and repairing benches.

Varieties.—Only two varieties, Erfurt and Snowball, (Fig. 82) are used to any considerable extent for forcing. They are early and compact growers, and they produce beautiful heads of the highest quality. The character of the strain selected is of much greater importance than the variety, for the best strains of either variety are excellent for growing under glass.

Seed.—Experienced growers fully realize the necessity of using good seed. They have learned that the use of poor seed may result in almost a total failure, because many of the plants may not produce heads at all, and those that do form are small and undesirable. Most of the cauliflower seed used in the United States is grown in Denmark and France. Much of this seed does very well under glass, but there is nearly always some concern as to whether the results will be wholly satisfactory. On account of the uncertainty of the crop when forced from imported seed, Shoemaker of the United States Depart-

Fig. 82.—A typical head of greenhouse grown cauliflower.

ment of Agriculture has been conducting experiments in growing seed in greenhouses. Small packets of the Government seed have been supplied to various agricultural experiment stations as well as to practical growers, and the crops produced from this seed have been highly satisfactory. He believes that cauliflower seed which is to be used for forcing purposes should be grown under glass, and we are indebted to him for the following information relating to the subject:

"In brief, our method of culture in the greenhouse has been about as follows: We have found that we can make two crops of commercial cauliflower in our greenhouses at Arlington Farm. If you have seen these houses you will remember they are not supplied with side ventilation and so are more or less unsuitable for crops which run into hot weather in the spring, since it is very difficult to keep temperatures down to the proper degree. Our most uniform success with a crop oi seed has come with the first planting, seed of which is usually sown about the middle of September. This crop is in marketable condition about Christmas, and if allowed to stay in the benches immediately shoots to seed and the seeds are ripe for harvest in late April or early May. Our second crop of cauliflower goes into the house as soon as the first one is out. Seed of this crop is planted the end of October or November 1 and is transplanted into the house about January 10. If the spring does not prove to be too hot this will set a very good crop of seed and will be ready for harvesting the latter end of May or June 1. Our plants are set in the greenhouse for seeding about 18 inches apart each way. I am inclined to think that the chances of success would be considerably increased by having solid beds rather than raised benches. We find that our troubles from disease invariably begin after the plant has passed the marketable stage, since it undoubtedly begins to lose its resistance to disease which has kept it going up to that time. I think that it would be quite necessary in going into this business to see that the soil is thoroughly sterilized. The best crop that we ever produced was from a second planting, which gave us 19 pounds of seed from a greenhouse 50 feet long and 20 feet wide. This is, I think, very much better than one could count on for an average."

Soil.—Most of the soils in which cauliflower is forced contain considerable sand. It is doubtful, however, whether sand is essential to the success of the crop, especially if manure is used in ample amounts. Nevertheless, as stated in previous chapters, some sand in greenhouse soils, regardless of the vegetables grown, possesses distinct advantages. But excellent crops are often forced in heavy soils.

Fertilizing.—There seems to be a consensus of opinion that the question of soil fertility is of much greater importance than that of soil texture. Whatever may be the natural character of the soil, it must be heavily fertilized in order to grow cauliflower successfully. There must be no lack of organic matter, for this is important from the standpoint of plant food as well as from that of the most favorable physical conditions of the soil. A constant and uniform supply of moisture in the beds is of the utmost importance, and an abundance of decaying vegetable matter is essential for the retention of moisture.

There is likewise no difference of opinion in regard to the condition of the manure when it is applied. All agree that it should be well decayed. The pioneer gardeners preferred cow manure for this crop, but any kind of old manure will give satisfactory results. Some of the most successful gardeners in this country and in England rely wholly on the use of horse manure. Top-dressing with poultry manure or liquid cow manure when the heads are forming is recommended. Nitrate of soda may also be used effectively as a top-dressing. In England a favorite practice is to top-dress the beds with partly decayed stable manure.

A chemical analysis of cauliflower was made at the Geneva (N. Y.) station, with the following results:

	Nitrogen	Phosphoric acid	Potash
Head	.279	.081	.326
Leaves	.363	.084	.470

It will be observed that both the head and the leaves require large amounts of nitrogen and potash. Inasmuch as most soils are deficient in phosphorus, that element should also be supplied in ample amount.

Some of the most successful commercial growers supplement stable manure with commercial fertilizers. For example, one of the most extensive gardeners on Long Island uses for cauliflower under glass a fertilizer containing 7 per cent nitrogen, 8 per cent phosphoric acid and 10 per cent potash. It is used at the rate of 1,000 pounds to the acre. If radishes and lettuce are grown between the cauliflower plants, 1,500 pounds of fertilizer to the acre is applied.

Wood ashes are employed by some growers. Bone meal at the rate of one pound to 20 square feet of space is beneficial. Lime should be used in the beds at least every other year.

Soil preparation.—Some of the most careful growers prefer to compost the soil and manure at least half a year in advance of planting the beds. This insures a thorough mixture of the manure with the soil, and no method will give better results. It is more expensive, however, than preparing the beds in the frames or greenhouses by applying stable manure and other materials and incorporating them thoroughly with the soil. The thorough methods used in preparing soils for lettuce will apply equally well in the preparation of beds for cauliflower, except that more stable manure might be used. The beds should be at least 8 inches deep.

Starting the plants.—Strong, vigorous plants are essential to a good crop. Many failures are attributable to poor plants. They are easily checked in growth and when stunted they seldom recover sufficiently to produce good heads. It is not uncommon for writers to say that cauliflower plants should be started in the same way as cabbage, but the fact is they demand much more careful attention. The plants, too, are very susceptible to damping-off fungi. To avoid losses from this source, the soil should be steam sterilized and the most careful attention given to watering and ventilating.

Sowings for the first crop are generally made between September 1 and November 1; if a succession is desired, sowings should be made at intervals of about two weeks.

It is an advantage to sow in rows 3 inches apart, and then water may be applied between the rows without wetting the plants, which is helpful in preventing damping-off. The seed should be sown thinner, too, than for cabbage, so that the plants will be strong and there will be free circulation of air among them—another preventive measure of damping-off.

It is best to make the first transplanting within two weeks from the date of sowing. The plants need not be more than ½ to ¾ inch high. They should be transferred from flats to 3½ or 4-inch pots (Fig. 83), and it is well to plunge the pots in soil or ashes to guard against drying out. The plants should be transferred to permanent beds just as soon as the pots are well filled with roots.

A large grower on Long Island made a sowing November 2. The plants were set in permanent beds January 1 and he began marketing the crop March 15.

Fig. 83.
Vigorous cauliflower plants are essential to success.

Another Long Island grower sowed December 1, and transferred potted plants to permanent beds February 1. Bailey made a sowing at Cornell University August 22, and the first heads were cut January 13. Another sowing made October 21 produced marketable heads March 29.

Seed that is two years old produces good results. Three and four-year-old seed must be sown thicker to get a satisfactory stand of plants.

Planting.—The distance between plants in the beds varies from 15 by 15 to 22 by 24 inches apart. Moderately close planting seems to be favorable to maximum returns. With a compact growing strain, 15 by 15 or 14 by 16 will permit the development of good heads. Liberal spacing is favorable, of course, to the growing of large heads, and if fancy prices can be obtained for very large heads, it may be most profitable to grow them. A common distance for planting is 16 by 20 inches. The spacing of the plants may be at such distances as will be most suitable for companion crops, such as lettuce and radish, as discussed in the next paragraph.

Intercropping.—A common practice is to grow lettuce or radishes, or both of these crops, between the cauliflower plants. Sometimes radish seed is sown broadcast in the beds after the cauliflower has been transplanted, but it is better to sow the seed in rows. See page 254 for particulars.

Watering.—The beds should be thoroughly watered immediately after the plants have been set. Thereafter water should be added as necessary to keep the soil moist to the full depth of the beds. This is unquestionably one of the most important factors in the forcing of cauliflower. Unusual care must be exercised for at least a month after the final transplanting in the beds. Lack of moisture at the roots is certain to check the growth of the plants and to result either in no heads or small, inferior ones. At the same time it is equally important to avoid over-watering, for this may cause excessive leaf growth at the sacrifice of head formation. After the plants begin to form heads, water should be applied more copiously with a hose, care being taken not to wet the heads or the foliage, and special fertilization may also be given at this period. Previous to the formation of heads there is no objection to applying water as a spray.

A moist atmosphere at all times is favorable to the growth of cauliflower. In warm, sunny weather it is of advantage to sprinkle the walks with water in order to increase the humidity in the house.

Temperature.—While cauliflower is often grown under glass with lettuce and radishes, it thrives best at somewhat higher temperatures than are required for these crops. The temperature at night may be 50 to 55 degrees, and by day 65 to 70 degrees, though good crops are often grown with less heat.

Ventilation.—Ventilation is essential to the growth of healthy plants and to the formation of good heads, but cauliflower is very sensitive to cold drafts, which may cause the leaves to droop and prevent head formation. Some fresh air should be admitted to the houses daily, but cold drafts should never strike the plants.

Cultivating.—The beds of cauliflower should be cultivated at frequent intervals. This is of special value in conserving soil moisture and in encouraging the most satisfactory growth. One of the chief objections to intercrops of lettuce or radishes is that they interfere to some extent with thorough cultivation.

Insect enemies.—The green aphis is the most serious pest of cauliflower grown under glass, but it is easily controlled by tobacco fumigation. (See page 105.) The larvæ of the cabbage butterfly sometimes feed on plants started during the fall months. Arsenate of lead, or, if preferred, fresh pyrethrum or insect powder, may be used to poison this pest.

Diseases.—Cauliflower is subject to the same diseases as cabbage and other brassicæ. The commonest are soft rot or stem rot, black rot and club root. They seldom appear on cauliflower grown in greenhouses, but steam sterilization of the soil is a safe precaution.

Frame culture.—Cauliflower is a popular frame crop in some sections. It may be intercropped with lettuce and radishes. See page 399 for further data on the culture of this crop in coldframes.

Head protection.—Unless the heads or curds of cauliflower are protected, they will not be pure white in color when ready for market. Uncovered or unprotected heads are yellowish in appearance and cannot be sold at as high prices as pure white heads. Again, snowy white heads are said to be more tender in texture and finer in quality.

Various methods are used to protect the heads when the crop is grown out of doors. Among them may be mentioned tying the leaves together over the heads with strings or small bands of rye straw; folding or breaking the leaves over the heads and securing them with toothpicks, or "tucking" them in an ingenious way so that they will remain in place. Although any of the plans used in field culture may be employed under glass, several thicknesses of brown paper placed over the heads will be found more satisfactory. This matter should have attention when the heads are about 2 inches in diameter. It is a simple matter to lift the paper to determine when the heads are ready for market.

Marketing.—Cauliflower should be harvested before the heads begin to break or become warty. Early marketing is essential from the standpoint of quality as well as appearance. Heads which are only 3 inches in diameter are marketable, but larger sizes command better prices. Under the most favorable cultural conditions, most of the heads should be 5 to 7 inches in diameter, especially if superior strains of seed have been used.

The utmost care should be exercised in cutting and handling the crop to protect the heads, which are extremely tender, from bruises or other injuries. Even the slightest marks or blemishes will detract from their appearance and probably require the grower to accept a lower price.

The leaves encircling each head are trimmed as shown in Fig. 84. Some markets prefer a "long trim," some a "medium trim" and others a "short trim." The leaves

Fig. 84.—Cauliflower trimmed for market. Head on right trimmed very short.

may be removed very quickly with a large, sharp knife.

Crates of various dimensions are used for marketing cauliflower which has been grown under glass. Most of the crates are made to hold either a dozen or two dozen heads. Louisiana gardeners, who ship cauliflower from field plantations during the early winter, use crates that hold only half a dozen heads. Such a crate should be even more valuable for the greenhouse product. The head pieces for the Louisiana crate are 7 inches by 14 inches by 3/8 inch in size. The lath are 3 or 3 1/4 inches by 22 inches by 1/4 inch. Cottonwood for these crates is preferred to any other lumber. The dimensions of the crate must be determined by the size of the heads which are ordinarily grown. When rigid grading of the different sizes is practiced, and this is always desirable, it is an advantage to have crates of various sizes. It is doubtful whether greenhouse cauliflower should ever be packed in larger lots than a dozen heads to the package. The crates should be lined with paper, and if a fancy trade is to be supplied, it will be a decided advantage to wrap each head in oiled paper to keep it clean and free from dust.

Cauliflower which has been properly grown and sold at average prices should yield a gross return of not less than 12 to 15 cents a square foot of greenhouse area. Prices for good heads are seldom less than $2 a dozen. Perhaps $2.50 a dozen is about an average price for this vegetable when grown under glass.

CHAPTER XVI

RADISH

Importance.—The radish is commonly forced near all large centers of population, though in commercial importance it does not approach lettuce, the tomato or the cucumber. While there is a large demand for forced radishes, it is an easy matter to overstock the markets. Most growers believe that the radish, as a forcing crop, does not pay as well as lettuce. On the other hand, many believe that the crop deserves more attention. It is one of our best salad crops and possesses special merit for garnishing or table decoration. Quick returns are obtained from it, and it can sometimes be grown with other crops, such as lettuce, and will thus add to the earnings of the house. The radish may be grown in low, cheap houses, where it is impossible to force the tomato or the cucumber.

There are times when lettuce growers would find it profitable to devote some of their greenhouse space to the forcing of radishes and thus avoid market slumps of lettuce. It is not a difficult crop to produce under glass, though careful attention must be given to its various cultural requirements.

Light.—Probably no vegetable forcing crop is more sensitive to shade or the lack of light than the radish. It may be grown successfully in old houses admitting the minimum amount of light, but the best results are obtained in houses of modern construction. Any obstruction to the light and sunshine is certain to favor the development of tops rather than large roots. The shading of other classes of plants should be avoided as much as possible.

Beds vs. benches.—The radish is forced both on raised benches and in ground beds. Most growers prefer ground beds. The winter crop may be matured on raised benches with bottom heat in from one to two weeks less time than on ground beds. If there are heating pipes under the benches, great care must be exercised to avoid forcing the crop too rapidly, as excessive top growth will be encouraged at the sacrifice of good roots. The regulation of temperatures and soil moisture will require less attention if ground beds are used. On the other hand, the space under benches, if heating pipes are located elsewhere, may be profitably used in forcing rhubarb and asparagus, and with the saving of time for each lot of radishes it is possible to grow an additional crop before planting the benches in the spring with tomatoes or cucumbers.

Varieties.—The large varieties which are commonly grown out of doors are not desirable for forcing. Most consumers prefer the small, turnip-shaped roots, and these attain a marketable size in much less time than the long-rooted sorts. The early turnip-shaped varieties may also be grown much closer together, and this is a decided advantage in obtaining maximum profits. The best strains of forcing varieties have very small tops, so that the rows need not be more than 4 inches apart and the roots may stand very close together in the rows.

The color of forced radishes is an important factor. As a rule, the markets prefer bright red rather than dark red roots. Some markets can dispose of a considerable quantity of white-tipped sorts. The olive-shaped varieties are often grown in frames.

The quality of the different varieties should also be considered. Icicle, a well-known white variety, is of very high quality, and though the color is unfavorable for winter sales, the demand for this variety is increasing.

Most commercial growers of large experience prefer

Scarlet Globe or one of its numerous strains. Among the varieties which are most commonly grown under glass may be mentioned Cardinal Globe, White-Tipped Scarlet Globe, Colonial Forcing, Carmine and Fireball.

Soil.—The finest radishes are invariably grown in soils containing a considerable quantity of sand. The roots in such soils are smoother and more uniform in shape than when they are grown in clay or silt soils, and less labor is required to wash them. Excellent roots may be produced in heavy soils which are well supplied with organic matter, though sand should be added to the beds if it is possible or feasible to do so. Sand also decreases the chances of heavy losses from the attack of damping-off fungi, and facilitates sowing, thinning and cultivating.

Fertilizing.—Experiments and practical tests made with commercial fertilizers for radishes have not given as good results as manure alone. Wheeler (Rhode Island Bulletin 128) reports that no combination of commercial fertilizer applied with short-cut straw (the latter mixed with the soil in sufficient quantity to alter its physical properties) gave as good results as well-decayed stable manure used at the rate of 75 tons to the acre. It is necessary to have an abundance of available plant food, but suitable physical properties of the soil are of greater importance than the mere question of plant food. The radish does not thrive in any soil which is lacking in vegetable matter. The soil must be loose and friable, and for this reason manure gives better results than do commercial fertilizers. It is possible that fertilizers can be used to advantage under certain conditions, but the radish does not seem to respond well to their application.

Fresh stable manure should never be applied immediately before sowing radishes, for it is favorable to excessive top growth instead of to satisfactory root development. The manure should be at least several months old and fine enough to mix well with the soil. An annual application of 40 tons of manure to the acre of greenhouse space should give most excellent results. Some gardeners prefer to apply a light dressing of manure before each crop is started, though a heavy application in the fall will be sufficient to grow several crops. Inasmuch as it is not feasible to sterilize the soil before starting each crop, probably the better practice is to apply all of the manure in the fall, unless the grower is willing to take chances in using manure that has not been sterilized.

Soil preparation.—Directions for the preparation of soils for vegetable forcing are given on page 70. As previously stated successful growers of radishes apply well-decayed manure to the beds either in the fall or before each crop is started. A more expensive plan is to compost sods and stable manure, but this is not considered practicable on a large commercial scale.

The turnip-rooted varieties may be grown successfully in beds only 4 inches deep. It is better, however, on account of more favorable moisture conditions, to make the beds from 6 to 8 inches deep, and a greater depth will be an advantage from this standpoint. It is probable, however, that the usual application of manure will give the best results when incorporated with the soil in beds that are not more than 8 inches deep.

Seed.—Disappointments in the forcing of the radish are often due to the planting of poor seed. Sometimes the seed is old and does not germinate well, but the most common loss is from seed of impure strains. The roots from inferior seed may be small and ill-shaped, or a large percentage of the plants may not produce roots of marketable size. Sometimes the radishes do not have the characteristic shade or color, and this may result in a heavy loss if a special market is to be supplied. Poor seed may also produce large tops and small roots.

When ordering radish seed it is important to specify that the best forcing strains are desired. Most of the seed houses have strains of special merit and these should be obtained if possible.

An excellent method is to buy small lots of seed of the desired varieties from different dealers and test them in the greenhouse. Seed of the best lot may then be purchased in sufficient quantity to last a year. After the larger shipment has been received the additional precaution of another test should be made before sowing extensive areas.

A small percentage of growers who are forcing radishes under glass grow their own seed. They claim that the results of home-selected seed are highly satisfactory if the work of breeding has been properly managed.

Many of the most successful and most extensive growers remove the smaller seeds by screening. Some gardeners discard one-third of the seed. Ordinarily, this will require a mesh that is about one-twelfth of an inch in diameter.

There are numerous advantages in planting large seed. Among them may be mentioned quicker germination, larger percentage of germination, larger individual roots and larger total yield. Extensive experiments with large radish seed were made by Cummings (Rhode Island Bulletin 177). The results were so striking that the complete report is given as follows:

"The radish was selected partly because its seed exhibit much variation in size and weight, but chiefly because it is one of the shortest of the short-term crops. Sixteen different trials were made during a period of three years. Only two varieties were used, but the many trials made have afforded fairly uniform and consistent results. Observations made on seeds of other varieties show the same divergencies in size of crop, and there seems to be no reason to suppose that the varieties chosen were in any way abnormal.

"Attention was first directed to the general results of seed selection with reference to size. The relative values of large and small seed are shown in the tables presented below:

Size of seed	Number of plants	Weight of roots, grams	Average weights, grams	Number 1 Number	Number 1 Weight, grams	Number 2 Number	Number 2 Weight, grams
EARLY FRENCH BREAKFAST							
Large	78	890	11.4	32	510	46	380
Small	55	425	7.7	4	50	51	375
EARLY SCARLET GLOBE							
Large	53	765	14.4	23	440	30	325
Small	56	573	10.2	16	220	40	353

"The superiority of large seed is shown in the greater weight of the edible portion of plants, approximately a 50 per cent increase; and in the greater proportion of No. 1 plants, both in terms of numbers and weight. Forty per cent of the crop grown from large seed was classified as No. 1, while only from 7 to 28 per cent of the plants grown from small seed were thus classified.

"After noting the relative productive capabilities of large and small seed, it then seemed necessary to observe other factors in comparing the different-sized seeds. The following table displays data as to variations in weight of seeds and number of plants produced, together with the quality and weight of plants at the time of harvest.

Size of seed	Number sown	Weight of seed, grams	Number of plants produced	Germination per cent	Total weight of roots at harvest, grams	Average weight at harvest, grams	Number edible	Per cent edible	Weight edible, grams	Number not edible	Weight of tops, grams
EARLY FRENCH BREAKFAST											
Large	4,700	54.4	3,466	74	46,560	13.4	2,688	77.5	21,120	778	23,040
Medium	4,700	43.5	3,270	70	36,960	11.3	2,077	.63.5	14,880	1,193	14,400
Small	4,700	24.7	2,316	49	21,960	9.5	1,325	57.2	10,560	991	9,600

"The large seed outweighed the small by 120 per cent; its viability was better by 50 per cent; the crop from the same number of seed grown was 117 per cent larger in terms of weights, 104 per cent larger in terms of numbers, 100 per cent greater in terms of weight of edible roots, and the tops were 135 per cent heavier. The total edible weight of the crop secured where small seed was used was just 50 per cent of that harvested from the sowing of large seed.

"The studies noted above were followed by others at germination time. Weights were made of the embryos during the first 5 days after applying moisture to the seeds. The differences in weight are shown in the table that follows:

WEIGHT OF EMBRYOS

Relative Weights of 15 Seeds During Germination

Size of seed	Weight of seed, grams	First day, grams	Second day, grams	Third day, grams	Fourth day, grams	Fifth day, grams
Large	.477	.654	.885	1.109	1.127	1.307
Medium	.432	.484	.560	-----	.849	1.042
Small	.316	.411	.434	.462	.581	.703

"The greater weight of the embryos of the large seed should be associated with the greater weight of mature plants, as noted in a preceding table. It seemed also desirable to correlate the matter of greater weight with that of the relative sizes of embryos; consequently there is added another table showing their measurements.

SIZE OF EMBRYOS

Days after germination	Number of measurements	Large		Medium		Small	
		Width of leaves, mm.	Length of embryo, mm.	Width of leaves, mm.	Length of embryo, mm.	Width of leaves, mm.	Length of embryo, mm.
1	15	7.3	25	6.9	24	5.6	21
2	15	7.4	33	6.6	27	5.5	21
3	15	7.3	41	6.3	32	5.3	22
4	30	7.4	43	6.8	36	5.5	31
5	30	7.7	47	7.2	39	5.9	27

"Beginning with the first day after germination, and continuing for five days, it was found that the embryos of large seeds have wider and longer leaves than those of small seeds, while the embryos of medium-sized seeds are of intermediate dimensions. If plants are larger from their start, and even before germination, it is to be expected that they will continue to prove superior in size as they develop.

"Observations have shown that radishes grown from large seed attain the edible stage sooner than those grown from small seed. It was thought that on this account they might contain more water; hence a number of plants were trimmed as for eating and their dry-matter contents determined:

Size of seed	Weight before drying, grams	Weight after drying, grams	Water, per cent	Dry matter, per cent
Large	43.8	1.84	95.79	4.21
Medium	29.2	1.55	94.70	5.30
Small	31.3	1.59	94.94	5.06

"This table is representative of several similar and concordant determinations made but not published. It shows the lower dry-matter content of plants grown from large seed. The plants were of the same age from seed, but were not of the same degree of maturity. Plants grown from small seed were about a week later in coming to edible maturity than those grown from large seed. It is doubtful if an exact comparison could be made by allowing the small seed crop to grow another week, for by so doing changed soil and air conditions might intervene. However, the water content of a radish is not a matter to cavil about. It is always extremely high. Radishes are not eaten for the food they contain, but as a relish. Good quality radishes must be rapidly grown, crisp and succulent, no matter how high their water content. Aside from size as related to quality, the plants grown from small seed were as good as those grown from large seed.

"The source of seed, whether from one parent or several, seems to make little if any difference in the value of the product. The following tables show the results of seed sorting according to size when the seeds in a series are derived from the same plants, the purpose in this instance being to eliminate the influence of individuality in different plants, and to insure similarity in such parental factors as relate to vigor and general growth force.

RADISH SEED OF DIFFERENT SIZES DERIVED FROM THE SAME PARENT

Size of seed	Number of plants	Total weight of plants, grams	Average weight of plants, grams	Weight of tops, grams	Average weight of tops, grams	Weight of roots, grams	Average weight of roots, grams	Actual gain of large over small seed in weight of roots, grams	Percentage gain of large over small seed in weight of roots
	Planted December 30, harvested March 1								
Large	39	737	18.9	335	8.6	402	10.3	1.7	20
Medium	40	678	17.0	307	7.7	371	9.3	—	—
Small	36	549	15.3	241	6.7	308	8.6	—	—
	Planted January 6, harvested March 1								
Large	39	475	12.2	280	7.2	195	5.0	1.3	35
Medium	44	502	11.4	292	6.6	210	4.8	—	—
Small	38	372	9.8	233	6.1	139	3.7	—	—
	Planted December 30, harvested March 1								
Large	100	1,658	16.6	777	7.8	881	8.8	2.3	35
Medium	107	1,503	14.1	713	6.7	790	7.4	—	—
Small	103	1,248	12.1	577	5.5	671	6.5	—	—

"Fully as emphatic results follow the selection of seed, all of which is from the same plant, as were secured by selection on the size basis, irrespective of parentage; so that the use of commercial seeds of large size has practical bearing irrespective of considerations of parental vigor.

"Large seed, regardless of its source, of mixed or unmixed heritage, is superior to small seed of the same source, because it gives larger plants, greater uniformity in stand at edible maturity, and a maturation gain of from 7 to 10 days. In greenhouse culture and elsewhere, when space is valuable or earliness imperative, an economic gain may be expected from the use of large seed. In actual practice this advantage may be secured by sifting out and discarding the small seed."

Sowing.—The beds should be smooth, level and fairly moist before the seed is sown. An occasional grower sows broadcast, but drills possess many advantages. The space between rows varies from 3 to 6 inches. Close planting has a tendency to produce small roots, to retard their maturity, and to encourage damping-off fungi and large tops. The rows may be relatively close if low temperatures are to be maintained.

Only an occasional grower plants as close as 3 inches and very few allow 6 inches between rows. The most common spacing is 4 inches, though many allow 4½ to 5 inches. Varieties which produce small tops and small roots may be planted at minimum distances. A successful grower of the Middle West spaces the rows 4½ inches apart. When the bulk of the crop is pulled, the second sowings are made midway between the first, so that the new and the old rows are only 2¼ inches apart for perhaps a week. This plan of intersowing is the most successful when the plants are thinned to from 8 to 10 to the linear foot of row.

The time for making each sowing must be determined by market conditions, season of the year, varieties grown, temperatures of the house and whether benches or ground beds are used. From four to eight weeks are required for the button varieties to mature. The amount of sunshine and length of days are important factors. In April and May, roots of small size may be grown in four weeks, while twice this length of time may be required at midwinter. There is no reason why the first sowings should not be made in October or perhaps earlier in houses which can be thoroughly ventilated. Radishes generally sell at good prices immediately before and during the Christmas holiday season. Scarlet Globe sown about November 15 should produce marketable roots a few days before Christmas. The beds should be resown as rapidly as they are cleared.

Most growers make rows or furrows for the seed by means of a thin, narrow board, long enough to extend nearly across the bed. By drawing it back and forth a few times, a furrow is quickly made. It need not be more than half an inch deep. The seed is distributed with the thumb and fingers or with an envelope. Twenty seeds to each linear foot of row should give a good stand of plants. The furrows are closed in some convenient way, and the beds firmed with a block of wood and then watered.

Thinning.—Two general policies are followed with reference to thinning. One is to sow enough seed to insure a good stand of plants without crowding, and then to do no thinning until they are large enough for market, when their removal will leave more space for the remaining plants. With this plan of management more time is required for all the plants on a given area to produce roots of marketable size. It is claimed by some growers that this method is more profitable than the usual plan of thinning the small seedlings.

The majority of commercial growers prefer to sow plenty of seed and then thin the plants soon after they are up. While this is a somewhat tedious task, there are distinct advantages in thinning. The smaller plants may be removed, leaving only the strong, vigorous ones which will be likely to produce good roots. Again, the roots will mature over a much shorter period than they will when thinning is not practiced, and they will be larger and more uniform in size and shape.

Some growers allow only ½ to ¾ inch of space between plants of the smallest varieties, but this is too close for the best development of most varieties. The more generally approved plan is to thin to from 8 to 10 plants per each linear foot of row. An inch and a half between plants is sufficient space for most turnip-shaped sorts. An occasional grower allows 2 inches. Larger roots are produced when the spacing is liberal, and higher prices for them may justify the practice.

Intercropping.—When radishes are used for intercropping with lettuce and cauliflower, it is important to select varieties of light foliage and to see that the plants are not crowded. If ample space is allowed between the rows as well as between the plants in the rows, good roots may be grown, and there will be no appreciable interference with the lettuce or cauliflower.

Watering.—A constantly moist bed provides ideal conditions for the radish. Over-watering, especially if temperatures are too high, is likely to cause damping-off of the seedlings. If they escape this disease, they will become top heavy and the roots will be small and late in maturing.

Beds should be watered thoroughly after the seed is sown, and sufficient water should be used at this time to require no further applications until the plants are up and ready to thin. When sowings are made under glass in warm, bright weather, two or three waterings may be necessary to supply moisture until the plants are up.

The beds are likely to dry out more rapidly next to the walks, and dry spots may appear here and there which will require extra applications of water. Such places may be watered very quickly with a special nozzle attached to a hose. Excessive watering when the radishes are nearly large enough to market may cause the roots to crack.

The radish thrives best in a humid atmosphere. Overhead watering, which diffuses a mist over the beds, provides the most favorable soil and atmospheric conditions so far as moisture is concerned.

Temperature.—Too high temperatures produce spindling plants and excessive top growth, and the roots will be small. Too low temperatures, on the other hand, cause slow growth and the development of roots that are lacking in quality. A night temperature of 43 to 45 degrees and a day temperature of 55 to 60 degrees will be found satisfactory. Sixty-five degrees or above on bright, sunny days will do no harm.

Ventilation.—The ventilators should be opened a little every day, unless the weather is unusually severe. In warm, bright weather, air should be admitted as freely as possible.

Cultivation.—Small weeders used between the rows are beneficial in conserving moisture and in keeping the soil in a loose, friable condition. In wide, ground beds, a five-prong weeder attached to a long handle, as illustrated in Fig. 75, will be found a most excellent tillage tool.

Enemies.—The radish, when grown under glass, has very few enemies. As previously stated, damping-off fungi may attack the seedlings in beds that have not been sterilized. The green aphis is the most important insect pest of this crop. It may be controlled by fumigating with tobacco. The radish is more susceptible to injury from tobacco smoke than is lettuce. The safer policy is to make light fumigations rather frequently.

Frame culture.—This is one of the most important crops for growing in hotbeds and frames. (See page 405.)

Marketing.—The proper time to begin pulling the roots depends on a number of factors. If prices are very good it may pay to begin selling them when they are quite small. Ordinarily, they are not sold until they are at least three-quarters of an inch in diameter. Market requirements should also have consideration.

Ill-shaped roots should be discarded. When the final pulling is made on a given area, there may be some very small roots, which should be thrown away or packed and sold separately.

Five radishes in each bunch is probably the most common number. If the roots are very small, it may be necessary to tie six or seven in a bunch in order to meet the requirement of the market to be supplied. Some growers put 10 to 12 in a bunch, and then sell at prices proportionally high. This saves labor in tying, washing and packing.

Raffia is commonly used for tying, though many growers use light cotton twine. The radishes are improved in appearance by clipping off the slender tips of the roots, which also saves time in washing. Holding the tied bunches in running water under a spigot may clean the roots sufficiently for market; but if they have been grown in clay soil, the use of a scrubbing brush will be necessary to remove the finer particles of soil.

The radishes may be packed in baskets and shallow crates of various kinds. Half-bushel splint baskets are highly satisfactory. They hold from eight to ten dozen bunches. If the inside of the baskets is lined with two or three thicknesses of paper, and the baskets, after the radishes are packed, are securely wrapped with paper and tied, it will be possible to ship the roots in severe winter weather.

Yields and returns.—About two dozen good radishes should be grown on each square foot of ground. In other words, about five bunches should be produced to the square foot. The prices are so variable in different markets and at different seasons of the year that it is impossible to give figures relating to returns which are of much value. Prices per dozen bunches range from 25 cents to 75 cents, or above, for large bunches of fine roots. A good crop of radishes should give a return of at least 12 cents per square foot of bed area.

CHAPTER XVII

TOMATO

History.—Practically no tomatoes were forced in this country for commercial purposes previous to 1890. A grower here and there would have a few dozen or perhaps a few hundred plants, but tomato forcing did not become an industry of real importance until about 1900. Small areas were planted in the greenhouses of many of the agricultural colleges during that decade, and the bulletins and articles published relating to the experiments attracted the attention of market gardeners, and no doubt influenced many of them to make small plantings under glass, the results of which eventually led to the forcing of the crop on a large commercial scale. Twenty-five or more years ago a few bearing tomato plants were often seen in conservatories of the wealthier classes, but the idea of commercializing the proposition apparently occurred to very few growers before 1890.

Importance.—As stated on a previous page, the tomato is now one of the three most important vegetable-forcing crops. Lettuce ranks first, cucumber second and the tomato third, and the tomato is increasing in importance every year. So far as consumers are concerned, it is a more popular vegetable than the cucumber, and some growers believe that it will ultimately occupy first place in commercial importance.

It is a more difficult crop to grow under glass than either lettuce or cucumbers. It requires much more heat than lettuce and closer attention than the cucumber. It is regarded by many as a hazardous crop, especially in the fall and winter. Great care is required in order to avoid serious attacks of various diseases. The white fly, unless the houses are properly fumigated with hydrocyanic gas, may practically ruin a crop. Skillful watering, heating, ventilating and pollinating are required to obtain a satisfactory setting of fruit. While serious difficulties may exist, there are now many growers who are experts in forcing this crop, and they have little fear of failure because they are thoroughly conversant with the numerous cultural details that must have close attention.

Southern competition should be considered in this connection. The tomato pays best as a spring forcing crop, and then the northern greenhouse product invariably comes into competition with tomatoes shipped from Florida and other southern points. While forced tomatoes, during the spring and early summer, undoubtedly command lower prices on account of southern competition, the greenhouse crop is so superior in quality and is grown at a cost so low that the fruit may be sold at comparatively low prices, say 10 cents a pound, and still leave a satisfactory margin of profit.

The tomato is an important vegetable for forcing because it fits so well into the rotation of greenhouse crops. Lettuce, radishes and cauliflower may be grown during the duller weather of the fall and winter, and tomatoes, set in the beds about March 1, will come into bearing the latter part of May and continue to produce until August 15. The spring crop is not so difficult to grow, and any careful gardener may be reasonably certain of success.

Hundreds of greenhouses are now devoted to the forcing of tomatoes. Some of the ranges occupy several acres of land. A small percentage of the growers produce tomatoes throughout the forcing season. Some grow them only in the fall and occasionally at midwinter, but the majority find that it is most satisfactory to use the houses for cool crops until spring and then to plant tomatoes, which are marketed mainly during the months of June and July.

Pots and boxes.—In the early years of tomato forcing, the plants were finally shifted to 8 to 10-inch pots, in which they were grown until all the fruits had ripened. Large pots are still used to some extent in conservatories. The potted plants, laden with beautiful pink or red fruits, are fully as attractive as many plants grown solely for ornamental purposes. It is more difficult, however, to grow good tomatoes in pots than in beds. There is insufficient soil, even in 12-inch pots, for the best results. The soil dries out rapidly and there is great danger of the plants being stunted or checked in growth, which invariably reduces the yield. Pots are convenient for shifting about the house in private establishments, and they may be separated as much as necessary in order to provide ample room for each plant.

Boxes were often used by the agricultural experiment stations from 1890 to 1900. They were a decided advantage over pots in providing more soil for the plants, and they could also be conveniently moved from place to place. Ordinarily, they were 10 inches to a foot deep. Cornell University used boxes that were 18 inches square, and set four plants in each box. The Tennessee station obtained fairly satisfactory yields by setting three plants in a box 1 by 1 by 3 feet in size. It is possible to get better results in boxes than in pots, but they are not practicable on a large commercial scale because of the increased cost of production and the smaller yields than those obtained in properly prepared beds.

Benches vs. ground beds.—It was soon discovered by the experiment stations as well as by practical growers that tomatoes produced larger and better crops on benches than in pots and boxes. In the first place, it is much cheaper to construct benches than to make individual boxes or to buy the required number of large pots. Furthermore, the soil does not dry out so rapidly in beds as in boxes.

FIG. 85.—TOMATOES IN KENNETT SQUARE (PA.) HOUSE.

For many years New England growers have used raised benches for the forcing of tomatoes, and they are now extensively employed in the Kennett Square section of Pennsylvania. (See Fig. 85.) There is a disposition, however, among growers in all sections to abandon the use of benches and to plant in solid ground beds, except when the crop is grown during the winter months. In the Ohio and Irondequoit (N. Y.) vegetable-forcing districts, ground beds are used almost exclusively, but the tomato, in these sections, is forced mainly as a spring crop. The great barrier to the use of benches in any locality is their cost of construction and maintenance.

Leaving the expense factor out of consideration, what are the merits of benches as compared with ground beds for the forcing of tomatoes? The tomato is a plant that requires a large amount of heat. For this reason, the plants grow more rapidly on benches with bottom heat than they do in ground beds. There is a difference of 10 days to two weeks in the maturity of the crop, if grown at midwinter. Even the spring crop will reach the ripening period quicker if there is bottom heat. On the other hand, it is claimed by experienced growers that total yields are greater from ground beds, so that earliness in the ripening of fruit from the benched plants is not all gain. It is more difficult to properly water the benches so that the soil throughout is as moist as it should be, and this objection is made by growers who prefer ground beds. When the soil in the benches is watered by sub-irrigation, it is an ideal system, especially during the dull winter months. The advantages of benches provided with sub-irrigation lines should be considered, and it is possible that this method will be more generally used when it is better understood.

For the spring crop, ground beds are entirely satisfactory. It is a simple matter to maintain proper soil moisture conditions in them, and the plants are easily reached for the pruning, tying, spraying and harvesting of the fruit.

Varieties of tomatoes which are used for forcing differ widely in habit of growth and character of fruit. It cannot be said that any variety in cultivation is ideal even for any one market or section of the country, for, while we have excellent sorts, there is much that should be done to improve them, and the progress being made in this direction is exceedingly encouraging.

In the selection of a variety for forcing, the first factor to consider is the plant. Has it the ability to mature a heavy crop? This question is fundamental in importance. Generally speaking, plants with short internodes are the most prolific. They bear the first clusters of fruit near the surface of the ground and a maximum number of clusters is produced on plants of a given height. The foliage of the plants should be highly resistant to disease. In this respect, there is abundant opportunity for improvement. In the matter of area or extent of leaf surface, there is some difference of opinion as to what is best. Theoretically, it would seem that plants with small leaves or sparse foliage would be most suitable for greenhouse culture, because such plants interfere the least in admitting light and in securing free circulation of air. In practice, however, most growers pride themselves upon the vigor and even the size of the leaves. The writer has seen expert growers handle large, healthy, green leaves with as much delight as a stockman would fondle a pet calf. Abundant foliage is apparently essential in the production of large, well-ripened fruit.

English varieties, such as Comet, produce more tomatoes in a cluster than do American varieties, such as the Globe. This tendency to set a very large number of fruits may require a certain amount of thinning in order to obtain specimens of marketable size.

Earliness is an important factor. If a certain variety will mature just as large and as good a crop in several weeks less time than a later variety, the cost of production will be materially less and profits proportionately larger. With an early-maturing variety, the house can be used later in the spring for lettuce or radishes, and have sufficient time to mature tomatoes for the June and July markets.

When tomatoes are cheap, the markets will take fruits of large size, but when they retail at 30 cents or more a pound, small specimens are desired. At midwinter, when maximum prices prevail, the fruits are generally used for salad, and usually cut into thin slices. The tendency, therefore, is to grow fruits that range from three to four ounces in weight for winter sales and larger sizes for the fall and early summer trade. When tomatoes are selling at 8 to 12 cents a pound wholesale, it is seldom that there is any complaint about their being too large. Some growers select varieties which, under ordinary conditions, yield fruit of small size, but by liberal fertilizing and the best cultural conditions produce specimens that are medium to large in size. It is especially important that the fruits run uniform in size.

The most popular forcing varieties produce globular fruits. They should be regular in shape and free from sutures. The color is almost wholly a matter of market preference. Most markets prefer bright red tomatoes, though there are many exceptions. The brilliant scarlet shades are somewhat more showy than the pink or purple colors. The flesh should be firm, tender, fine in texture, juicy and of good quality. The skin should not be subject to cracking.

The testing of varieties is such a simple proposition that every commercial grower should satisfy himself by tests in his own houses that he is using the variety which is best for his particular market and conditions. He should be on the alert for improved varieties or strains, small plantings of which should be made to determine whether they are really superior to the variety which is being grown on a large scale.

There are two general classes of tomatoes—the English and the American—grown in the greenhouses of this country. The English varieties are typical forcing tomatoes, used wholly for forcing purposes in England, where climatic conditions are unsuitable for growing the crop out of doors. The leaves of English varieties are smaller than the leaves of American sorts. English varieties also differ from our common sorts in setting a larger number of fruits to the cluster, and the fruits are smaller and generally more uniform in size, especially if the clusters are thinned. The size of certain English varieties, grown in this country, has been materially increased by selection.

The following varieties are the best known among American growers of greenhouse tomatoes:

Beauty.—An American tomato that is largely grown as a spring crop in Ohio. The Ohio station has found this to be a most excellent forcing variety. The plants are vigorous and prolific. The fruit is pink, large, solid and of excellent quality.

Best of All.—An English variety the fruits of which are somewhat larger than ordinary strains of Comet, but it is not so productive.

Bonny Best (Fig. 86) is probably the most generally and the most extensively grown of the American class. It is universally popular for fall and spring culture, and is often grown at midwinter. The fruits are larger than Comet, though not as bright scarlet in color. The plants are vigorous and prolific. Fruits solid, roundish, oblate in shape and very good in quality. The earliness of Bonny Best is one of the most commendable points.

Carter's Sunrise is a small, red, English variety that ripens several weeks earlier than Comet. The clusters

Fig. 86.—Bonny Best tomato.

are very large and often shouldered, and thinning is necessary to obtain fruit of satisfactory size. The liberal feeding of the plants of this variety after the fruit is well set is also an advantage in increasing the size of the fruit.

Comet (Fig. 87) is undoubtedly the best known of the English type. The plants are thrifty in growth and highly prolific. The roundish, solid, bright red, large-celled fruits are exceedingly attractive and their quality is excellent. The Comet and other English varieties do not require as much attention in pollination as American varieties.

Earliana, the most largely cultivated of early American varieties, is not extensively grown under glass. A few growers have found it highly profitable for spring culture, but the comparatively poor quality and irregular shape of the fruits have resulted in its condemnation by most greenhouse growers. If this variety is used, the best strains should be selected. It is doubtful, however, whether Earliana should ever be chosen in preference to Bonny Best.

Frogmore is a peach-shaped English variety of good size. It is larger than Comet and is recommended for spring planting.

Globe (Fig. 88) is a popular, pink American tomato, well adapted to greenhouse conditions. It is quite extensively planted for the spring crop. The plants are vigorous and very prolific; fruits large, solid and of good quality. It is seldom grown as a winter crop.

Lorillard is one of the oldest of the American varieties

Fig. 87.—Comet tomato.

used in greenhouse culture. It was probably the most prominent forcing variety from 1890 to 1900, but has been almost wholly displaced by better sorts. It is not nearly so prolific as Bonny Best or Comet.

Magnus, a large-fruited pink tomato, has been a favorite among Ohio growers, and it has been planted under glass to some extent in other sections. It belongs to the potato leaf type, so that the foliage is much more extensive than on the most common forcing varieties. The fruit is solid and of excellent quality.

Peerless (Fig. 89) an English variety, is a selection of Lord Roberts, developed by Chauncey West of Irondequoit, N. Y., about 1908. It is preferred to Comet by some of the most successful and extensive growers. The fruit is borne in large clusters, and the individual specimens are medium to large, solid and of superior quality. It is one of the most satisfactory red tomatoes, suitable for cultivation at any time during the forcing season. It requires heavy feeding.

Stirling Castle is an old English variety recommended by a few American growers. The fruits are smaller than Comet, and thinning and high fertility are necessary to secure specimens of satisfactory size for commercial purposes.

Stone, a well-known very late American variety, has given most excellent results at the Ohio station as well as in some commercial establishments. However, it is losing in popularity largely because of its extreme lateness. The large, solid, beautiful red fruits are of the best quality.

Numerous miscellaneous varieties are mentioned in

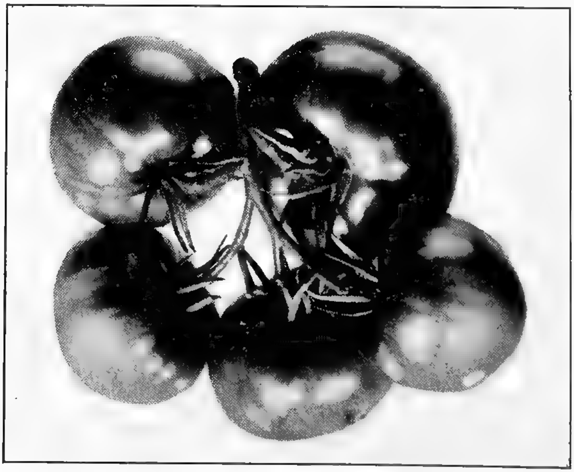

Fig. 88.—Globe tomato.

Fig. 89.—Peerless tomato.

the literature relating to tomato forcing. In addition to the foregoing list, perhaps the following are the most common: June Pink, Combination, Fordhook First, Winter Beauty, Industry, Success, Mayflower, Hummer, Alpha Pink, Burpee's Earliest Pink, Eclipse, Holmes's Supreme, Dwarf Champion and Hubert Marvel.

Soil.—A great many different soil types are used in growing tomatoes under glass. With the data available it cannot be said that larger or better crops can be grown in one soil, referring only to texture, than in another. Unusually heavy greenhouse crops are grown in the very coarse sandy soils of Irondequoit. Many other sections are producing heavy yields in fine sandy soils, and some of the largest yields have been obtained on extremely heavy clay or silt soils. The general advantages of the lighter soils have been recognized in Chapters III, V and VI, and if such soils are available for the forcing of tomatoes, they should be chosen in preference to heavy soils, other factors being equal. It is unmistakably true that any soil suitable for agricultural purposes will, when properly prepared and cultivated, produce a satisfactory crop of greenhouse tomatoes.

Fertilizing.—Experienced growers agree on the necessity of liberal feeding in order to obtain satisfactory yields of greenhouse tomatoes. Impoverished soils invariably produce weak, spindling plants which fail to bear profitable crops. On such plants the number of fruits is limited and the individual specimens are small in size and inferior in quality. High fertility is essential from every standpoint.

While liberal feeding is necessary, it is important to maintain a proper balance in the elements applied. An excessive amount of nitrogen and a deficiency of potash and phosphoric acid will be certain to result in a rank growth of low production plants. On the other hand, a superabundance of the mineral elements and very little nitrogen will result in light stems and small leaves and solid but undersized fruit. There can be no shortage in any of the elements without affecting the yield as well as the quality of the crop.

Jenkins and Briton, of the Connecticut Experiment Station, found that tomato plants on 100 square feet of bench space assimilated, from February 1 to July 1, 226 grams of nitrogen, 74 grams of phosphoric acid and 391 grams of potash. To meet these requirements it would be necessary to apply 3 pounds 10 ounces of nitrate of soda, 1 pound of boneblack and 1 pound 12 ounces of muriate of potash. It is customary, however, to apply more than enough food to merely meet the needs of the plants because all of it is not accessible to the roots. Any surplus at the close of any one harvest will remain for succeeding crops, except that there is constant loss of nitrogen by volatilization.

Comparatively few gardeners use commercial fertilizers at all in the growing of the greenhouse crop. They claim that when stable manure is used in sufficient quantity to

FIG. 90.—A GOOD CROP OF GREENHOUSE TOMATOES.

maintain proper physical conditions of the soil, there will be as much of the various elements of plant food as the crop can utilize. Many of the heaviest crops are grown year after year without employing chemicals or any kind of commercial fertilizer. Other growers claim that light dressings of complete fertilizers have increased yields as well as profits. A fairly common practice is to use a little nitrate of soda about each plant after the fruit is set. Others feed the plants with liquid manure after the fruit is set. This method is used in the Kennett Square section of Pennsylvania. Mulching with stable manure, as described on page 78, has practically the same effect. Bone meal, wood ashes, tankage and sheep manure are often used in the smaller forcing establishments.

Soil preparation.—The general remarks on Soil Preparation, Chapter V, and Soil Sterilization, Chapter VI, apply to the fitting of beds for growing tomatoes. If tomatoes only are grown in the houses year after year, without any rotation, it will be an advantage to change the soil at least every fifth year, though with thorough steam sterilization there may be continuous cropping for a long term of years. Whenever benches are used, as in the Kennett Square district of Pennsylvania, the usual plan is to change the soil every year or two. In most of the large establishments, containing an acre or more of glass, and where ground beds are employed, the commonest plan is to apply liberal amounts of manure for lettuce during the fall and winter and then to use no manure for the tomatoes, which are generally grown as a spring crop, except the manure mulch, which is as a rule applied after most of the fruit is set. Any soil, however, which needs additional plant food or organic matter should be enriched by spading or plowing in well-decayed manure before the beds are planted with tomatoes.

In the sections near Philadelphia where mushrooms are grown on a large scale it is usual to apply about 4 inches of manure (see page 424 for composition), which has been used for growing mushrooms, to suitable areas in the field. The land is plowed a few times during the summer and the soil placed on raised beds in the fall for the culture of tomatoes and carnations. Bone meal is generally mixed with the soil when it is transferred to the houses, and the tomato plants are fed with liquid manure after the fruit is set.

Seed.—Very few vegetables are more susceptible to improvement from seed selection than the tomato. Numerous examples could be cited of growers, who, being pleased with certain characteristics of perhaps well-known varieties, have made decided progress in improving them by means of careful seed selection. This statement applies to Bonny Best, Lord Roberts, Comet and other prominent greenhouse varieties. In some instances, the improvement has been so marked that a new name has been given the superior strain, as when Peerless was developed as a selection of Lord Roberts.

Seedsmen often make a specialty of varieties suitable for forcing purposes. In some instances the strains are most excellent and growers would not make a mistake by purchasing such seed. Scores of growers, however, do not care to take any risks in the matter of planting the best seed, so that there is a general and an increasing tendency to make careful selections from plants in their own greenhouses. When an unusually good crop is produced it is possible to save enough seed from robust, productive plants to last five years or even longer, so that it is unnecessary to give this matter attention every year.

The grower should establish high ideals with reference to the most important points—such as color, size and shape of fruit, productiveness of the plants and their ability to resist disease—and the desired characteristics should be kept constantly in mind in selecting fruit for seed purposes.

Cuttings.—Tomato plants are easily propagated by means of cuttings. They may be made of any convenient size, preferably short and stocky, and rooted in sharp sand. If a little bottom heat is provided, the cuttings will root in five or six days, when they can be potted and grown to proper size for planting in the beds. The few experiments which have been made seem to indicate that plants propagated from June cuttings are not as prolific as those grown from seed, so that no advantage in general cropping is gained by using cuttings. There are instances, however, when it is desirable to perpetuate a stock of choice plants, and this can be done only by means of cuttings. If an unusually fine plant is found, seed should be saved from it for testing, and additional trials may be made of the plants rooted from cuttings.

Plants large enough for the beds or benches may be grown in much less time from cuttings than from seed, but this is probably of no value from a commercial viewpoint, because seedlings require so little space until they are large enough for potting. It is simply a question of sowing early enough to grow plants of proper size for planting in the beds at the desired time.

Starting plants.—The proper time of sowing depends upon a number of factors: (1) Earliness of the variety. Some varieties require nearly a month longer than others to mature fruit. Bonny Best sown July 1 in central Pennsylvania produced a few ripe specimens October 11. Stone probably would have produced no ripe tomatoes before November 1. (2) Amount of sunshine. There is more bright, sunny weather in some sections than in others, and there is much more sunshine late in the winter and spring than during the fall and early winter. Probably four or five weeks more time would be required to mature Bonny Best sown November 15 than for the same variety started February 1. (3) Temperature of the house. High temperatures, especially when the plants are young, necessarily shorten the time from seed sowing until the ripening period. (4) Market demands. This question should have most careful consideration. For

FIG. 91.—ECLIPSE X EARLIANA TOMATOES AT THE NEW HAMPSHIRE EXPERIMENT STATION.

example, prices for the spring crop are always higher early in June than later in the month, and it is important to sow in ample time to mature the crop so as to obtain the highest prices.

Seed for the fall crop is usually sown from June 20 to July 1. A few growers sow from July 15 to August 1, but this is regarded as very late sowing. There should be special reasons for starting the fall crop later than July 1. The fruit should be well set by the middle of November, when there is usually much more cloudy weather than earlier in the fall. Seed for the winter crop may be sown in succession from August 15 to November 15.

There is considerable difference of opinion regarding the best time to sow for the spring crop. Many of the most extensive growers sow from January 1 to 15. Others, who use the earlier varieties, such as Bonny Best and Comet, sow from January 15 to February 1. A prominent Irondequoit (N. Y.) grower sows Peerless from January 15 to February 1. Many growers aim to set the plants in the permanent beds about March 1, and such plants will begin to ripen fruit the latter part of May or early in June. The earliest varieties will give very good results if not planted in the beds until March 15 or even April 1.

The commonest practice is to sow the seed in flats or beds, as explained in Chapter IX. There should be ample space between the rows and the seed should be sown thinly so as to induce the growth of stocky plants. It is desirable to transplant the seedlings before they show any tendency to become spindling. Ordinarily, the first shift can be made in three weeks from the date of sowing. The plants are generally set in flats or beds and spaced from 2 to 3 inches apart. When they begin to crowd, a second shift is made to 3½ or 4-inch pots. Some growers make four shifts, the first into flats or small pots, the second into 3 or 3½-inch pots and the third into 5-inch pots, and finally into the permanent beds. The most extensive commercial growers seldom make more than three shifts, including the final transplanting into the beds.

An extensive grower at Cleveland, Ohio, sows in beds and then sets two plants in a quart berry basket; these are ultimately set, basket and all, in the ground beds. It is claimed that the results are just as satisfactory as when pots are employed and that the expense in starting the plants is less.

The utmost care should be exercised in the growing of strong, robust plants. They should not be permitted to become pot-bound at any time. Careful watering and ventilation are of urgent importance.

Planting distances.—There is the greatest diversity of practice in the planting distances adopted by different growers. Some tests have been made at the experiment stations, but the results with different varieties under variable conditions are so contradictory that conclusions of real value cannot be drawn.

Close planting undoubtedly results in smaller tomatoes and smaller yields to the plant, but not necessarily smaller yields per square foot. The tendency of commercial growers, however, is to become more liberal in the amount of space between rows, which is a decided advantage in caring for the plants and in harvesting the fruit. Formerly the most common practice was to plant 16 by 18, 18 by 18, 20 by 24 or 24 by 24 inches. Now the more frequent plan is to allow 2½ to 4 feet between rows and to set the plants a foot to 18 inches apart in the row. For example, one of the most successful growers at Irondequoit has only seven rows in a house 30 feet wide, and the plants are 18 inches apart in the rows. A prominent Cleveland grower allows 3 feet between rows, and berry baskets, each containing two plants, are set at intervals of 27 inches. A well-known grower in Western Pennsylvania plants 3 feet by 15 inches; an Erie, Pa., grower 3 feet by 12 inches, a Massachusetts grower 3 feet by 15 inches.

When grown with carnations, a common distance is 20 by 20, or three rows on benches 4 feet wide. Another well-known Ohio grower plants 4 by 1 foot apart, and a Grand Rapids grower 3½ by 1. Some growers are pleased with the following hexagonal plan which gives each plant the maximum amount of space in every direction:

x x x x x

x x x x

x x x x x

Planting.—As previously stated in this chapter, the plants should not be allowed to become pot-bound before they are shifted or transferred to the beds. The plants may be set a trifle deeper than they stood in the pots, and it is generally desirable to water the beds after they are filled with plants. See page 278 for dates on which to plant.

Intercropping.—Tomato plants soon develop a large amount of foliage which retards the development of smaller crops, such as lettuce and radishes, so that they are not very well adapted to companion cropping, except when they follow carnations. See Chapter XXI for data on systems of cropping.

Training.—When tomatoes are produced under glass there must be some means of regulating the habit of growth. Numerous experiments have been made with a view to determining the best system of training. In most of the trials, the plants have been trained to one, two and three stems, respectively. Perhaps the most extensive work along this line was conducted by the New York station. Beach, in drawing conclusions in Bulletin 123, states: "Single-stem training (as seen in Figs. 90, 91 and 92) is clearly superior to three-stem training for forcing tomatoes in winter—in this climate. The superiority is seen in the larger yield of early ripening

FIG. 92.—A HOUSE OF PLANTS GROWING IN POTS—ENGLAND.

fruit and in the larger total yield. There is but slight difference in the average size of fruit produced under the two methods of training, but on the whole the fruits of the single-stem plants seem to be slightly the larger."

The advantages of single-stem training over two-stem training are not so marked, and yet the fact that practically all of the most extensive growers of forced tomatoes use the single-stem system is a strong testimony in its favor. It is doubtful whether growers are ever justified in using any other system of training. It is the simplest and most satisfactory in every respect.

There are various ways of supporting the plants. The commonest is to tie them to twine or cord stretched from the base of the plants to wires or rafters above the plants. Many growers stretch wires above each row, running the full length of the house. They may be secured at the ends in any convenient way and fastened with staples to the rafters, or by other means if desired. Sometimes wires are also stretched across the beds at the surface of the ground, but they interfere with tillage and are an unnecessary expense. Twine (binder twine is excellent) looped to the base of the plants and tied taut to the wire above will be very satisfactory. Waid recommends the use of "screw wires" of No. 10 or 11 wire which are screwed 4 or 5 inches into the soil close to each plant. These are provided with a loop at the top to which the twine is tied. Waid gives the following description in the *Market Growers' Journal* of a simple device for the making of these wire screws:

"It consists of a piece of inch and a quarter pipe about 6 inches long, through which a ¾-inch pipe is run, extending out at one end far enough to attach a handle, and at the other about 5 inches. Two holes are bored in the smaller pipe, each just large enough to admit the wire. One hole is near the end of the pipe and the other about 4 inches from the end or close to the end of the larger pipe. The larger pipe is placed in a vise and the device is ready for operation. The wire is cut 10 to 12 inches in length, one end placed in the hole in the pipe the farthest from the end. Precaution must be taken not to let it in too far, or it will be troublesome to get the wire out after it is twisted. The handle is turned backward with one hand while the wire is held firmly against the pipe with the other. Two full turns of the handle are made, and the wire should be guided so that it will be near the outer end of the smaller pipe when the turns have been made. The straight end of the wire is then turned so that it is parallel with the pipe. The other end of the wire is then extracted from the hole by means of a screw-driver. The straight end of the wire is next placed in the hole near the end of the pipe and the handle given a half turn. This last move makes the loop to the wire and finishes the operation. The reason for turning the handle backwards in the first case is to make the wire so that it will screw into the soil the same as a screw turns into wood. If the handle is turned forward the wire will have to be screwed into the soil backwards. When a person becomes accustomed to making the wires he can make at least 500 a day."

A few growers prefer to use very thin strips, as explained for cucumbers on page 399. Others have found special wire trellises highly satisfactory. They may consist of five to seven wires running lengthwise of the house with cross wires at frequent intervals. The trellises are attached or hinged to pipe purlins above, so that they can be swung up out of the way when not in use, and dropped in a few minutes when they are needed for the support of plants. This plan is most commendable in every particular. An important advantage of the plan is that jarring the trellis to which the plants are tied with a stick at mid-day when the sun is shining is a most effective aid to pollination. See page 288.

When twine supports are used, it is customary to tie the plants at about four points with raffia or coarse twine. The loops should be made as far as possible below the nodes of the plants, in order to provide more perfect support. An excellent plan is to coil the plant as it increases in height about the twine, when it is unnecessary to make so many ties.

All lateral shoots are pinched off, when they are very small, with the thumb and finger. The plants should be looked over at least once a week so that none of them will attain any considerable size before being removed. When the plant reaches the desired height, the terminal is pinched off. Most growers prefer plants that are 6 to 7 feet high. In eastern sections they are sometimes grown to a height of 8 to 10 feet. Alertness is required to observe all the lateral shoots and to avoid pinching off the terminal shoot before the desired height of the plant has been secured.

Growers do more or less pruning of the leaves. This seems to be an advantage when the growth is very rank, but it is a matter which should be managed with extreme care. Excessive defoliation is certain to result in diminished fruit production. When the lower leaves become badly diseased, they should be promptly removed and destroyed.

Watering.—Tomato plants require an abundance of water, and this is especially true after they have grown to a height of several feet. There is always danger of insufficient water being applied and the moisture failing to reach the bottom of the beds. In very heavy soils which do not contain enough organic matter, repeated watering on the surface of the ground is likely to compact the soil and thus prevent the percolation of the water to the full depth of the beds. This is one of the main arguments for mulching with manure or watering by means of subirrigation. When the supply of soil moisture is insufficient, blossom end rot of the fruit is likely to occur, the plants will not be thrifty in growth and the fruits will be small. While an abundance of moisture is absolutely necessary, a saturated condition of the soil must also be avoided, for this invariably causes the growth of weak, spindling plants with yellowish leaves and low fruit production. Diseases are also more destructive when the soil contains too much water. Over-watering is most likely to occur during the winter months when there is so much dark, cloudy weather. During the bright spring and warm summer weather an enormous amount of water can be applied without danger of injury. At this season of the year it may be necessary to water daily or even twice a day under certain conditions.

The method of watering should have careful consideration. Watering has a very close relation to the question of pollination. (Page 288.) A dry atmosphere is most favorable to the discharge of pollen and the setting of a maximum number of fruits. It is also important to protect the flowers from water, which may wash away the pollen grains and thus result in a small setting of fruit. The foliage, too, when it becomes wet, is more susceptible to fungous diseases of various kinds. Overhead watering is used to a considerable extent in growing tomatoes, but it is readily seen that the arguments are in favor of applying water with a hose, care being taken to keep the plants as dry as possible. From the standpoint of saving labor, avoiding diseases and securing a heavy crop of fruit, sub-irrigation seems to possess special advantages. Experiments made by Waid in a two-year test on raised benches at the Ohio station gave the following results:

Method of watering	Yield per square foot lbs.	oz	Av. sizes of fruit oz	Amount of rot per sq. ft. oz
Surface watered -------	1	15.0	5.0	4.7
Sub-irrigated ----------	2	4.5	5.9	1.9

"With two houses, each having 960 square feet of bench space planted to tomatoes and both treated alike except in the manner of watering, the sub-irrigated house would yield, calculating the yield according to the above table, 330 pounds more of tomatoes than the surface-watered house. The surface-watered house would give, on the other hand, 168 pounds more of fruit affected by rot than the sub-irrigated house."

Temperature.—The night temperature for tomatoes should never be lower than 60 degrees, and the temperature on cloudy days during the winter should be about 70 degrees. In warm, bright, sunny weather, no injury will result from very high temperatures. It is a common occurrence for the temperature to rise in the houses to over 100 degrees during the months of June and July.

Ventilation.—As previously stated (page 166), the houses should be ventilated as freely as weather conditions will permit. Some fresh air should be admitted every day, even in the coldest weather. In warm weather it is desirable to keep the ventilators open all night. During the late spring and summer months doors and ventilators should be opened full width unless storms make it necessary to close them for a short time. Thorough ventilation is exceedingly important in the control of fungous diseases. It is also an aid in the pollination of the flowers.

Cultivation.—When the beds are not mulched it is important to cultivate the soil as often as may be necessary to keep the surface in a loose, friable condition. When 2½ feet or more of space is allowed between rows, it is possible to till the soil with a wheel hoe. Tillage must not be deep enough to injure the roots of the plants.

Mulching.—The majority of greenhouse growers of tomatoes mulch the beds with horse manure. Among the advantages which may be mentioned are the conservation of soil moisture, prevention of weed growth, saving of labor in cultivating, saving of labor in watering so frequently, and the feeding of the plants by food leached from the manure after every surface application of water. Unless the soil is excessively rich in nitrogen, mulching with manure is probably always beneficial, and should there be a surplus of this element in the soil, cut straw might be substituted.

Mulching is most beneficial when surface watering is practiced, but it is also an advantage with sub-irrigation. Almost any kind of organic material may be used for mulching, but fresh horse manure is generally employed. Care should be exercised in order to avoid burning the leaves with ammonia that may escape from hot manure. Such injury may be prevented by spreading the manure in thin layers until it is cool, or it may be soaked with water immediately after it is applied to the beds. A depth of 3 or 4 inches is necessary for the best results. Mulching is most commonly employed with the spring crop. If surface watering is practiced, most of the manure will be sufficiently decayed by midsummer to spade or plow into the soil preparatory to the fall crop of lettuce or cauliflower.

An experiment made at the Ohio station demonstrated the superiority of a strawy manure mulch over straw alone. There were two plots, each 120 square feet in area, and 28 plants were set in each plot. The results were as follows:

Variety	Number of fruits	Weight lbs.
Plot 1—Manure Mulch		
Magnus	326	102
Stone	299	104
Beauty	256	72
	881	278
Plot 2—Straw Mulch		
Magnus	234	63
Stone	234	75
Beauty	234	76
	702	214

The plants in the manure-mulched beds averaged about 9¼ pounds each, while those in the straw-mulched beds averaged about 7¾ pounds to the plant.

There is considerable difference of opinion among growers concerning the proper time to apply a mulch. If straw is used, there can be no objection to putting it on immediately after the plants are set, and some growers who use manure, mulch at this time. It is claimed by others that the danger of early mulching, causing excessive plant growth with more or less hindrance to fruit development, makes it desirable to defer this operation until at least three clusters of fruit are set. The latter policy is certainly safe and is probably followed by the majority of growers. It is also believed by some growers that a mulch kept constantly wet from the first promotes the development and dissemination of diseases. But this is not so likely to occur if the mulch is applied late in the season when there is warm, sunny weather.

Pollinating.—The tomato grower should fully understand the function of the various parts of the flower. The green, starlike outer portion is the calyx and its separate parts are known as the sepals. Apparently, the only function of this organ, but a very important one, is to furnish protection to the young, tender buds. The yellow corollas, formed of separate parts called "petals," which in many flowers attract certain insects, do not seem to have any particular functional value in the culture of tomatoes, because bees refuse to visit them and thus to convey pollen from flower to flower. The stamens, the next set of organs, form a tube which incloses the pistil. They are the male portions of the flower, and the anthers, borne in a column surrounding the pistil, produce the pollen grains which fertilize the central or female organ, the pistil. The top of the pistil is called the stigma, and this is larger than the pedicle below, which is called the style. The base of the pistil is known as the ovary, which contains the ovules in which the seeds develop.

As the flower matures, the pistil elongates until it generally protrudes above the stamens. The minute, dust-like pollen grains then ripen and, under favorable atmospheric conditions, are discharged into the air, when some of them will lodge on and adhere to the sticky and moist stigma of the same flowers or of other flowers. If the house is properly heated, the pollen grains will germinate, and each produce a slender, threadlike tube that will pass down through the style to an ovule, and each ovule thus fertilized will develop into a seed.

If pollination does not occur, the flower withers and drops off. When only a few pollen grains germinate, the fruit is likely to be small, rough and lopsided. In other words, thorough pollination is essential to satisfactory crops. Numerous experiments and observations have been made to determine the effect of cross pollination and the influence of various degrees of pollination. Some of the most exhaustive studies were made by Fletcher and Gregg at the Michigan Experiment Station, who report as follows in Special Bulletin 39:

SUMMARY OF EXPERIMENTS

"1. The six varieties under experiment were Ignotum, Stirling Castle, Earliana, Best-of-All, Lorillard and Frogmore. The blossoms on four plants of each variety were self-pollinated, and the blossoms of eight plants of each variety were cross-pollinated with two other varieties. All set fruit equally well. The 265 fruits produced from self-pollination on all six varieties had an average weight of 77.3 grams. The 534 fruits produced from cross-pollination on all six varieties had an average weight of 79.1 grams.

"2. Four plants of each variety were used in an experiment to determine the effect of using varying amounts of pollen. All the flowers on one plant of each variety were emasculated and pollinated on one side of the stigma only. These invariably produced lopsided and small fruits. All the flowers of one plant of each variety were pollinated with from one to five pollen grains. These produced very small, solid fruits, with an average weight of but 34 grams and having no seeds, or but one or two. All of the flowers on one plant of each variety were pollinated with a large amount of pollen, spread all over the stigma. These produced fruits that were smoother and that averaged 12 grams heavier than fruits produced from flowers that had but a small amount of pollen applied all over the stigma.

CONCLUSIONS

"1. The results of the investigation indicate that it is not of primary importance to cross-pollinate any of the six varieties of forcing tomatoes used in these experiments, although it does no harm and may be a slight advantage in some cases.

"2. When pollen falls upon one side of the stigma only, a one-sided tomato always results. The larger the stigma the greater the irregularity.

"3. The amount of pollen applied to the stigma determines, to a great extent, the size and smoothness of the tomato; but after applying a certain amount of pollen no further increase in size or weight results by applying more. The small irregular tomatoes grown under glass are caused largely by insufficient pollination.

"Similar results, as regards the effect of insufficient pollination, were obtained by Bailey and Munson; and the conclusion that cross-pollination is not essential is supported by Troop, who found that Success tomato, when grown under glass, matured practically as many and as large tomatoes from self-pollination as from cross-pollination with Stone and Combination."

In the culture of tomatoes at midwinter, it is believed that light yields are due more to imperfect pollination than to any other factor. After March 15, when there is more sunshine and temperatures are higher and ventilation freer, the atmospheric conditions are more favorable for a full setting of fruit.

When tomatoes are grown out of doors, there is no need of artificial pollination. In the greenhouse, conditions are quite different and some assistance is needed, especially during the winter months.

The best results in hand pollination are obtained if the work is done when the sun is shining and the air of the house is as dry as possible. Ordinarily, from 10 to 12 o'clock in the morning is the best time of the day. Care should be exercised that the plants be as dry as possible at this time and also that the humidity be low.

Pollen is not discharged from the anthers, nor are the stigmas receptive to pollination until the flowers are well developed, a condition shown by the fully expanded petals.

Various methods of artificial pollination are employed and are effective under different conditions. The most thorough method is to collect the pollen grains in a shallow receptacle like a glass or a small ladle and then to pass from flower to flower. The receptacle, attached to a slender handle about 15 to 18 inches long, is held under the flower, which is tapped or jarred with a spatula or a small stick. If the flowers are sufficiently developed to be discharging pollen, a visible quantity of the grains will soon be collected, and then the operator proceeds from flower to flower, holding the ladle so that the stigmas of each pistil will come into contact with the pollen grains as each flower is tapped. The quantity of pollen gradually increases as the work proceeds. This seems like a very slow, tedious task, but the increased yields may more than pay for the expense involved. This method is especially desirable, because of its thoroughness, for use during the winter months.

Some growers pass from flower to flower with a camel's hair brush. Under favorable conditions sufficient pollen will adhere to the brush to make the method fairly effective, but it is not as thorough as when a shallow receptacle is used.

The commonest plan in pollinating for the spring crop is to jar the plants. This is generally done with a padded stick or perhaps a piece of rubber hose placed over a stick of convenient length. The stem of the plant should be tapped near the flowers which it is desired to pollenize. Growers who use a rigid wire trellis simply jar it at intervals of several feet. This plan results in heavy settings of fruit when English varieties are used, such as Comet and Peerless. When the jarring method is used the plants or trellises should have daily attention. Every other day is considered sufficient when each flower is separately pollinated.

Inasmuch as the earliest fruits command the highest prices, and weather conditions are usually most unfavorable for pollination, some growers hand pollinate each flower on the first cluster or two and then jar the plants to distribute the pollen for the balance of the crop. Varieties differ greatly in their ability to set a good crop of fruit. English varieties are especially profuse in the discharge of pollen.

Insects.—The white fly is the most serious enemy of greenhouse tomatoes. For description, life history and methods of control see page 120. The nematode is also a serious pest. (See page 116.) Red spiders (page 123) and the green aphis (page 119) sometimes make it necessary to use control measures.

Diseases.—General questions relating to the control of diseases affecting greenhouse crops are discussed in Chapters VI and VIII. The tomato has its full quota of diseases. Most of them are much more serious during the late fall and winter months. This is one of the chief reasons for growing them most largely as a spring crop. In the control of the various diseases affecting greenhouse tomatoes, the greatest reliance should be placed on preventive measures, such as soil sterilization, careful watering, proper ventilation and skillful fertilization. All diseased parts should be promptly removed if possible and destroyed.

Leaf mold (Cladosporium fulvum, Cooke) is considered the most serious disease of greenhouse tomatoes. It is likely to cause particular trouble during cool, cloudy weather. It appears first on the lower leaves as irregular yellow areas on the upper surface, while on the under side of these areas are found the olivaceous growth of the fungus. Leaves which are badly infected turn yellow and then wilt and die, so that the entire plant may be defoliated by the spread of the disease. If the infection appears soon after the plants are set in the beds, it is extremely difficult to prevent the loss of the entire crop. If the plants are not attacked until the fruit is set and well developed the loss may be very slight. Early and general infection invariably seriously interferes with nutrition, and results in a light crop of small fruits inferior in quality. The most thorough, early and repeated spraying of the upper and under surfaces of the leaves with bordeaux mixture is regarded as fairly effective in preventing serious ravages of the mold. It is exceedingly important to avoid working among the plants when they are wet, in order to prevent the spread of the fungus. If the disease becomes well established, no kind or amount of spraying will prove effective.

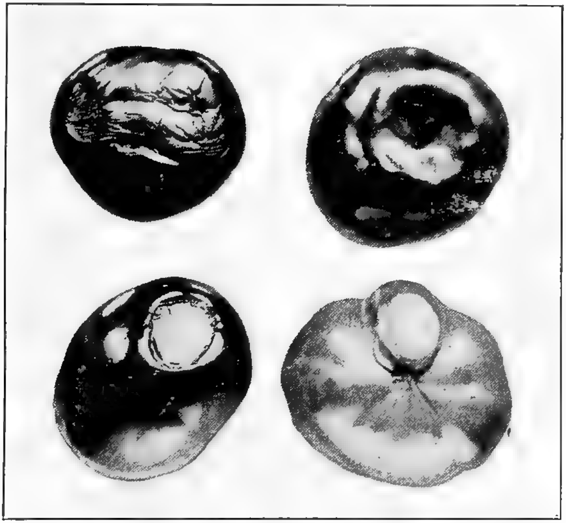

Fig. 93.—Blossom end rot of tomato.

Blossom-end rot is familiar to all growers of greenhouse tomatoes. The characteristic appearance of the affected fruit is shown in Fig. 93. The Ohio and other experiment stations have studied the causes of point rot and the means of preventing it, and there seems to be almost a consensus of opinion that the trouble will not appear to any considerable extent if the beds contain a constant and abundant supply of moisture. In this connection, Bulletin 214 of the Ohio Station contains the following statement: "It was stated in Bulletin 73 that this trouble was observed to be most destructive in cases of scant water supply in the soil. This observation was again confirmed by the horticultural department of the station during the season of 1899. The trouble was checked by abundant and careful watering, even when it had been very bad, and was again produced by withholding water and allowing the plants to dry out. The cause appears to be largely due to conditions of drouth, and while other causes than the one just stated, notably a certain bacterium, do join to produce point rot, none other appears so under control as water conditions. The remedy lies, of course, in the avoidance of drouth from which the rot may indirectly result."

Brooks, who conducted some studies at the New Hampshire station, reached conclusions which were different from the views of Selby and other investigators. He reports as follows in the October (1914) number of *Phytopathology:*

"1. The blossom-end rot of the tomato is not due primarily to bacteria or fungi.

"2. Plants are most susceptible when in a condition of great activity.

"3. Either continued excessive watering or a sudden check in the water supply may produce the disease.

"4. With liberally watered greenhouse plants potassium chloride increases the disease, and lime and sodium nitrate decrease it. These facts have not been found to hold true under field conditions.

"5. Ammonium sulphate, dried blood and cottonseed meal have increased the disease more than sodium nitrate containing an equivalent amount of nitrogen.

"6. Heavy applications of stable manure have increased the disease out of proportion to the increase in vigor of the plants.

"7. When well supplied with water plants on a sandy loam have developed less disease than those on a clay loam.

"8. Raising the soil temperature of greenhouse plants has increased the disease.

"9. The writer is of the opinion that the increase in the disease from heavy watering is due to the development of harmful humic and ammonium compounds and an accompanying decrease in nitrates.

"10. Susceptible tissue has more starch and more oil than normal tissue and its cell sap has a higher osmotic value.

"11. The protoplasm in the cells from the fruit of the heavily watered plants is more granular and contains more oil than that of the lightly watered ones."

Fig. 94.—A convenient picking basket.

Leaf spot or leaf blight (Septoria Lycopersici Speg.) sometimes attacks greenhouse tomatoes. It appears on the leaves as numerous oval or circular spots. The interior of the spots is light in color while the margins are dark. Bordeaux mixture is recommended for the control of this disease.

Alternavia solani (E and M) J and G, is another form of blight which is sometimes encountered in the culture of greenhouse tomatoes. Bordeaux mixture is apparently the best spray material to combat this disease.

Various other diseases, such as Fusarium wilt, anthracnose, mosaic or calico leaf and bacterial blight, are often found on greenhouse tomatoes, but the most important diseases are the Leaf Mold and Blossom-End Rot.

Fig. 95.—Each paper box holds six pounds of tomatoes, and eight boxes may be packed in a standard bushel box, such as is used in the Boston district.

Marketing.—Greenhouse tomatoes should not be harvested until they are well colored, because quality is invariably sacrificed if they are picked too green. If to be sold on a local market, there is no necessity for picking them before they are fully ripe. It is desirable to examine the plants at least three times a week in order to remove all specimens at the proper degree of ripeness. The fruits should be handled with great care, to avoid bruising, and it is customary to pick them with the calyx attached. Early in the forenoon is the preferable time for gathering the fruits because they are then cooler and more solid than at midday when the sun may be shining and the houses are very warm.

The fruits are wiped, if necessary, with a damp cloth and then graded. Rigid grading is absolutely necessary if a reputation for first-class fruit is desired. No. 1 or fancy grades should be free from very small, ill-shaped, cracked, bruised, spotted or otherwise defective specimens. Ordinarily there is no advantage in having more than two grades.

Fig. 96.—Tomatoes are sometimes wrapped and packed in the manner shown in this illustration.

A great many different kinds of packages (Figs. 95, 96, 97 and 98) are used for the handling of forced tomatoes. They vary in capacity from 4 to 25 pounds. Baskets similar in shape to those in which grapes are packed so extensively are most largely employed. The quantity commonly packed in a basket is 10 pounds, though 15 and 20-pound sizes are not unusual, especially for the spring crop, when prices are relatively low. Some growers use paper cartons of various descriptions. New England growers often pack eight paper boxes, each holding six pounds of fruit, in their standard bushel box, which may then be crated for shipment. The weighing of the tomatoes should be accurate, so that there can be no complaint on that account.

Winter tomatoes are always wrapped in paper unless they are sold on a local market. To insure safe transportation a common practice is to place a layer of excelsior in the bottom of the basket and also between layers of the fruit to prevent bruising. It is an advantage to place a layer or two of paper on top of the excelsior, before packing the tomatoes. Lids may be used or the baskets may be wrapped in paper and securely tied preparatory to shipment.

Yields and returns.—Yields of greenhouse tomatoes are extremely variable. Late fall and winter crops are the lightest and spring crops the heaviest. Two pounds per square foot is considered a satisfactory yield, though this amount is often exceeded. The following yields have been reported by prominent growers in the various sections indicated: An Irondequoit (N. Y.) grower averaged 12 pounds to the plant one season, with Peerless as a spring crop in a 30 by 180-foot house; seven rows in the house, 120 plants in each row, or 840 in the house, about 10 clusters on each plant, and an average of six tomatoes per cluster. This grower usually averages about 10 pounds to the plant. A Cleveland grower harvested

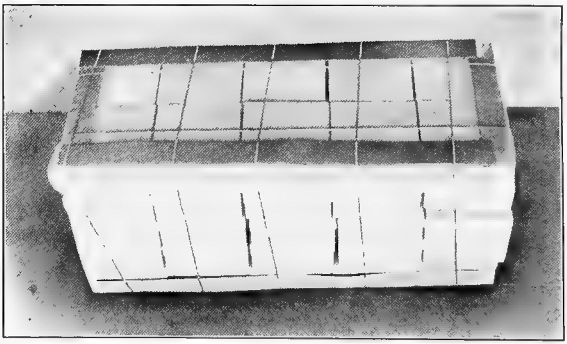

Fig. 97.—A unique way of packing a number of small boxes of tomatoes.

4,000 pounds of Globe and Magnus from 400 plants, 18 to 25 tomatoes to the plant. A New Castle (Pa.) grower averages about 10 pounds of Globe to the plant. A Boston grower picked 13,360 pounds of fruit from 1,670 plants set 15 inches by 3 feet. Eight pounds per plant were picked from 2,200 plants of Grand Rapids Forcing by a western grower. Five to seven pounds to the plant is a common yield of Comet, set 20 by 20, in the Kennett Square (Pa.) region.

Prices for greenhouse tomatoes vary from a few cents a pound to 40 cents or even more sometimes. The winter crop, of course, commands the highest prices. Perhaps 30 cents a pound is a fair average for the winter crop. The spring crop generally starts at about 15 cents, sometimes higher, the bulk being sold at 10 to 12 cents, and the last few pickings at 9 cents or less. Perhaps 11 cents a pound is a fair average wholesale price for the spring crop in most sections, covering a period of 10 years. The spring crop ought to produce over 20 cents per square foot of bed area.

Fig. 98.—The Boston bushel box, showing the upper tier of six-pound packages.

CHAPTER XVIII

CUCUMBER

History.—The cucumber has been grown under glass in the United States since the earliest days of vegetable forcing. The largest plantations during the decade of 1890 to 1900 were found in the Boston district, in which W. W. Rawson was the best-known grower. At first the long English type was cultivated, but American consumers have had a preference for the shorter cucumbers of the White Spine type, and the popularity of this class has been largely responsible for the development of the cucumber-forcing industry in other parts of the country, especially in the Central West.

Importance.—It is impossible to give a very definite idea of the importance of the cucumber as a forcing crop. In every vegetable-forcing district of the United States it occupies an important place. In the Boston district it ranks next to lettuce in commercial importance, and it is believed that it would rank second in importance if the entire country were considered. There is scarcely a large vegetable-forcing establishment anywhere in the United States that does not at some time or another grow cucumbers for market. If a crop requiring high temperatures is to be grown, either the cucumber or the tomato is generally selected. It is largely a matter of personal preference or of the demands of the markets to be supplied. See page 1 for more complete data regarding the history of vegetable forcing.

Season of culture.—The cucumber is a "warm" crop, which requires even higher temperatures than the tomato. Because of its demands for heat, this vegetable is most extensively grown as a spring crop. It generally follows lettuce, which occupies the beds until the arrival of bright,

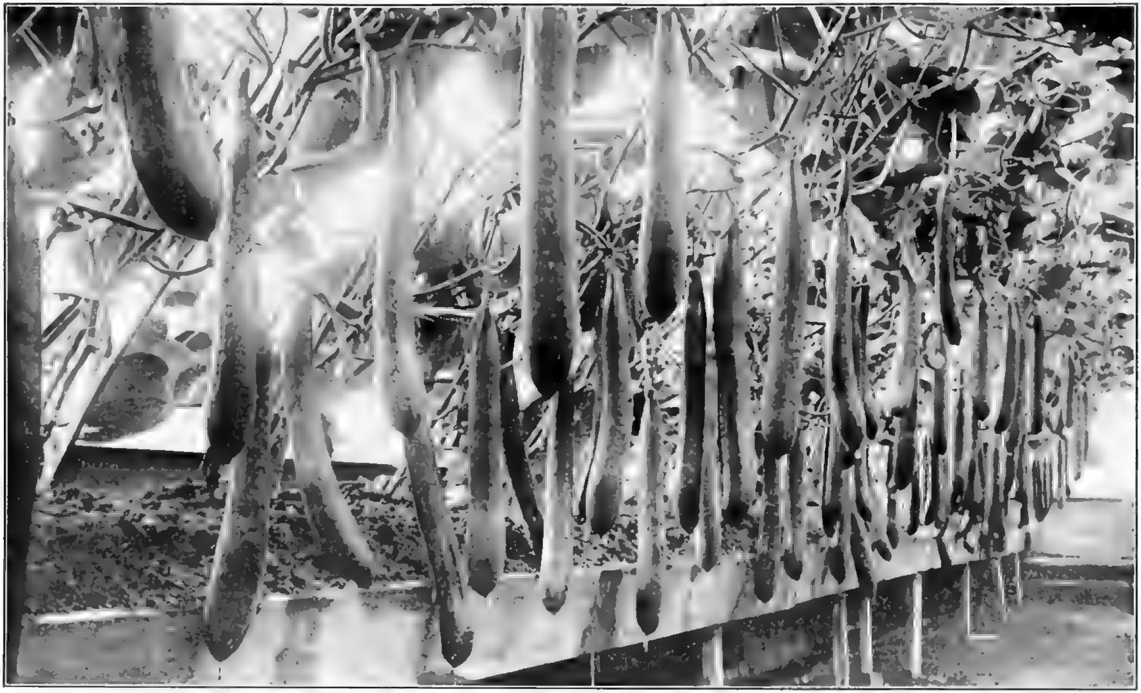

FIG. 99.—ENGLISH CUCUMBERS IN AN ENGLISH HOUSE.

sunny spring weather. When its culture is undertaken through the dull, cloudy weather of the fall and winter, the plants are more susceptible to disease and they grow much slower than during the spring. The yields, too, are much lighter in the winter season and more attention must be given to pollination than in the spring.

In fact the greatest precautions are necessary in the production of late fall and winter cucumbers, and only experienced growers should undertake their culture under such unfavorable conditions. Though the price for winter cucumbers may be four or five times that of the spring crop, the extra labor and the additional coal required generally make it difficult to realize a profit, and for this reason most greenhouse men prefer to grow lettuce until spring or late in the winter and then start cucumbers or tomatoes.

Ground beds vs. raised benches.—As stated on page 322 there is no question about the value of bottom heat, but this fact does not indicate that raised benches are preferable to ground beds for the forcing of the cucumber as a spring crop.

Experiments conducted by Waid at the Ohio Experiment Station show that raised benches produced the largest amount of early fruit, but ground beds the largest total yield. The results were as follows: Plants trained upright on 228 square feet of raised bench produced 655 firsts and 87 seconds previous to July 4. Plants trained upright on 228 square feet of ground bed produced 586 firsts and 67 seconds previous to July 4. The total yield of firsts and seconds from the raised benches was 748 and 144, respectively, and from the ground bed 824 firsts and 168 seconds. While arguments can be advanced in favor of growing cucumbers on raised benches, practically all growers prefer ground beds. The question of the influence of bottom heat is discussed on page 322.

Varieties.—There are two distinct types of cucumbers,

Fig. 100.
Good specimens of White Spine cucumber.

commonly known as the English (Fig. 99) and the American (Fig. 100). The English varieties are seldom grown out of doors. While they possess special merit in some respects for forcing, they have not met with general favor in this country. The quality of the fruit does not seem to appeal to our consumers. The plants are thrifty in growth; they develop thick stems and large leaves and are exceedingly prolific. The fruits vary in length from a foot to 2 feet or more, and individual specimens have been grown which weighed over 10 pounds, though this is more than double the size of normal English cucumbers. The green, cylindrical fruits contain few seeds. The American type, best represented by White Spine, is extensively grown in nearly all of our vegetable-forcing establishments. The plants are vigorous in growth, though not equal in this respect to those of the English class. The length of typical fruits is usually about three times their thickness, but the fruits of the various strains show marked variation in this particular.

English varieties.—The Telegraph, shown by the longest specimen in Fig. 101, is the best known and the most largely cultivated of the English varieties in this country.

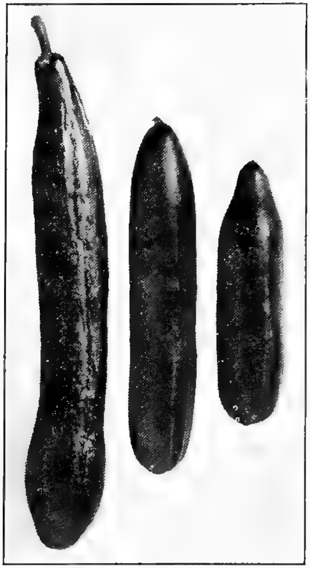

Fig. 101.—The long cucumber at the left is Engl sh Telegraph. The short one at the right is a strain of White Spine. The middle specimen is Abundance—a cross between the other two varieties.

In one of the fruits illustrated, 38 seeds were found and all of them were within 2 inches of the stem of the fruit. The seeds were slightly larger than those of American cucumbers. It was observed that the flesh between the seed cavity and the skin was about the same as in Davis Perfect, which is a cross between an English and an American variety, and the flesh was not as crisp as that of the latter class. Numerous varieties are described in English catalogues, but Telegraph is the only one that has received much attention in the United States.

American varieties.—There are two general classes of American cucumbers, which may be designated as "Dark Spine" and "White Spine." The Dark Spine is not suitable for forcing purposes; therefore all pure American forcing varieties or strains belong to the White Spine type. Some seedsmen simply use the term "White Spine" as a varietal name, while others apply such terms as Improved Arlington White Spine (Fig. 102), Arlington Extra White Spine, Perfection White Spine, Extra Long White Spine, Evergreen White Spine, Forcing White Spine, Improved White Spine Forcing, etc. Other names used for strains of White Spine are Hill's Forcing, Vickery's Forcing, Rawson's Hothouse (Fig. 103), New Emerald, Stokes's Hothouse Perfection and Bay State.

Markets differ in their requirements, but most of them prefer fruits which are fairly long and dark green in color. They should be uniform in diameter almost to the tip of each end (see Fig. 104), and the surface should be smooth and regular. When the fruits are ready to pick, the seeds should be poorly developed. The flesh should be crisp, tender and of the best flavor.

American English crosses.—As previously stated, the texture and flavor of English varieties appeal to comparatively few American consumers, though the long, green, cylindrical fruits are highly attractive in appearance.

Fig. 102.
Arlington White Spine cucumber.

The great vigor and prolificacy of English varieties have interested our greenhouse growers, and these factors, perhaps, have had the greatest influence in causing numerous crosses to be made between the two types. Most of the crosses have been very unsatisfactory. The plants have been thrifty and prolific, but the fruits, in most instances, have been too pointed or tapering and irregular in shape. However, there are some notable exceptions. One reason for the use of crosses is the fact that artificial pollination is not so essential as with pure American varieties.

Davis Perfect (Fig. 105), a cross, is largely grown. The plants are vigorous and productive, both the stems and leaves being very large. The fruits vary from about 6½ inches to 9 inches in length, the average being about 7½ inches, and the circumference in the middle about 7 inches.

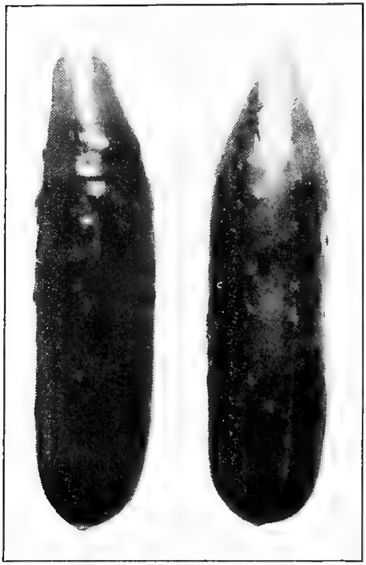

Fig. 103.—Rawson Hothouse cucumber.

The fruit is a trifle larger at the stem end. Although the name indicates perfection, this is not the case, for the fruits are too much curved and there is too much irregularity in size and shape. But it is regarded as a highly desirable and successful variety.

Abundance is a cross produced by Chauncey West of Irondequoit, N. Y. Fig. 106 shows the regularity of the fruits in size and shape. It is grown exclusively in the Irondequoit district and is gradually being introduced into other sections. This cucumber is in great demand in the Rochester and Buffalo markets. First-class specimens range from 8 to 10 inches in length, the average length being about 9 inches and the circumference 7 inches. The seeds are more numerous in the blossom end of the fruits than in fruits of the White Spine, but there are no developed seeds within about 5 inches of the stem end. The flesh is tender and crisp and of excellent quality.

Davis Perfect X Rawson Hothouse.—A grower in Western Pennsylvania, who usually plants about two acres of cucumbers under glass, has developed this cross, which he prefers in meeting the demands of local markets.

Seed.—No vegetable which is used in forcing is more influenced by the character of seed planted than the cucumber. Failures and disappointments are often traced to the use of inferior seed. They may be responsible for low yields, a large percentage of culls and serious losses from the depredations of diseases of various kinds. Cucumber growers cannot give this matter too much attention.

There need be practically no uncertainty about the ability of the seed to produce, under favorable conditions, a large crop of the finest specimens. Small plantings should be made of each lot of seeds in order to determine their merits before large areas are planted for commercial purposes. The adoption of such a policy will be certain to result in more uniform success from year to year.

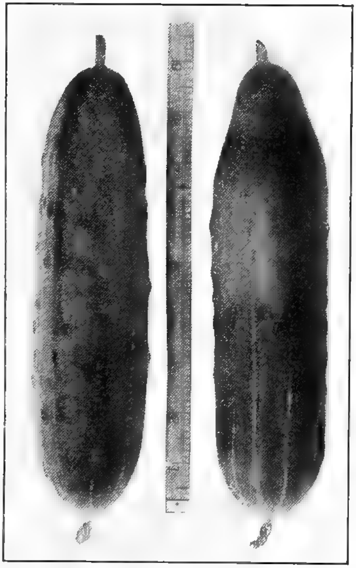

Fig. 104.—White Spine cucumber. The left specimen is of much better form at stem end.

Some of the seedsmen catalogue special forcing strains or varieties of cucumbers, and many of them are excellent. Most of the largest commercial growers prefer to produce and save their own seed. It is not unusual for them to have small houses (Fig. 107) in which the seed crop is grown. Vigorous, productive, disease-resistant plants are selected, on which the fruits are as uniform as possible in color, size and shape. The fruits should be thinned to five or six specimens on each plant. Fig. 108 shows some choice seed specimens of a Middle West grower. One hundred cucumbers of Abundance produced two pounds of seed. The fruits should be allowed to become thoroughly ripe before they are picked for seed. The

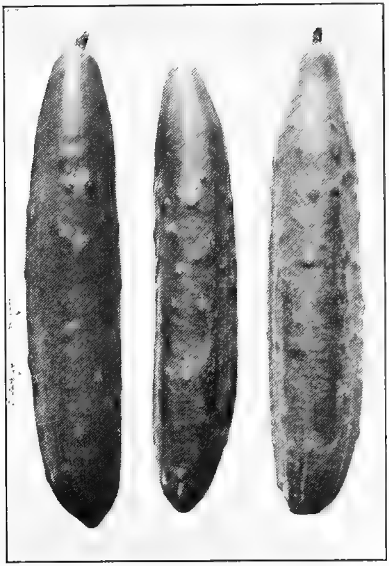

Fig. 105.—Davis Perfect from the originator.

seeds are easily separated from the pulp by washing. The plump, heavy seeds will settle to the bottom of the vessel and the pulp and light seeds will float, and may be poured off. The seed should be thoroughly dried after washing and then stored in a dry, warm room. The atmospheric conditions of any room in a residence provided with heat will be satisfactory for the storage of cucumber seed.

It has been conclusively demonstrated that cucumber seed should be at least two years old before it is planted, and some growers believe that even older seed is preferable. The seeds are usually viable even at seven years, and if properly preserved they will retain their vitality several years longer. New seeds produce the strongest stem and leaves, but old seeds yield the largest crops.

Starting the plants.—The time required from seed sowing until marketable fruit develops will depend on varieties planted, season of year and temperature of the house. Ordinarily, specimens of good size are obtained in from 70 to 90 days. The development of the crop is slowest during the dull, short days of the fall and winter, and most rapid during the long, bright sunny days of the spring and early summer. Seed sown the first of September should produce some specimens of marketable

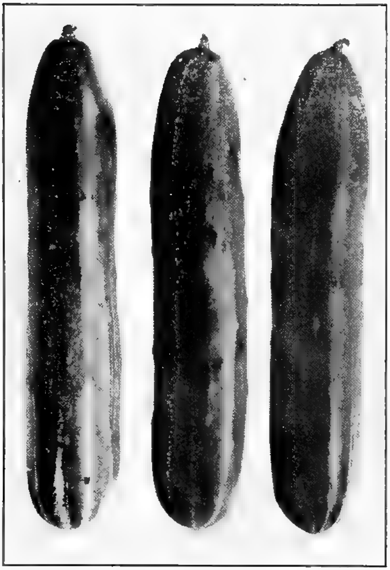
Fig. 106.—Abundance from the originator.

size early in November; there should be full pickings at Thanksgiving and a liberal supply for the Christmas market.

There is a wide variation in the time of starting the plants for the spring crop. A few growers sow about February 15. Many sow early in March, while some of the most successful greenhouse growers wait until the latter part of March, thus growing an extra crop of lettuce before cucumbers are planted in the beds. Then, too, later sowing not only saves time, but the plants are generally thriftier and probably more productive on account of higher temperatures and more sunshine. Nothing is gained by very early sowing unless a special market is to be supplied. If the houses are not adequately heated, it is especially important to defer sowing until March 1 or possibly March 15. Plants which have been started March 1 should be large enough to bench early in April, and in full bearing during the months of June and July.

Too much emphasis cannot be placed on the importance of growing good plants. The success of the crop depends largely upon setting in the beds strong, vigorous plants that have not been stunted, injured or checked in growth at any time. Such plants never fully recover, and they generally produce a large percentage of small, irregular cucumbers that grade as seconds or perhaps as

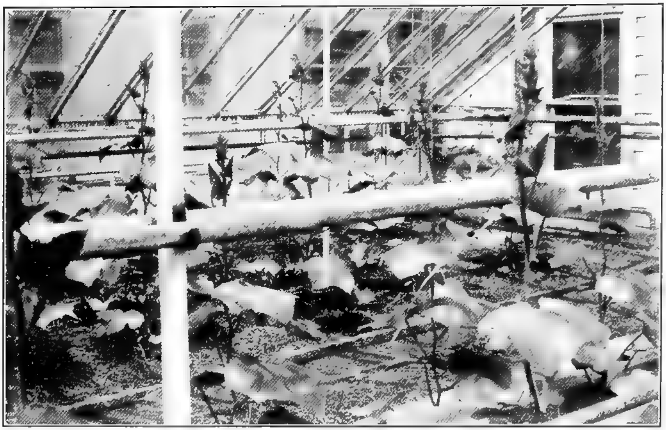

Fig. 107.—Cucumber seed production house.

culls. The young plants must be given the best care in every respect in order to avoid injuries which are certain to be disastrous to the crop. Very few greenhouse plants are so sensitive to ill treatment as is the cucumber.

The soil should contain a liberal proportion of sharp sand, if it is available, and plenty of decaying vegetable matter. It should be sterilized with steam, if necessary, to prevent the ravages of damping-off fungi.

Several methods are employed in starting the plants. The seed may be sown in the beds where the crop is to mature, but this is not economical in the use of greenhouse space.

Many successful growers sow in pots, which may vary in size from 3 to 6 inches. Some of the most extensive commercial growers contend that there is no advantage in using pots that are larger than 3½ inches. It is likely that 4-inch pots are used for this purpose more frequently than any other size. Ordinarily, several seeds are sown in each pot and the plants are thinned to one or two, according to the preference of the grower and the size of

Fig. 108.—Special White Spine cucumbers grown for seed.

the pots. It is not unusual for the seed to be sown in 2 or 2½-inch pots, the plants being shifted later to 3½ or 4-inch pots before they are set in the beds. They should not be entirely filled with soil; a little space at the top will facilitate watering. If they are placed on raised benches, they should stand on a layer of sand, sifted coal ashes or other material to prevent too rapid drying out. If additional precaution is considered necessary, the pots may be plunged in soil which is kept moist. It is an advantage to shift the plants once or twice before they are planted in the beds. Turning the pots, changing location of plants and allowing more space between the pots may be an advantage.

The commonest method is to sow the seed in beds or probably in flats. Many growers sow broadcast, so that the seeds are fairly close together. Others prefer to sow in rows, which vary from 1½ inches to 3 inches apart. Whatever the method, the seeds need not be more than barely covered with soil. One benefit in using flats is that they may be covered with glass which will protect the seed from mice, conserve the moisture in the seed bed and aid in providing a higher temperature for germination. In a week's time or less the seedlings will be up and should be promptly transplanted to pots of sizes previously indicated, berry baskets, or perhaps beds. (Fig. 109.) This work should be done with extreme care in order to avoid breaking the tender roots. If the flats or beds are watered a few hours before the seedlings are pricked out, there will be less breakage of the roots.

Excessive amounts of water applied to the young plants will cause them to become weak and spindling if accompanied by high temperatures and, under such conditions, there will be very poor development of the roots. Excessive watering and low temperatures will check the growth and stunt the plants. They seldom recover or

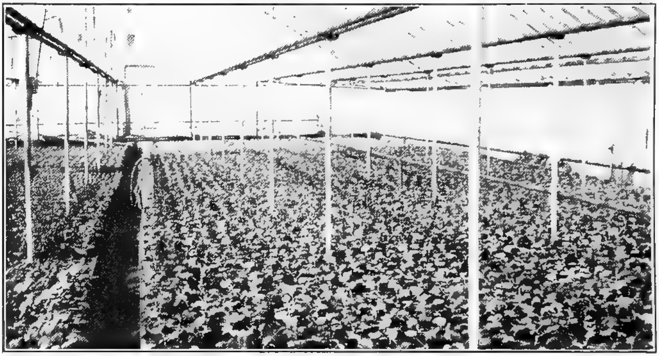

Fig. 109.—A cucumber nursery in the Boston district.

produce satisfactory crops. On the other hand, insufficient watering must be guarded against, for this also prevents proper development. Good judgment must be exercised in this the most important operation in the growing of good plants.

Young cucumber plants are easily injured by low temperatures. They demand a night temperature of at least 65 degrees, and 5 degrees higher is preferable. The day temperature, with ventilation, may range from 75 to 90 degrees. A fairly moist atmosphere is favorable

FIG. 110.—CUCUMBERS SHOWING UPRIGHT TRAINING.

to the young plants, and diseases may be guarded against to a considerable extent by spraying with bordeaux mixture. Insect pests should be controlled by the employment of proper measures. See page 337.

Soil.—Greenhouse cucumbers are grown in a great diversity of soil types. Most excellent results have been obtained in heavy soils, especially if they are well filled with organic matter. It is conceded, however, that the light, sandy types are the best for the growing of this vegetable, whether in the open or under glass. Apparently the most extensive root development occurs in sandy soils; and for various other reasons, which were discussed in Chapters III, V and VI, it is desirable to use the lighter soils, if they are available. Nevertheless, any soil which will produce a good crop of either leaf or head lettuce with proper management will yield a satisfactory crop of cucumbers.

Fertilizing.—The cucumber requires liberal feeding, in order to obtain heavy crops of first-class fruits. Satisfactory yields or profits are never realized from soils that are not well supplied with available plant food. A deficiency in this particular is certain to result in a large percentage of small, irregular fruits. Rapid growth from the date of sowing until the crop is harvested is essential to success.

All growers of greenhouse cucumbers depend mainly upon various kinds of animal manures as a source of plant food. Horse manure, fresh or partly decayed, is most generally employed. Cattle manure from city stockyards is used by some of the most prominent growers. It is fine in texture and easily applied. Pulverized sheep manure and poultry droppings are also excellent for this crop.

Organic fertilizers, such as dried blood, tankage and bone meal, are valued by growers who find it necessary to supplement insufficient applications of stable manures.

They may be applied in large amounts without danger of injuring the plants. For example, a well-known Illinois grower sometimes uses 20 pounds of bone meal for a row of cucumbers 100 feet long.

Fig. 111.—Cucumbers and narrow strips for their support.

Nitrate of soda, employed in small amounts as a top-dressing, may be an advantage. Acid phosphate and potash salts should be used sparingly and cautiously, for the tender roots of the cucumber are easily injured by chemicals. Whatever the kind or character of the fertilizer employed, applications seem to be most effective rather late in the development of the crop, after there is more or less exhaustion of the supply of plant food in the soil when the crop was planted. The same principle is involved in the application of manure mulches, page 315 which meet the food requirements of the plants when they are most in need of special nourishment.

Soil preparation.—The general directions of Chapters V and VI may be followed in the preparation of soils for the forcing of cucumbers. One of the most important considerations is to see that the bed is well supplied with organic matter. If stable manure has been used in large amounts for lettuce, it may be unnecessary to apply more manure immediately before planting cucumbers, especially if fresh horse manure is to be applied as a mulch after the plants have grown to a height of several feet.

Planting distances.—There are three distinct systems of training cucumbers, and the proper spacing of the plants in the beds will depend mainly on the plan to be followed.

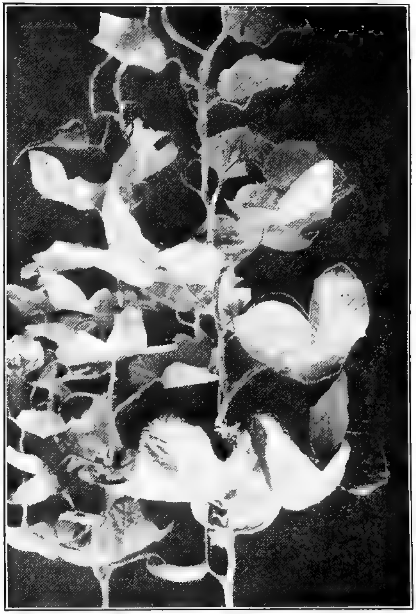

Fig. 112. — Single stem cucumber training. Note how the plant has been twined about the string.

When the upright system is used (Figs. 110, 111 and 112), the space between rows varies with different growers from 2 to 4½ feet, and the distance between plants in the rows ranges from 10 inches to 2 feet. A prominent Boston grower plants 2 by 4 feet apart, another 16 inches by 4 feet, and a third grower 12 inches by 4 feet, so that uniform planting distances are not followed in any particular forcing district. A grower at Cleveland, Ohio, plants 18 inches by 4 feet, one at New Castle, Pa., 15 inches by 4 feet, another at Erie, Pa., 2 feet by 3 feet, and another at Toledo, Ohio, 16 inches by 4 feet. When two plants are grown in each pot, the tendency is to allow more space between the pairs of plants, though the average distance between plants may be about the same as when they are planted singly. As with tomatoes, the spacing is more liberal than formerly. However, experiments made by Waid at the Ohio Experiment Station are favorable to close planting, as is shown by the following tables:

TABLE NO. 1

Table showing yield of cucumbers on raised bench

Distance Test

Plot No.	Sq. feet occupied	Distance apart set	Yield to July 4 Firsts No.	Yield to July 4 Seconds No.	Total yield Firsts No.	Total yield Seconds No.
1	114	Two by two feet	365	50	439	83
2	114	Rows two feet Plants 1 ft. in rows	342	54	395	93
3	114	Rows four feet Plants 1 ft. in rows	313	33	353	51

TABLE NO. 2

Table showing yield of cucumbers on ground bed

Distance Test

Plot No.	Sq. feet occupied	Distance apart set	Yield to July 4 Firsts No.	Yield to July 4 Seconds No.	Total yield Firsts No.	Total yield Seconds No.
1	114	Rows two feet Plants 1 ft. in row	329	37	467	88
2	114	Rows four feet Plants 1 ft. in rows	257	30	357	80

Waid, in the *Market Growers' Journal*, draws the following conclusions from the experiment:

"A careful study of the accompanying tables will show that, so far as this test is an indication of what may be expected, a larger yield per square foot can be secured by spacing the rows two feet apart than four feet when the plants are set one foot apart in the rows. Also that single plants set two feet apart each way will give a higher yield per square foot than any other distance of planting tried in this test. The thicker plantings not only gave the greatest total yield, but also gave the largest amount of early fruit. A comparison between the tables will show that the raised bench gave the most early fruit, but the ground bed gave the largest total yield."

When the A-form system of training (Fig. 113) is followed, the plants are set from 10 inches to 18 inches apart in the row, 12 inches to 14 inches being the most common distances. The distance between the rows under the trellis varies from 8 to 15 feet, and it is probable that nothing is gained by allowing more than 9 or 10 feet. It is unnecessary to allow more than a narrow walk between the rows outside of the trellises, though this will depend largely on the type of house construction and the width and arrangement of the beds.

The English class of cucumbers, and the crosses between the English and American types, are often trained upright with the trellis overhead, as illustrated in Figs. 114 and 115, which show the Abundance growing in a house at Irondequoit, N. Y. The plants in this house are 4 by 5 feet apart. Other plantings have done well at 3 by 5 feet and 4 by 4 feet apart.

Planting.—The time of planting in the beds will depend on the age and size of the plants and whether space is available. Poor markets or unfavorable conditions of the weather make it impossible sometimes to harvest the lettuce or other crops that precede the cucumbers as early as had been anticipated, when it may be necessary to hold the cucumbers longer than is good for the plants. The roots should not become pot-bound, nor should the plants become so large before they are transplanted that it is difficult to handle them without injuring the stems or leaves. It is best to set them in the beds before they are a foot high. The plants are generally placed in the beds before April 1, though it is not uncommon for planting to continue until May 1.

Great care should be exercised, in transplanting, not to break the balls of earth. The soil should be pressed closely and firmly about the roots, and the beds watered as soon as possible.

Watering.—The moisture conditions of both the soil and the atmosphere of the house demand the closest attention for the forcing of cucumbers. The large, succulent leaves, stems and fruits require a large amount of water, and any marked deficiency in humidity or soil

FIG. 113.—CUCUMBERS TRAINED ON A-FORM TRELLIS.

moisture may cause the wilting of the leaves or of the entire plant, with consequent reductions in the total yield as well as in the size and quality of the cucumbers.

The plants are benefited by syringing with water, especially during hot, sunny weather. This operation may be effected very quickly by producing a mist-like spray with the overhead system of irrigation. If there are reasons for not wetting the plants, the humidity may be increased by sprinkling the walks. A moist atmosphere is unquestionably of great importance in the forcing of this vegetable.

As previously stated, the beds should be watered as soon as possible after the plants are set out. This will cause the soil to settle about the balls of earth and roots from the pots, and thus help to exclude the air and to establish close relations between the moisture of the soil and the roots of the plants.

Unless the spring season is well advanced when the plants are set, large amounts of water will not be needed until they are 4 or 5 feet high, but from that time on profuse applications will be required to meet their needs. During the months of June and July it is practically impossible to apply too much water. The overhead system of watering is extensively employed in the growing of greenhouse cucumbers.

Cultivation.—It is desirable to cultivate the beds while the plants are small, but tillage after the soil is well filled with roots (and many of them are surface feeders) should not be advocated. Any damage to the roots, even by shallow tillage, is certain to impair the crop of cucumbers.

Mulching.—The advantages of mulching in the forcing of tomatoes were fully discussed on page 286. It is possible that the practice is not quite so general in the culture of cucumbers under glass, though a large percentage of the growers use mulches of some kind. As a rule fresh horse manure is employed, and a layer about 3 inches thick is placed on the beds after the plants have attained a height of several feet. The conservation of soil moisture and special nourishment of the plants are especially important when fruit formation and development are most active. As pointed out in the previous paragraph, many of the cucumber roots feed near the surface of the ground where they are easily injured by cultivation, and this is an additional reason for reducing the escape of soil moisture by means of mulches rather than by tillage. Very fine crops, however, are often grown without mulching, so that this operation cannot be regarded as absolutely essential to success.

Temperature.—The cucumber requires even more heat than the tomato, as explained on page 285, and it is extremely sensitive to sudden and repeated changes in temperature. Abnormally low temperatures, after the plants are set in the beds, will stunt or check the growth and render the plants more susceptible to the ravages of diseases.

There is a considerable difference of opinion concerning the proper night temperature, but most growers agree that it should not be lower than 65 degrees or higher than 70 degrees. Some growers who plant cucumbers for the spring crop in beds of lettuce, compromise in the heat requirements of the two crops by maintaining a night temperature of about 60 degrees, which is not ideal for either vegetable.

On dull, cloudy days the temperature should be only a few degrees higher than at night, otherwise the plant tissues will become succulent and tender and subject to disease, and the plants will be almost certain to wilt when bright sunshine causes a sudden and pronounced rise in the temperature, which cannot be fully controlled by means of ventilation. Ordinarily, the day temperature with sunshine should be from 80 to 85 degrees, or 15 degrees higher than the night temperature.

The temperature of the soil is a subject of interest among greenhouse growers of cucumbers. This topic was alluded to on page 302, in the discussion of ground beds vs. raised benches. It will be recalled that cucumbers are sometimes forced on raised benches. In New England, hot horse manure is sometimes placed in trenches in the greenhouse previous to setting potted plants, where it has much the same effect as when used in hotbeds.

The higher soil temperature thus secured is regarded as a decided advantage by some growers, especially for the winter crop, and the additional fertility must also have an influence on the growth of the plants. The increased expense, however, involved in the employment of this method should be carefully considered before one decides to follow it.

Moore of the Wisconsin Experiment Station conducted experiments for three seasons to determine the influence of bottom heat. Greenhouse benches, with various degrees of bottom heat, were employed. The results of these studies are summarized as follows in the 24th Annual Report of the Wisconsin station:

"1. That a soil temperature of approximately 74 degrees gives greater fruitfulness during the same length of time than temperatures ranging either much higher or much lower.

"2. That earliness of production is increased very little, if any, by the increase in soil temperature.

"3. That flower production is influenced only slightly, if any, by various degrees of soil temperature. Sunshine, atmospheric temperature, and individuality of plants are the important factors in this respect.

"4. That higher soil temperature shortens the fruiting period of the plants.

"5. That the advantages gained by higher soil temperature would not warrant the additional cost entailed in increasing it above that

FIG. 114.—ABUNDANCE CUCUMBER AND ARBOR FORM OF TRAINING.

which would usually exist under ordinary forcing conditions employed in growing this crop.

"6. That plants possess an individuality which has more to do with their behavior than the different treatments which would commonly be given in greenhouse operations. That this individuality shows itself in the form of plant, relative number of flowers and fruit produced, and rapidity of germination and growth. That better results can be obtained by using seed from the best individuals than by attempting to influence production by increased soil temperature."

Shading.—Shading is not considered necessary by all growers of the spring and early summer crop. Some of the most successful and extensive growers do not shade the houses. If wilting can be prevented by proper ventilation, sprinkling and watering, it is doubtful whether there is any special advantage in shading, except that the houses are more comfortable for the workmen. Shading, however, is practiced by some of the best growers, but applications of any kind should not be made to the glass until the season is well advanced and there is a real reason for reducing the temperature by this means. See page 36 for information on methods.

Ventilation is necessary to maintain the health and vigor of the plants. Inasmuch as the cucumber is very sensitive to drafts and extremes in temperature, the utmost care should be exercised in ventilating. The vents should be opened only a trifle in the morning, when the temperature has risen to almost 75 degrees, and later in the day they should be opened sufficiently to hold the temperature if possible at about 85 degrees. In the summer time the temperature often exceeds 85 degrees, but injuries seldom result if moisture conditions of the house and soil are properly controlled.

Training and pruning.—The systems of pruning and training the cucumber are not so distinct and well defined as are those used with the tomato. Growers in various parts of the country differ greatly in their ideas of training and pruning. Formerly, there was a disposition to do as little pruning as possible, and that of a haphazard nature. The English growers have exercised great care in this operation and, in recent years, American growers have more fully realized the advantages of systematic training and pruning. The agricultural experiment stations as well as many commercial growers have demonstrated the value of following a fairly well-defined plan. Unless the vine growth is limited by pruning, there is certain to be a large percentage of culls, and unless the plants are properly trimmed, there will be too much shading and too little circulation of air.

The labor item in keeping the plants well pruned is considerable, but if a promising market is expected, the expense of such labor is more than justifiable. Whatever the plan, the work should always be done with care and promptness. When the season is well advanced and the vines are becoming exhausted, and prices are materially lower, due to the outdoor crop, perhaps, too much time should not be spent in pruning. A leader here and there may be removed without much expenditure of time, and the results may be highly beneficial.

Four fairly distinct systems of training are used by American growers, namely, the fan or English system, the arbor system, the A form and the upright.

The fan system does not have many advocates in this country. It consists in growing a single stem to the height of about 18 inches, when the top is nipped, which induces the formation of a number of lateral branches, four or five of the strongest being selected to train over a wire trellis. In England the trellis generally runs parallel to the roof of the house, and if the house is narrow, it will extend to the ridge. The branches run out fan-shaped from the main stem and then they proceed to the top of the trellis, where they are nipped. The laterals of these leaders are cut back more or less and the cucumbers hang below the trellis. A certain amount of tying is necessary to secure the leaders to the wires of the trellis. This system of training is best adapted to varieties that are most vigorous in growth, such as the English type. It is necessary to set the plants 4 or 5 feet apart in order to have sufficient space to train up the branches.

The arbor (or modified upright) system of training is well illustrated in Figs. 114 and 115. With this system of training a single stem is grown until it reaches the wire arbor at a height of about 6 feet from the ground. The laterals of this stem are pinched just beyond the first female blossom, but, as a rule, not more than five or six cucumbers are allowed to develop below the trellis. After the main stem is pinched back, branches grow out in every direction and soon cover the trellis, forming an arbor with the cucumbers suspended below. A certain amount of pruning is then necessary to prevent too much vining. This system is especially well adapted to the Abundance or other American-English crosses. The main stem is supported by a string and the trellis is made of No. 16 wires, 6 inches apart, running through light strips placed at intervals of about 8 feet.

The A-form system is largely used in the United States. It is popular in New England and also in western forcing sections. The system as shown in Fig. 113 is considered highly satisfactory by many growers, especially in the amount of light and sunshine which each plant receives. The trellis may be made of wires placed about 10 inches apart, running through 2 by 4 scantlings, which are connected in the form of the letter A sufficiently close to give proper support to the wires and plants. Single-stem plants are trained over the trellis, by tying them as they reach each wire, until they reach the last wire, when the tops are nipped. All of the laterals are also nipped, usually just beyond the first female blossom. Secondary laterals may be allowed to develop if desired, but this is

FIG. 115.—ABUNDANCE CUCUMBER AND ARBOR FORM OF TRAINING. SEASON WELL ADVANCED.

not necessary to get a good crop of fruit. The cucumbers are easily harvested as they hang under the trellis.

The upright form of training (Figs. 110 and 112) is unquestionably the most popular system used in the United States. It provides for a single stem that may be trained only a few feet high, or it may be grown to a height of 8 feet or more. Ordinarily it is not more than 7 feet in height. Each lateral is generally pinched beyond the first node, where one or more fruits nearly always develop, and cucumbers are also borne along the main stem. Some growers allow considerable branching overhead, where the vines are supported by wires, and such branches produce fruit late in the season or during the latter period of harvesting. This plan is popular in the Boston district, where the rows run across the house instead of lengthwise. Wires are stretched overhead the full width of the house and fastened with screw hooks or perhaps secured to pipes. A few light wires which are above the heavier cross wires run lengthwise, thus forming a sort of trellis. Wires are also run across the beds at the ground, below the overhead cross wires, and they are secured to staples driven in the wooden side boards of the beds. Several-ply jute twine is stretched for each plant, between the lower and upper wires, and the plant as it grows is quickly twined about the string, no tying being necessary. This system of training is well adapted to the American type.

Some growers prefer not to allow the plants to branch at the top. This results in a more intensive system. For example, in one section of Massachusetts, where the houses are comparatively small and there are many of them, the plants are set, rather early in the fall, on raised beds with bottom heat. In some instances the plants are not permitted to attain a height of more than 4 feet.

The soil on the beds is about a foot deep and the plants are liberally fed with liquid manure to prevent them from becoming exhausted. With such an intensive system, and with soil that is fairly heavy, the fall-set plants are kept in bearing until June or July. The closest and most careful attention is required to accomplish this, and the system does not appeal to extensive growers of greenhouse cucumbers.

Fig. 111 represents a system of support devised by a prominent Toledo grower. A strip of wood ½ by 1 inch and about 7 feet long is placed beside each plant. A thin block 3 inches long is nailed onto the lower end to prevent the strip from sinking into the ground. The tops of the strips are secured to wires running lengthwise of the house. Pairs of nails are driven through the flat way of the strip at intervals of a foot apart and the nails are ½ inch apart. One nail is twice as long as the other, so that it can be bent at right angles. The stem of the cucumber is placed between the nails, and when the bent nail is turned until it rests upon the other nail, the stem is held securely in place without any tying.

Fig. 116.—Single stem training of cucumbers. Note location of male and female flowers and the small pickles.

Pollination.—The cucumber is monœcious, that is, the sexual organs, pistils

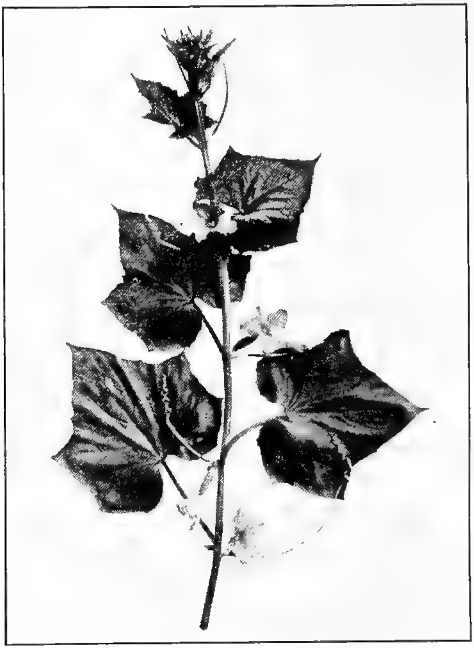

Fig. 117.—Branch of cucumber showing male and female flowers. The latter may be recognized by the miniature pickles.

and stamens, are borne in separate flowers on the same plant. Figs. 116 and 117 show that the flowers are axillary and that several flowers or pickles may be produced in the axil of the same leaf, whether it is on the main stem or an axillary branch, as illustrated in Fig. 116. This fact should be kept in mind when pruning, in order that no more cucumbers will be left on the vines than will attain large size. The female or pistillate flower is easily recognized by the ovary or tiny "pickle," as seen in both of these illustrations. The yellow corolla is somewhat larger than in the sterile flowers. The pistil is compound and the stigmas are two-lobed. The male or sterile flowers are much more numerous than the fertile flowers, and their stamens are more or less coherent.

When cucumbers are grown out of doors, bees and other insects carry the pollen from the male to the female flowers and thus fertilize them. In the greenhouse, bees must be kept, or the pollen transferred by hand, in order that the flowers may be pollenized. It is well known, however, that pollination is not always necessary in order to insure the development of fruit; but this statement applies more particularly to the pure English varieties rather than to American or American-English crosses. In this connection, Bailey, in Bulletin 31, Cornell station, makes the following statement:

"There is a question, however, if pollination is advisable in the house, for it is certain that the English cucumber will grow to perfection without seeds and entirely without the aid of pollen. I do not know if this is true of the common cucumbers, but we have made several unsuccessful efforts to grow Medium Green (Nichol's Medium Green) in the house without pollination. White Spine sets without pollen, apparently. In the early days of cucumber forcing hand pollination was practiced, but it has been abandoned by many growers. It is possible that the forcing cucumber sets more freely now without pollen than it did before its characters were well fixed, or perhaps the early gardeners performed an unnecessary labor. Many gardeners suppose that pollen causes the fruit to grow large at the end, and they therefore aim to produce seedless cucumbers for the double purpose of saving labor and of procuring straighter and more shapely fruits. For two winters we have performed many experiments upon these questions, but we are not yet able to make many definite statements concerning them. We have found, however, that it pays to pollinate by hand if early fruits are desired. The early flowers nearly always fail to set if pollen is withheld, but late flowers upon the same plant may set freely with no pollen. We follow the same method advised by Abercrombie and other writers of last century—pick off a staminate flower, strip back the corolla, and insert the column of anthers into a pistillate flower. Fruits which have set without pollination are uniformly seedless throughout, the walls of the ovules remaining loose and empty. Pollination does not occur when the fruits are left to themselves in the forcing house, especially in midwinter, when pollen-carrying insects are not present. Upon old plants we often prevent pollination, for experimental purposes, by tying together the flower tube, or occasionally by cutting off the flower bud altogether from the ovary or young cucumber, but this latter method is uncertain."

Whatever may be the practice of English growers with their favorite varieties, American greenhouse men have found it necessary to give close attention to the matter of pollination, whenever American varieties or crosses are employed. Unless the female flowers are fertilized they wither and fall off.

The pistillate or pollen-producing flowers are open only one day; they close in the evening and fall off a day or two later. The female flowers may remain open two or three days. They close as soon as fertilized and then the petals soon wither and drop.

The pollen grains may be transferred to the female flowers by the use of a camel's hair brush, or by taking the male flower and bringing the anthers into contact with the pistils, as previously explained. Both methods, however, are tedious and impracticable and require too much time for employment in commercial establishments.

American greenhouse growers of cucumbers rely almost wholly upon bees to carry the pollen from flower to flower. Formerly, apiaries were kept near the greenhouses, and growers depended on enough bees entering the houses through the ventilators to pollenize the flowers. But the plan was not thorough, and now hives of bees are placed in the houses or just outside, with panes of glass removed from the house at the hives. A great many bees fly from flower to flower, thus conveying the pollen, a plan which insures a heavy setting of fruit. A record was kept in one of the Boston sections of the sales of cucumbers fertilized by 61 hives of bees, and the average return for a colony was $815. Our American growers attach great importance to the part which the bee takes in producing large crops, and the matter demands the most careful consideration.

The number of bees or hives required for a given area depends upon the strength of the colonies. One strong colony with a prolific queen may do as much work as two or three weak ones. It is exceedingly important that an ample number of bees be provided, otherwise there will be a poor setting of fruit. Close observation of the bees at work, as well as the setting of the fruit from day to day, will enable one to determine whether all the flowers are being pollenized. There is much difference of opinion among growers concerning the number of hives required, but one strong colony for a house of average

Fig. 118.—Hive of bees at end of greenhouse.

width and 200 feet long should be adequate, though two colonies, one at each end of the house, would be more certain of providing the thorough pollination of all flowers. In very large establishments hives are usually placed at intervals throughout the houses, so that the bees will be well distributed.

Many growers, even with small ranges, prefer to keep the hives of bees inside the houses, and this is necessary if the bees must work before outside weather conditions are suitable for their comfort. The hives are generally at the ends of the houses, and they should be shaded to keep them as cool as possible.

Other growers keep the bees just outside the houses, as shown in Figs. 118 and 119. This plan is preferable from the standpoint of the bees, for the conditions, except when they are working in the houses, are normal and they keep in better health. If desired, there may be openings into the hives on two sides, so that the bees may enter the greenhouse where a pane of glass has been removed, or they may work on plants out of doors, which

Fig. 119.—Box containing several hives of bees.

has the effect of stimulating better health and greater activity. This plan is now followed by some of the most careful and successful growers, and especially by those who are interested in bees as well as in cucumbers. Bees should be placed in the houses as soon as the plants begin to blossom. The earliest fruits are the most profitable, and there should be no uncertainty about the flowers being properly fertilized.

The use of bees in cucumber houses is necessarily exhaustive to the insects. They naturally resent confinement and such abnormal conditions. The cucumber, too, though it supplies pollen which the bees gather, produces practically no nectar. Unless unusual care is exercised, the colonies soon become very weak and unfit for the performance of their important work in the forcing of cucumbers. Most of our commercial growers are not apiarists, and they have no interest in bees except as they are essential in the forcing of cucumbers. Such men do not devote more time to the bees than is absolutely necessary. They often prefer to buy new colonies every year, and then simply sacrifice them for the crop of cucumbers. In some sections, as around Boston, some apiarists make a business of producing bees mainly or perhaps especially for cucumber growers, and a good price is generally charged for the colonies. Pure Italian bees are considered the best workers, and they are also more docile and not so ill-tempered as common bees and crosses between the blacks and Italians.

The hives of bees should be placed in the houses during the night and the entrances opened the next morning. The bees will be very impatient for a few hours or perhaps a day or two, and some of them are always lost in their repeated attempts to escape by flying against the glass. If the ventilators are kept closed, or nearly so, for a couple of days, or until the bees have adjusted themselves to the new conditions, comparatively few will escape. It is unnecessary to screen the ventilator openings, for a large percentage of the bees that venture outside will find their way back to the hives. Placing the hives just outside the houses is a great advantage from this standpoint. An excellent plan when the weather is warm is to remove a pane or two of glass in the corners of the houses so that the bees can get out when they worry themselves by bumping against the glass. They will find their way back through the ventilator openings to the hives if they are placed outside the greenhouses.

Unless the colonies are well supplied with honey, it will be necessary to furnish additional feed, except when the colonies are outside and there is satisfactory bee pasturage in the neighborhood. The feed may consist of honey or sugar syrup. The bee needs a certain amount of water. Some growers think it is an advantage to keep water in a few crocks, with thin boards floating on the surface. By most growers it is believed that the bees get all the water they need without any special provision. Care should be exercised not to spray the plants when the bees are working for they are easily knocked to the ground and drowned. Early morning watering will usually avoid any trouble of this kind.

The bee moth is especially destructive to greenhouse colonies. The hives should be examined at frequent intervals and the larvæ of the moth removed before they have done much injury. Mice are also destructive to bees and the openings to the hives should be so small that mice cannot enter.

With fair treatment, a colony of bees kept inside will last at least 8 weeks, or long enough to pollenize a spring crop. If the colonies should become weak and inefficient at any time, new ones should be promptly substituted.

An additional argument for placing the hives outside the houses is that fumigation with tobacco or cyanide will not impair the health of the bees, as it certainly will unless the hives are removed at such times.

Intercropping.—The cucumber, on account of its large leaves and vigorous habit of growth, is not well adapted to companion cropping. However, lettuce and other vegetables are sometimes grown for a time with cucumber plants. For details, see Chapter XXI on systems of cropping.

Frame culture.—The cucumber is well adapted to frame culture and the crop is largely grown in frames of various descriptions. See page 400 for cultural directions.

Insect enemies.—Various insects feed on greenhouse cucumbers. One of the most serious pests is the red spider. Methods of control are discussed on page 123.

Unless preventive means are employed, the white fly often appears in such numbers as to inflict heavy losses. Either potassium or sodium cyanide gas may be used to check the ravages of this insect before its depredations have become serious. Full instructions for their use are given on page 109.

Interesting experiments were made by Stone and Thomas at the Massachusetts station, relative to the influence of various light intensities and soil moisture contents on the development and character of cucumber plant tissues. Plants which received the least light and the most water were soft and tender and much more susceptible to injury from hydrocyanic gas than were plants which received full light and normal amounts of water. The investigators emphasize the importance of noting the condition of the plants before proceeding to fumigate with cyanide. If cloudy weather and perhaps high temperatures have prevailed for a few days and the plants have been supplied with an abundance of moisture, the tissues will be soft and tender, and injuries will be much more likely to occur than when the fumigation follows several days of sunshine and normal conditions of heat, humidity and soil moisture. Growers will do well to consider these factors before fumigating their houses.

The nematode is regarded by most growers as one of the worst pests of greenhouse cucumbers. Sterilization with steam is the usual method of controlling this enemy. See page 116.

The aphis is also an enemy of greenhouse cucumbers. For methods of control, see page 119.

Fall and spring plants are often attacked by the common striped cucumber beetle. The adults deposit their eggs on the stems near or below the surface of the ground, where they hatch, and the tiny, transparent larvæ feed on the young roots and also bore into the stems of the plants. The young insects do much greater injury than the beetles. Serious attacks of this pest sometimes cause growers to believe that the plants are infected with bacterial wilt. Preventive measures are important in order to guard against losses from this pest. Cucumbers and melons should not be grown near the greenhouses, for the beetles usually enter the houses during the fall months and remain well protected in the soil until the spring crop of cucumbers is started. It is a difficult pest to destroy, and though numerous methods might be suggested they are not very satisfactory. The doors and ventilators should be kept closed, if possible, in the fall, when there is danger of large numbers of the insects entering the houses.

The squash bug or "stink bug" sometimes feeds on greenhouse cucumbers. The same preventive measures should be taken as suggested in the previous paragraph for the beetle. They inject a poisonous substance into the plants and also inoculate them with the dreaded disease, bacterial wilt. This well-known insect and its conspicuous eggs are easily seen and they should be removed and destroyed as soon as discovered. The sciara maggot, thrips, flea-hoppers and a few other insects of minor importance sometimes appear on greenhouse cucumbers.

Diseases and their control are discussed in Chapter VIII, and soil sterilization in Chapter VI. The directions in these chapters for the prevention and treatment of diseases affecting greenhouse vegetables apply to most of the cucumber diseases, so that a lengthy discussion here is unnecessary. All of the troubles to which the cucumber is subject when grown in the open may appear under glass. If the plants are not stunted or checked in growth at any time, they are not likely to become diseased.

Anthracnose *(Colletotrichum Lagenarium (Pass.), E. & H.)* is a fungous disease which attacks the cucumber and other cucurbits, appearing upon the leaves, stems and fruits. There are times when it becomes very troublesome in the greenhouse. Dead spots which are usually more than half an inch in diameter appear on the leaves, and elongated, discolored and shrunken areas occur on the stems. The attacks may become so serious as to kill the plants. Either copper sulphate or bordeaux mixture is valuable in checking the ravages of the disease. The dead vines at the close of the season should be promptly removed from the houses and burned, in order to prevent the further dissemination of the disease.

The different forms of "damping-off" fungi may attack greenhouse cucumbers. Bulletin 214, Ohio Experiment Station, says: "It is serious often where plantings are made following lettuce attacked by rosette. The fungus in that case is the same as lettuce rosette (Rhizoctonia) or lettuce drop (Sclerotinia). There is a strictly damping-off fungus (Pythium De Baryanum Hesse) that is sometimes troublesome. A species of the Botrytis fungus at times attacks pruned parts of cucumber plants, also extending its attacks to the blossom ends of young fruits. The results of Rhizoctonia on greenhouse cucumbers have been curious owing to attacks on the smaller root branches or rootlets. The growth of the vines is at times checked, accompanied by coloring of the leaves and reduced fruitfulness. Some growers have given the name 'leaf-curl' to this phenomenon, but it is strictly the effect of the fungus named. It has been found necessary in soil treatments where cucumbers follow affected lettuce to increase the strength of formalin drench to four or five pounds per 50 gallons of water."

Downy Mildew *(Peronoplasmopara Cubensis (B. & C.) Cl.)* is a fungous disease that attacks the leaves of cucumbers. The angular, yellowish spots are followed by the yellowing of the entire leaf and, if the infection is severe, the death of the plant may occur. The cucumbers on diseased plants are small and inferior in quality. Under favorable conditions the disease develops and spreads to other plants with marvelous rapidity. It is one of the most destructive enemies of greenhouse cucumbers. Insufficient light and sunshine, high temperatures and high humidity are the conditions which are most favorable to the rapid development and dissemination of this fungous trouble. Spraying with bordeaux mixture is valuable, but sanitary measures and the proper regulation of cultural conditions are most important.

Powdery Mildew *(Erysiphe Cichoracearum, D. C.)* is often destructive to greenhouse cucumbers when conditions of heat, light and moisture are favorable to the progress of the disease. This disease makes its appearance on the upper surface of the leaves, where the fungus produces a superficial growth which is powdery white in appearance. Severe attacks cause the plants to become sickly and finally to die. Bordeaux mixture, applied promptly and thoroughly, is valuable in checking the ravages of this disease.

A bacterial wilt *(Bacillus tracheiphilus, Smith)* is often found on greenhouse cucumbers. Most entomologists believe that the disease is transmitted by the cucumber beetle and the squash bug. The disease causes the plants to wilt as if they were suffering from the lack of water, and they finally die.

Another wilt *(Fusarium niveneum, Smith)* is also fairly common in the greenhouse. It is a fungus which works internally in the stem of the plant and finally closes water vessels, thus interfering with the functions of the stem, causing the plant to wilt and die. This disease is also transmitted by the cucumber beetle and squash bug, and war should be waged on these pests, not only for the damage which they may inflict by feeding, but also as transmitters of these two diseases. Spraying is of no value for either of the wilts. Infected plants should be pulled up and burned.

Greenhouse Mosaic Disease has been studied by Selby in Ohio. Concerning it he writes: "This disease is analagous in character to the mosaic disease of tobacco and tomatoes and to the yellows of the peach. It is due to an oxidizing ferment in the leaves and is transmitted like the tobacco mosaic disease, by touching first diseased and then healthy plants. The fruitfulness of these variegated yellow plants is very low, and it is best at all times, upon the appearance of the disease, to remove the diseased plants and destroy them."

Other diseases such as Leaf Spot, Pickle Spot, White Pickle or Mosaic may appear on plants growing under greenhouse conditions, but none of them should prove

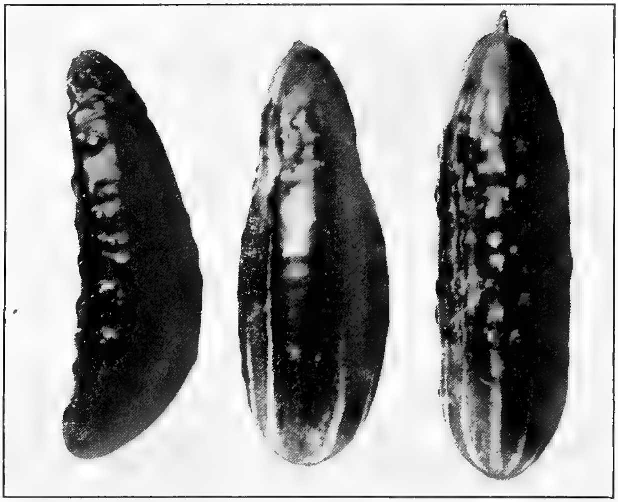

Fig. 120.—Three grades of cucumbers.

serious if proper sanitary measures are observed and if suitable cultural conditions are maintained.

Marketing.—After the fruits have reached marketable size, it is important to look over the plants at least three times a week so that every cucumber will be picked at the proper time. If they are left too long on the vines the seeds will become hard, which is objectionable from the consumer's viewpoint; the quality deteriorates and the color of the rind becomes lighter, a condition always objectionable to both dealers and consumers. Again, the plants become exhausted more rapidly if the seeds are allowed to develop to any considerable extent, and this in itself is an important reason for early harvesting.

The large markets demand from two to four grades. There can be no doubt concerning the advantages of careful grading. Fruits of practically the same size, shape and shade of color should be packed together. Three grades, besides the nubbins, which should be left at home unless there is a local demand for them, will be found very satisfactory. Fig. 120 will present an idea as to how the fruits should be graded.

There are many kinds of packages for the marketing of cucumbers. Barrels holding three or four bushels are employed by some of the Middle West growers. Fig. 121 shows some of the packed barrels covered with burlap. In the Boston section, the bushel box (Fig. 122) is the favorite package. It holds from seven to nine dozen cucumbers, the number depending upon the size of the fruits. The inside of the box may be lined with paper. When closed with strips or thin boards, it makes a very satisfactory package.

In some sections, crates holding four to five dozen fruits are employed. Baskets (Fig. 123) of the same kind and size as those used for packing lettuce are employed by many New York, Pennsylvania and Ohio growers. The baskets may be packed level full so that

FIG. 121.—CUCUMBERS PACKED IN BARRELS.

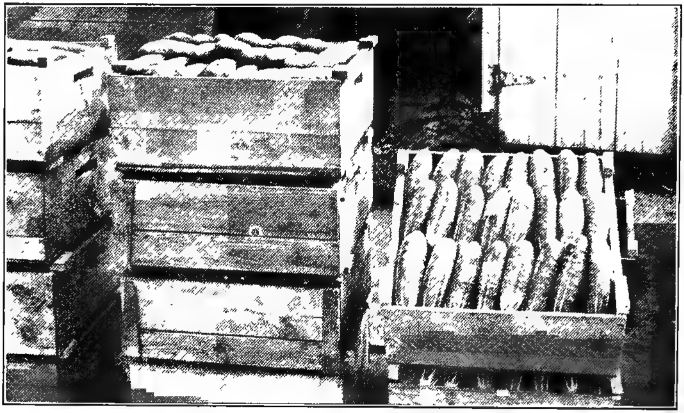

Fig. 122.—Cucumbers packed in bushel boxes.

they can be set on top of one another without danger of bruising the fruits. When wrapped with paper, the basket makes a pleasing and satisfactory package. A basket holds from 24 to 30 cucumbers, the number in each being marked on the handle.

Yields and returns.—There is the widest variation in the yields of greenhouse cucumbers. From 45 to 60 fruits to the plant are expected by most growers in the Boston district, though much larger numbers are often harvested. When a short season is planned and the growth is limited to a single stem with its axillary branches, 30 fruits to the plant is a good yield, especially if the plants are set close together.

With the arbor system of training, as employed at Rochester, N. Y., where the spacing is liberal, a single plant may produce 50 or more specimens. One house in this district containing 550 plants averaged nine dozen to the plant. Two thousand dozen cucumbers of the variety Abundance from a 30 by 180-foot house is considered a good yield in the Rochester district, and as many as 3,500 dozen have been harvested from this area. Very much depends upon the system of training, spacing, variety and duration of picking season.

Cucumbers during the winter season sometimes command $2 or more a dozen, but such prices cannot be obtained for a great length of time. As the spring season advances the prices decline until in June not more than $1 may be obtained, and a large part of the spring crop is generally sold during the summer at 50 cents or less per dozen. An average of 50 cents for the spring crop is considered fairly satisfactory. Growers are sometimes forced to sell large quantities at 25 to 40 cents a dozen.

Fig. 123.—Cucumbers packed in half-bushel basket.

CHAPTER XIX

MUSKMELON

Importance.—In England the muskmelon is one of the most important forcing crops, being grown on a large commercial scale both in frames and in greenhouses. It is produced most largely as a spring and an early summer crop. While the cool, dull, cloudy weather of England is not at all favorable to the culture of this vegetable, which revels in heat and sunshine, the English gardeners have become so skillful, and such excellent varieties have been developed, that they succeed in spite of adverse climatic conditions. Melons have been grown in the greenhouses of the wealthy in the United States for many years, and private gardeners in America have given much more attention to the crop than they did only a few years ago. A host of people are extremely fond of melons, and it is not surprising that private gardeners are urged to give the crop greater consideration. The quality of well-grown greenhouse melons cannot be equaled by melons produced out of doors under the very best conditions.

As a commercial proposition in the United States the industry has made very little progress. A greenhouse man here and there has tried small plantings, and sometimes with fair success, but they have not been sufficiently encouraged to plant large areas for market purposes. It is possible that our growers have not given the crop enough attention to fully understand and master every detail in its culture, as they have in the growing of lettuce, cucumbers and tomatoes. It is an acknowledged fact, however, that the melon is much more difficult to grow than the other crops just mentioned, and that fancy prices must be obtained in order to realize a profit. The statement is often made that greenhouse melons cannot be sold for less than $1 or perhaps $1.50 each and enable the grower even to meet expenses. Such prices certainly make melons class as a luxury and the demand for them is necessarily limited.

The melon, in its cultural requirements, is very similar to the cucumber, though much more exacting. The insect and fungous foes are also similar.

House.—A greenhouse which is suitable for the forcing of cucumbers will be found satisfactory for growing melons. It should be amply provided with heating pipes. It should be high enough to give room for the training of the plants. Inasmuch as the plants are extremely sensitive to cold drafts and sudden changes in temperature, small storm houses should be provided wherever there are outside doors that must be used. Melons are generally grown on raised benches provided with bottom heat, though the spring crop may be grown with entire success in solid ground beds. Some growers prefer boxes which may be placed on raised benches. A box 3½ feet long, 12 inches wide and 8 inches deep will hold three plants.

Varieties.—There are numerous English varieties and several American sorts that do well under glass. Among those which are most frequently mentioned are Sutton's Emerald Gem, Royal Jubilee, Superlative and Ringleader. There are three classes of melons according to color of flesh, namely, green-fleshed, scarlet-fleshed and white-fleshed. The green-fleshed sorts are considered the best in quality by some, and the scarlet-fleshed by others. Turner, in "Fruits and Vegetables Under Glass," makes the following classification: Green Flesh: Sutton's Ringleader, Best of All, Perfection, Sutton's Emerald Gem, Windsor Castle, Turner's Seedling, Royal Jubilee, Emerald Gem (American strain); Scarlet Flesh: Superlative, Sutton's A1, Sutton's Scarlet, Sutton's Triumph and Sutton's Invincible; White Flesh: Royal

Favorite, Hero of Lockinge and Buscot Park Hero. All of these varieties are recommended by Turner of New Jersey, who has had extended experience in forcing melons. Other varieties recommended by growers are Blenheim Orange, Rocky Ford and Paul Rose.

The utmost care should be exercised in procuring good seed. Some of the seedsmen, especially in England, make a specialty of producing pure strains of the leading varieties. Melons mix very readily in the greenhouse where two or more varieties are growing. If bees are flying from flower to flower, mixing is almost certain to occur, and it is unlikely that the seed from such crosses would produce satisfactory fruits. If only one variety is used and bees are not entering the houses from outside plantations, there is no reason why one should not save seed from plants which are giving the best results.

Starting plants.—Melons are started in the same way as cucumber plants. See page 308. Seed may be sown in pots, shifts being made as explained for the cucumber on page 310, or they may be sown in beds or flats and the seedlings pricked into pots or perhaps into beds, as shown in Fig. 109. Whatever the method, the growth of the plants must not be checked at any time, for such plants never recover and produce good crops. The night temperature should be from 70 to 75 degrees and the day temperature in bright weather 10 to 15 degrees higher.

Seed should be sown not later than September 1 if fruit is wanted for Christmas. December 15 is a satisfactory time to sow for spring harvesting and later sowings will produce early summer melons.

Soil.—While many of the finest field melons are produced on sandy soils, fairly heavy types of soil seem to give the best results in the forcing of this vegetable. Some of the best yields have been obtained in clay soils, though a moderate amount of sand mav be an advantage.

FIG. 124.—MUSKMELON GROWN AT THE NEW HAMPSHIRE EXPERIMENT STATION. NOTE THIN STRIPS OF WOOD WHICH SUPPORT THE FRUIT.

Fertilizing.—The fertilizer requirements of the melon and cucumber are very similar. Good melons cannot be grown in a soil that is not well provided with plant food. Although a fertile soil is essential, excessive fertility, especially in available nitrogen, must be avoided, since it will encourage a rank growth, and result in the production of low quality melons. In the preparation of the soil, one should endeavor to supply nutrients sufficient to cause a healthy, normal growth until the fruit is set, and then more liberal feeding should be practiced. Nitrogenous manures and fertilizers used in the preparation of the beds should not be employed in large amounts, if at all. Among such materials may be mentioned fresh horse manure, poultry droppings, sheep manure, nitrate of soda and dried blood. Well-decayed manures, particularly cow manure, may be used in large amounts without danger of disastrous results in any respect.

When the fruit is set, then more liberal feeding is required to insure the production of large melons and the development of high quality. A common practice is to employ at this stage liquid cow manure and to apply it as often as may be necessary. The frequency of the application will depend mainly on the fertility of the bed. Ordinarily, one or two applications a week will meet the needs of the plant.

Some growers prefer to apply chemical fertilizers after the fruit is set, for they claim that materials like the potash salts, acid phosphate and nitrate of soda produce melons of higher quality than does liquid cow manure. Wood ashes are sometimes employed as a top-dressing. Lime is also considered beneficial. If the roots appear in large numbers near the surface of the ground, a dressing of rich soil an inch deep will be found beneficial.

Soil preparation.—The English growers attach special importance to the use of old sods in the preparation of soil for melons. The sods may be several inches thick, composted for a month or more and then chopped up with a spade into small pieces. Sods and manure may be composted together, as discussed on page 72, and sods are often placed in the bottom of the beds before they are filled with properly prepared soil. While the soil should be firm and fairly compact, yet it must be open and porous. Melon roots revel in soils which abound in vegetable fiber, as provided by the use of chopped up sods and rotten manure, and the drainage conditions must be perfect. Because of the loose structure of soils prepared in the manner described, it is necessary to do more or less packing of the compost when the beds are filled.

Melons are planted at about the same distances as cucumbers. From 15 to 18 inches between plants, and the rows 30 to 36 inches apart, will be found satisfactory. Planting distances, however, will depend mainly on the system of training which is to be followed. The plants should be removed from the pots with care so that the balls of earth will not be broken.

Watering.—The melon requires an abundance of soil moisture, though over-watering must be avoided. It is desirable to have a liberal supply of moisture in the soil when the beds are planted and to add enough water after the plants are set to settle and compact the earth about the roots. After this operation no more water should be applied than is necessary to maintain normal, healthy growth until the fruits are formed, and then the plants will require more water. After the fruit has practically attained full size and the ripening process has begun, less water should be used, for a superabundance of water during the ripening period is detrimental to the flavor of the fruit. The wilting of the plants should not be permitted at any time.

The humidity of the house for melons seems to require about as much consideration as the moisture content of the soil. A high humidity is essential, except when the flowers are being pollenized and when the fruits are ripening. It is customary to sprinkle the walks two or three times a day in clear weather, and also to syringe or spray the plants with water when atmospheric conditions require such treatment. See notes on watering the cucumber, page 318.

Temperature.—The melon requires high and uniform temperatures, 70 to 75 degrees at night and 10 to 15 degrees higher by day in clear weather.

Training.—Anyone who understands the pruning and training of cucumbers (page 324) should have no difficulty in performing these operations with melon plants. Though various systems are employed, probably the best for American greenhouses is the single stem. (See Figs. 124 and 125.) That is, one stem is grown to the desired height—it may be erect—secured to a trellis, stake or string, or it may be trained over a trellis which runs parallel to the roof of the house. The fruits are borne on the laterals of the main stem, and the laterals are nipped just beyond the first leaf. A certain amount of thinning and pruning is necessary to remove surplus leaves and to prevent the growth of secondary branches. Some growers use divergent systems of training, as explained for cucumbers.

Pollinating.—The flowers of the muskmelon are monœcious. They require the same attention in pollinating as does the cucumber, though this operation should be given closer attention. (See page 329.) A camel's hair brush may be employed, but a plan more certain of success is to collect the pollen in any convenient receptacle and then to bring the pollen grains into direct contact with the stigma of the pistillate flower. Another approved plan for winter melons is to pluck a staminate flower, strip it of the corolla and bring the anthers into contact with the stigma of the flower to be pollenized.

FIG. 125.—MUSKMELONS GROWING IN AN ENGLISH HOUSE.

One male flower will serve to fertilize two or three female flowers, but since the male flowers are much more numerous, there is no need of economy in the use of the pollen. Both flowers should be fully expanded when this work is undertaken. A bright, sunny day is preferable, and, as previously stated, the humidity of the house should be comparatively low.

It is highly important to defer pollinating until four or five or perhaps more female flowers are ready to receive the pollen. If only one or two flowers are pollinated and no others have attention for 10 days or a week later, the first fruits will develop rapidly and those which follow will be small and of poor quality. If all the fruits on a given plant set at practically the same time there will be uniform development and no one specimen will be nourished more than another. When the melons attain considerable size they should be supported by a string net. Raffia is sometimes used to tie up the fruit, but nets are much more reliable.

Ventilation.—See notes on the ventilation of cucumber houses. Even greater care should be exercised in ventilating houses in which melons are being forced.

Insect enemies.—The red spider, green aphis, white fly, striped cucumber beetle, thrips and mealy bug are the most destructive pests. See notes on cucumber pests, page 337.

Diseases.—See diseases of cucumber, page 338. Powdery mildew and anthracnose are among the most serious troubles.

Yields and size of fruit.—Two good melons on a plant at midwinter is a satisfactory average. Some plants may have four or five and others none. An average of four or five in the spring is an excellent crop. The winter melons may not average in weight more than two pounds. An average of four or five pounds to the fruit is very good for the spring crop. Six and seven-pound specimens are fairly common, and occasionally eight to ten-pound melons are harvested, but the unusually large melons are generally inferior in quality.

Greenhouse melons ripen very quickly after they have attained full size. They change in color, emit a strong but most agreeable perfume and separate easily from the stem when they are ripe. The fruits should not be kept very long in a refrigerator for this will cause them to deteriorate rapidly in flavor.

When melons are shipped they should be unusually well protected with cotton, wool, excelsior, or other material to prevent bruising. It is safest to use crates provided with a separate receptacle for each fruit, in which it can be securely packed, so that there can be no bruising.

CHAPTER XX

MISCELLANEOUS VEGETABLES

Although the entire list of vegetables may be grown successfully under glass, not all of them yield satisfactory profits when forced for commercial purposes. The most important ones have been discussed in separate chapters. This volume, however, would not fulfill its purpose if it did not contain a chapter on the vegetables of minor importance as greenhouse crops. While the 20 vegetables considered in this chapter may never attain the commercial rank of any of the crops treated on previous pages, yet some of them are making gradual gains as business propositions, and all receive more or less attention in the greenhouses of private establishments. Of the 20 vegetables which will be discussed in this chapter, only three —the bean, the eggplant and the pepper—can be classed as warm plants, requiring comparatively high temperatures day and night. The others may properly be called cool plants because of their relatively small heat requirements. The entire list of miscellaneous vegetables will be discussed in alphabetical order.

BEAN

The bean is well adapted to greenhouse culture, but the financial returns do not seem to justify the planting of large areas. Occasionally an entire house is planted with this vegetable, but it does not occupy an important place in the operations of greenhouse growers in any part of the United States. In England, where climatic conditions are radically different, the forcing of beans is a profitable enterprise. It is not unusual for them to sell in the London market at Christmas for 75 cents to $1 a pound. Early summer beans may retail for 10 cents a pound. The demand for forced beans in this country may increase rapidly when more of our wealthy consumers learn of the superior quality of the greenhouse product. Under the controlled conditions of the greenhouse, the plants grow rapidly and produce large, tender pods with a most delicious flavor.

Beans may be grown under glass throughout the forcing season. It is possible to start the first crop in September or October and by successive sowings at intervals of 10 days or two weeks make continuous pickings until midsummer of the following year. Any time after March 1 is the most popular time for planting in the United States. The large amount of sunshine at this season of the year is most favorable to the rapid growth of the plants. Success will be even more certain if planting is deferred until April or May.

A common practice in England is to force beans in pots not less than 6 inches in diameter. Both pots and boxes of various sizes are used in the United States. Most of our growers prefer benches containing soil 6 to 8 inches deep with heating pipes underneath. Bottom heat is absolutely necessary for beans during the winter months, for they refuse to make a satisfactory growth in cool soils.

When the spring is well advanced, the seed may be planted in solid ground beds, for the soil will then be warm enough to insure rapid growth. The bean requires all the light and sunshine that can be provided. It cannot thrive if planted in the shade of walls, pipes or other plants.

Numerous varieties are grown under glass. Some growers prefer the bush class, while others grow the pole sorts. Whatever the variety or class, the plants should make a rapid growth, come into bearing early and produce heavy crops of long, straight, symmetrical pods.

Both wax-podded and green-podded varieties are grown under glass. English varieties are most generally recommended.

Of the American bush beans, Black Valentine seems to be well adapted to forcing. An Indiana grower has obtained good results with the Long Yellow Six Weeks, which, with bottom heat, produced pods of edible size in six weeks. A Tennessee grower is enthusiastic concerning a pole variety of local origin, supposed to be a cross between Kentucky Wonder and the Brown.

Fig. 126.—Pole beans growing in an English house.

Of the dwarf English varieties, Sutton's Forcing, Osborn's Forcing, Ne Plus Ultra and Canadian Wonder are most popular. English climbing or pole varieties (Fig. 126) recommended are Princess of Wales, Veitchi Climbing French, King's Earliest of All and Wonder of France.

Bush beans are generally planted 12 to 15 inches apart in rows about 18 inches apart, two or three beans at a place. If preferred, the beans may be planted in small pots and then shifted to larger ones when the roots become crowded. A common practice is to plant in 4-inch pots and then to shift to the beds or benches. One plant of a pole bean in each place seems to produce a larger crop than two plants. The pole varieties may be supported by trellises, twine or light stakes.

In general, greenhouse beans require about the same cultural conditions as the cucumber. The soil must be rich, but it should not contain an excessive supply of quickly available nitrogen. Fresh stable manures should never be employed and rotten manures should be well mixed with the soil. Liquid cow manure is applied by some growers after the pods are formed.

A night temperature of 60 degrees will do, but 5 to 10 degrees higher will give better results, and the day temperature should range between 70 and 80 degrees. Careful ventilation is necessary. Sufficient water should be applied to keep the soil moist, and a moist atmosphere is also desirable. When the plants are flowering, a fairly dry atmosphere will aid the self-fertile flowers to set a good number of pods.

The red spider, the aphis and the white fly are the most serious pests of the bean when grown as a forcing crop.

Growers cannot count on more than two or three pickings from greenhouse plants. The pods may be tied in bundles of 25 to 50 for marketing, or the spring crop can be sold in bulk.

BEET

The beet is grown in greenhouses, to a limited extent, both for greens and for the roots. The soil should be rich and friable. Temperatures which are suitable for lettuce will meet the requirements of the beet, though it grows more rapidly at higher temperatures.

For the fall crop, it is common to sow in drills 10 inches to a foot apart, and to thin the plants to 2 or 3 inches apart. If space is an important consideration, it is more economical to sow the seed in beds or flats, and then prick out the seedlings into beds on the ground or on raised benches. The beet is sometimes used as a companion crop with tomatoes and cucumbers. Early varieties, such as Egyptian, are the most satisfactory for greenhouse culture.

CARROT

The carrot requires about the same cultural conditions as the radish, except that a larger percentage of sand is needed to grow smooth, regular roots. The small-topped, early Short Horn type is the best for forcing purposes. The seed may be planted in rows 6 inches apart and the plants thinned to an inch apart. Sowings made at intervals of three weeks will give a succession of roots. It does best as a spring crop, though with bottom heat it may be grown with entire success at midwinter.

CHINESE CABBAGE

Some attempts have been made to grow Pe Tsai or Chinese cabbage (Fig. 127) under glass, but with only fair success. It seems to rebel against the artificial conditions of the greenhouse. There is no difficulty in growing the plants for several weeks, but specimens of good size tip burn very easily unless unusual precautions are taken. The transpiration of water from the large, fleshy leaves is so rapid that the roots cannot supply moisture as rapidly as it is lost from the leaves, and tip burning necessarily results. It is thought that a very rich soil and low temperatures for about 5 weeks would cause the formation of an extensive root system,

Fig. 127.—Chinese cabbage.

which, with rather copious watering after that period, would prevent the breaking down of the tips of the leaves.

According to experiments made by Hepler at the University of Wisconsin, 12 to 16 weeks are required to grow Chinese cabbage to marketable size. It is possible that special strains of this interesting salad plant could be developed which would thrive well under glass. The trouble is that Pe Tsai was never accustomed to greenhouses in old China.

CRESS

Water cress *(Nasturtium officinale)* is one of the easiest crops to grow in the greenhouse. A small planting of it is always desirable in private establishments, and commercial places, which are located near markets that are not regularly supplied with cress from outdoor sources, find sale for a limited quantity.

Water cress may be propagated from seed or cuttings. The usual plan in the greenhouse is to use cuttings which root very quickly in moist sand. The plants may then be shifted to flats and later to the permanent beds. Bottom heat is unnecessary. In fact, the plant does better in soil that is rather cool. The supply of soil moisture should be abundant and constant. Water cress may be grown under benches where there is fairly good light, or in any kind of a bed or a box provided with proper conditions. When well established, it will renew itself and require little attention, except watering.

CELERY

Celery is not regarded in any part of the country as an important forcing crop. It is possible, however, to grow good celery under greenhouse conditions, and the difficulties involved are probably no greater than in the production of some other crops—the melon, for example. Whether celery forcing will ever become an important commercial industry is extremely doubtful. A grower here and there is fairly optimistic concerning the outlook, but as a financial proposition there is not very much encouragement in the results of even the most successful greenhouse growers. In general, it may be said that celery requires practically the same conditions as lettuce, though it is far more exacting in its requirements of heat and moisture.

Market opportunities seem to be best during the months of April, May and June, or after the stored supply has become exhausted. To mature the crop at that time, the seed should be sown the latter part of November or early in December.

The so-called self-blanching varieties have been almost universally employed and recommended for forcing.

Bailey, more than 25 years ago, found the Kalamazoo to be one of the best varieties for culture under glass, and it is still recommended by practical growers. A few gardeners speak enthusiastically of White Plume, but Thorne found that it had a marked tendency to "bolt" or produce seed stalks. He also found that Golden Self-Blanching was a slow grower and subject to heart rot. Of the varieties tested by Thorne, Snow White gave the best results. A prominent greenhouse grower at New Castle, Pa., has had the best success with green varieties. Though they are more difficult to blanch, the product is of much higher quality than that of self-blanching varieties.

The small plants grow very slowly. Seed sown December 1 will produce plants large enough for the first transplanting by January 1, when they should be set about 3 inches apart in flats or beds. In five or six weeks from transplanting they will be ready for the permanent beds, which should be on the ground rather than on benches. The plants should be large enough to market seven or eight weeks later.

There is a difference of opinion among growers as to the most desirable distances for planting. The tendency is to use the "new celery" culture plan, and set the plants 6 inches by 6 inches or 7 inches by 7 inches apart. Others claim better results by allowing 15 inches or 16 inches between rows, and by placing the plants about 4 inches apart in the rows. The latter plan is probably best for green varieties.

Celery requires an abundant supply of moisture throughout the period of growth. A deficiency of moisture at any time is likely to prove disastrous. Excessively high or very low temperatures are also decidedly objectionable, for either condition may cause a large percentage of the plants to produce seed shoots.

it is desired to force the crop. A few coils of pipe will provide the required amount of heat for this hardy plant.

EGGPLANT

It is a simple matter to grow the eggplant under glass. For many years it has been forced in private establishments, and it has attracted attention occasionally for its business possibilities. The spring crop—the fruits being harvested during the months of May, June and July—seems to be the most promising as a business venture, largely because weather conditions at this season are more favorable for the production of a crop that requires plenty of sunshine.

Any of the varieties may be grown under glass, but the large, purple-fruited type is the most desirable. New York Improved is probably one of the best varieties for greenhouse culture.

In the spring of the year a little more time is required from seed sowing to ripened fruit than is needed for the tomato. Seed sown February 1 should produce plants in full bearing in June.

The plants require a large amount of heat, fully as much as cucumbers, throughout the period of growth. Night temperatures should never be below 65 degrees and day temperatures with sunshine may run up to 80 degrees or higher if the ventilators are open. Cold drafts and sudden changes in temperature should be carefully avoided, for unchecked growth is one of the most important factors in producing a successful crop.

The seed may be sown in flats or in a warm bed, and in about four weeks the plants should be set in 2½-inch pots. As soon as the pots become well filled with roots the plants should be shifted to 4 or 5-inch pots and later to the beds, space between plants being 2 feet apart each way. Raised benches with bottom heat should be used for winter forcing, but the spring crop does very well in solid ground beds.

The soil for eggplants should be sandy if possible and well enriched with rotten manure. This plant makes the most rapid growth and produces the largest fruits when the soil is filled with decaying vegetable matter.

The eggplant does not need a large amount of water. It thrives best when the soil is only fairly moist.

No trimming or tying is necessary, but the pollination of the flowers must have careful attention. The fruits set without being fertilized, but they never develop to edible size. Hand pollination, as explained for melons, page 352, is most thorough and unquestionably the best method for winter eggplants, but bees (page 332) are satisfactory for the spring crop.

The eggplant is subject to the attack of most of the greenhouse insect pests, and only constant vigilance will prevent serious injuries.

KOHL-RABI

A few greenhouse growers have tried kohl-rabi (Fig. 129), and some report that the profits are at least fairly satisfactory. The plants are started in the same way as cabbage. Seed may be sown in beds or flats and the plants at three or four weeks of age pricked into flats. A month later they will be ready for the ground beds, or the raised benches. Six to 8 inches between plants will provide space for the development of good roots. White Vienna is an excellent forcing variety. The tender stems are of the highest quality.

MINTS

The different kinds of mint, especially sage and spearmint, are easily grown in greenhouses which provide about the same conditions of heat and moisture as are

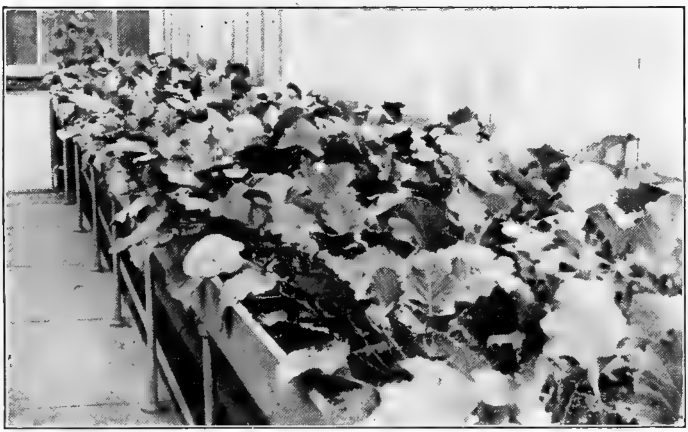

Fig. 129.—Kohl-rabi at the Ohio State University.

required for lettuce. If desired, special plants may be grown in the open and transferred to the house in the fall. The demand for mint is very limited.

MUSTARD

Mustard is grown under glass, to a limited extent, for salad purposes and also for greens. Chinese, a broad-leafed variety well adapted to greenhouse culture, will make more herbage than any other variety. The most economical use of space is to start the plants in flats and transplant seedlings of large size into beds where the crop is to be grown. The plants may be set 6 to 8 inches apart. Mustard requires practically the same cultural conditions as lettuce.

ONION

The onion is forced to some extent for commercial purposes. It requires the same conditions of heat and moisture as lettuce, though it is more hardy. Sets of any of the varieties may be used for forcing, but the Egyptian or Top onion is most generally employed. It is an extremely hardy onion that endures the hardest freezing.

An Ohio grower describes his method as follows in the *Market Growers' Journal:*

"I plant the largest sets I can get in the open ground early in September, 2 inches deep, 4 or 5 inches apart in the row, and the rows 14 or 15 inches apart. These will make a nice growth before cold weather sets in and winter nicely without protection. I cultivate the following summer just as any other garden crop, and harvest the sets during July or August. After the top sets have been harvested we cut the old stem off about 1 inch below the surface of the ground. This leaves the ground level and ready for the mulching which is the secret of long green onions for bunching. We cover the entire surface with coarse manure 4 or 5 inches deep, just as it comes from the livery stable. We are careful that no heavy bunches of manure lie directly on the row. Within a few weeks the onions are through the mulch and make a number of long, green shoots from 3/8 to 5/8 of an inch in thickness and from 12 to 20 in number. Roots and all are harvested in the late fall just before hard freezing sets in, and stored in any protected place.

"We use unoccupied coldframes and pack as closely as the onions can be set, with a little earth between the rows, packed well against the roots. This gives us access to them at any time in the winter. We begin forcing about December 1 by placing them under our propagating benches in the greenhouse, always in a perpendicular position to avoid having them grow crooked. We allow about three weeks for the first setting to grow a new top and to be ready for our market. Toward spring, less time is required for them to attain marketable size. They grow so rapidly when placed in a house that only a few can be put in at one time. We put in new stock each day when we take out any for sale."

Sometimes the garden beds of sets are heavily mulched during the winter, dug early in the spring and taken to the greenhouse for forcing. Another plan is to plant the top sets in August or early in September. Before the ground freezes late in the fall the sets are dug and heeled in close together in a cool shed, from which they are taken as wanted to the greenhouse and planted in the beds. Whatever kind of sets or bulbs may be used, they should be planted very close together in order to obtain a heavy and profitable crop. It is also desirable to plant deep so as to produce long, well-blanched stems.

PARSLEY

There is always some demand for parsley. The leaves are tied in small bunches, which generally retail at about 5 cents a bunch. Plants for forcing purposes are grown in the open ground from seed sown early in the spring. The seed should be sown in drills and the seedlings thinned to stand not less than 10 inches apart, if strong plants are desired. In the fall of the year, any time before there is hard freezing, the plants are cut back to the crown and the roots planted in the greenhouse. If conditions of heat and moisture are provided which would be suitable for lettuce, new leaves will soon develop and these may be cut from week to week until the plants are exhausted. The plants are easily grown from seed sown in the greenhouse early in the fall. Any of the curly-leafed varieties may be used for forcing.

PEA

The pea is not a profitable forcing crop, though it is easily grown under glass. The early, dwarf varieties are preferred for forcing. Nott's Excelsior is a dwarf, wrinkled variety of superior quality and it is probable that this variety would thrive just as well under glass as the smooth, extremely early sorts. The soil should be deep and rich. A large proportion of rotten manure is valuable in securing a full crop.

The distance between rows will depend on the space requirement of the variety planted. Under greenhouse conditions, 12 to 15 inches between rows should provide ample space for dwarf varieties, especially if they are well supported by wires or by some other means. Peas should have a night temperature of 40 to 50 degrees and a day temperature of 55 to 60 degrees. The plants are very sensitive to heat and no attempt should be made to continue the crop after April 1. They grow better in solid ground beds than on raised benches, and plenty of water must be supplied during the entire period of forcing. The forcing of peas is seldom undertaken in commercial establishments.

PEPPER

The pepper is not forced to any considerable extent in either commercial or private establishments. The fruit of this vegetable stands shipment much better than the tomato, so that southern competition prevents the development of pepper forcing in the North. However, it is not a difficult crop to grow under glass. The plants are started in the same manner as tomatoes, and then shifted from 3 or 4-inch pots to the beds where the crop is to mature. The distance between plants in the beds should be determined by the space requirements of the variety selected. A foot between plants in the row is generally space enough for them, and the rows need not be more than 18 inches apart. Experiments at Cornell University seemed to indicate that the plants grow best at temperatures slightly lower than those required for melons and cucumbers, though excellent results were obtained in the same houses. The plants produced marketable specimens in 3½ months from seed sowing. Sweet Mountain was the favorite variety in the Cornell experiments. It is important to force pure strains of the best sweet-fruited sorts. Artificial pollination, according to the Cornell observations, is unnecessary.

SEA KALE

Sea kale is an important forcing crop in European countries. It is grown under glass to some extent in this country, and it would seem that the vegetable should have greater consideration by those who are endeavoring to diversify their operations.

The plants are readily propagated from seed or root cuttings. Root cuttings are preferred by some growers, but, for the production of crowns for forcing, seed is entirely satisfactory. Two seasons are required to grow the strongest forcing roots. The seed should be sown in rich soil as early in the spring as the ground can be worked. The drills should be about 2 feet apart and the plants thinned to stand at intervals of 6 to 8 inches. A vigorous growth should be encouraged. The following spring the plants should be transplanted 3 by 3 feet apart into soil of high fertility.

Special feeding as provided by a manure mulch or dressings of nitrate of soda will be found beneficial. The seed stalks should be removed whenever they appear. Any house which provides suitable temperatures for lettuce will meet the requirements of sea kale. The plants may be forced under greenhouse benches, in mushroom houses and other inexpensive structures, such as were described on page 195 for the forcing of rhubarb. The crowns are set as close together as possible, in the dark if desired, with fine soil filling all spaces between the roots. Sufficient water is applied to keep the soil moist. The crisp, tender leaves are picked whenever they attain a length of 4 to 6 inches. When the plants are lifted in the field at the end of the second season, the crown buds should be cut out to prevent the plants from producing seed.

SPINACH

There is some inclination among the greenhouse growers of the United States to commercialize the forcing of spinach. For example, Waid calls attention, in the *Market Growers' Journal,* to a Grand Rapids grower who has been producing spinach under glass for several years and who has found the crop as profitable at 10 cents a pound as lettuce. A bed at Grand Rapids, 15 by 150 feet in area, yields in a single crop from 1,500 to 2,000 pounds of spinach, which is sold for $1.25 to $1.50 a bushel of 15 pounds. The weight of the crop from a given area is about the same as for lettuce.

A number of varieties have been suggested for forcing. The vigorous, broad-leafed sorts seem to be most popular. Victoria and New Zealand are recommended, and the latter variety is of special merit. Spinach seed germinates very slowly, and time and space may be saved by soaking the seed before it is sown. An excellent plan is to mix it with moist sand and place it in a covered dish which is kept over warm pipes for a week or 10 days, when the seeds will start to sprout and should then be sown. It is important to note in this connection that spinach is easily transplanted. There is no reason why the plants cannot be started in flats or beds in the same manner as lettuce and then set in the beds where the crop is to mature. The best planting distances have not been determined, but it is probable that the rows should be 8 to 10 inches apart.

Spinach requires the same cultural treatment as lettuce. High temperatures should be avoided. The beds should be kept moist, and the surface cultivated when necessary. There should be no shortage in plant food at any time. Applications of nitrate of soda will prove beneficial unless the soil is well supplied with nitrogen. Rapid growth is essential to high quality.

SWISS CHARD

Swiss chard is popular as greens, which offers possibilities for greenhouse culture. It requires practically the same treatment as lettuce. The seed may be sown in drills where the crop will be matured, or time and space may be saved by starting the plants in flats in the same manner as lettuce. High fertility and an abundant moisture supply are essential to heavy yields and good quality. The leaves may be picked whenever they have attained the size desired, and new ones will continue to grow out from the heart of the plant during the entire forcing season. Lucullus is one of the best-known varieties. Large plants in the garden may be cut back in the fall and transferred to the greenhouse beds. It is likely, however, that younger plants will give better results for midwinter forcing.

TURNIP

It is a simple proposition to grow turnips in greenhouses where conditions are suitable for the forcing of lettuce. Early varieties should be employed. The drills should be 8 to 10 inches apart and the plants thinned to about 2 inches. Turnip tops are sometimes grown for greens from large roots planted close together. The leaves should be blanched in order to secure the highest quality. Leaves of edible size may be grown in three weeks.

WITLOOF CHICORY

This vegetable is one of the most important salad crops of France, Belgium and England. It is variously known as witloof chicory, French endive and English endive. Perhaps the most appropriate name is witloof chicory, because it is a development of the common chicory.

Until the great European war broke out in 1914, thousands of baskets were imported every year from France and Belgium to the United States. Since that time and on account of transportation difficulties and the scarcity of the product, American gardeners have become more interested in the crop and some of them are making it an important factor in their operations. Wholesale prices in this country previous to the war probably averaged from 25 to 30 cents a pound, while more than double this price has been obtained since the supply has been so greatly decreased.

There can be no doubt concerning the superior merits of witloof chicory as a salad plant. It does not appeal to all alike, but most people are very fond of the vegetable and do not need to cultivate a taste for it. The heads or shoots (Fig. 130) are creamy white in color, extremely tender, crisp, delicate and agreeable in flavor. Though it is generally used as a salad, seasoning and flavoring it in any manner that may be desired, the heads may also be cooked before they are served.

Fig. 130.—Witloof chicory.

There can be no question about this vegetable affording opportunities to the commercial growers of the United States. Our markets are poorly supplied, and the demand, as the vegetable becomes better known, will increase. Many of the American gardeners have probably thought that there was something peculiarly difficult or mysterious about the culture of witloof chicory, but we have learned that the crop is no more difficult to grow than many other vegetables which receive our attention and contribute to our earnings.

The roots for forcing are grown in the open. The soil should be deep, rich and moist, but well drained. Any soil which will grow good parsnips will produce good witloof roots. Liberal amounts of rotten manure (fresh manure should never be used) are valuable in growing large roots, and large roots are necessary for growing large heads. Small, crooked, inferior roots never produce a first-class product.

Care should be exercised in buying seed. If ordinary chicory seed is obtained, the results will be most disappointing. A pure forcing strain is essential to success. If the seed is sown too early in the spring, a large percentage of the plants may go to seed, and the roots of such plants will not do for forcing. Again, roots started too early in the spring do not seem to possess the vitality of younger roots. While the seed may be sown any time during the month of May, there is evidence that just as good and perhaps better roots may be grown from seed sown about June 1, or even a week or two later.

The rows should not be closer than 15 inches, and 18 inches between rows in rich soil will give better results. If the crop is to be cultivated with a horse, not less than 28 inches should be allowed between rows. Some growers advocate thinning the plants to stand 6 to 8 inches apart, but this seems to be more space than is really needed to grow large roots, especially if the soil is fertile. If the plants stand at intervals of 4 to 5 inches, the results should be highly satisfactory. The crop should have thorough tillage throughout the summer and early fall. The plants are just as easy to grow as are parsnips.

The roots should be dug as late as possible in the fall, but before the ground is frozen. The tops are cut back within an inch of the crowns and the roots are then stored in a cool shed, frame or cellar where they can be kept fairly moist and perfectly dormant. Storage conditions which are suitable for asparagus roots (page 182) will be satisfactory for withloof roots.

Witloof chicory may be forced under greenhouse benches, in cheaply constructed houses, as explained for rhubarb and asparagus, in cellars and in out-of-door trenches. A temperature of 50 to 60 degrees will meet the requirements of the crop. Higher temperatures cause the growth of long shoots, and the total weight of the crop will be less than when it is grown at lower temperatures.

The roots, of course, may vary considerably in size. This necessitates grading them according to size before they are planted. In deep, rich soils some of the roots will be nearly a foot long, while others may be not more than half that length. It is best to make about four grades. Each grade is also cut to an approximately uniform length. That is, the slender tips are cut off so as to make each grade of roots about the same length; the crowns will then be on the same level when the roots are placed in the beds.

The roots may be taken from storage at any time from late fall until spring. In order to secure a succession of heads or shoots, new plantings should be made every week or two. An inch or two of soil is placed in the bottom of the bed. The roots are then arranged to stand erect. (Fig. 131.) There is some difference of opinion as to the spacing of the roots, but there can be no serious objection to placing them so close together that they almost touch. It is likely that the best results will be obtained if each root is completely surrounded with moist soil or sand. This is easily sifted between them as the planting proceeds.

In order to blanch the shoots or heads and to make them grow compact, as shown in Fig. 130, it is necessary

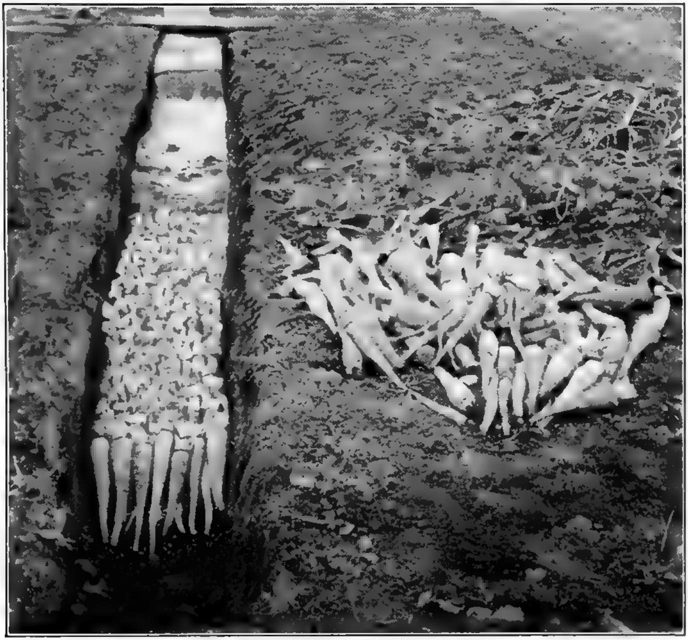

Fig. 131.—Planting witloof chicory in trenches.

to cover the crowns with fine soil, sand or sawdust. Sand is probably the favorite material. For the early crop this need not be more than 4 or 5 inches deep, but ordinarily from 6 to 8 inches of sand should be placed over the crowns, after they have had a thorough soaking with water. One or two additional waterings may be needed, or several waterings if the evaporation of moisture from the beds is very rapid. If there are comparatively high temperatures, shoots may appear at the surface of the sand in two weeks, when they are ready to cut, though three to four weeks are usually required.

Most excellent witloof may be grown in out-of-door trenches. They should be about 18 inches deep and 15 inches wide. The roots are planted as explained, and covered with sand in the usual manner. Heat is provided by covering the trench with 2 feet of hot horse manure, which should extend about 1½ feet on either side of the trench. With this method, about a month is required for the shoots to grow through 8 inches of sand.

If desired, the trenches may be dug in the fall, the roots planted at once and the hot manure used at any time during the winter. In this instance, the trenched roots should be covered sufficiently with manure in the fall to prevent hard freezing.

When a crop sells at 25 cents or more a pound, special care should be exercised in preparing it for market. Though most of the French and Belgian product is shipped in 20-pound baskets, smaller packages would be an advantage, especially when the crop is selling at very high prices. It would seem that pound lots, wrapped in paraffined paper and packed in small baskets, would appeal to dealers as well as to consumers.

CHAPTER XXI

SYSTEMS OF CROPPING

Necessity of intensive methods.—The student who has followed the discussions of previous chapters has doubtless observed that vegetable forcing is a most intensive type of horticulture. It calls for large expenditures of capital and labor upon relatively small areas. The investment on one acre of land may be greater than on a farm of 100 acres.

The first cost of the land is a small factor. But the range of houses with its equipment of boilers, heating pipes, water lines, packing room, etc., may represent thousands of dollars, though it may be a mere garden patch in size. Furthermore, we must bear in mind that the cropping operations themselves are far more expensive than similar lines of work in the field or garden. Every need of the crop must be met by the employment of artificial methods. Large amounts of fuel must be consumed annually. Even the water must frequently be paid for, in addition to the labor involved in applying it. Temperatures must be regulated and the ventilators operated as often as may be necessary. It is necessary to maintain the highest fertility of the soil, and sometimes to sterilize it in order to prevent diseases or insects pests from gaining the upper hand. Some of the vegetables require special attention in the way of pruning, training, pollinating and spraying. The houses require more or less attention annually in order to keep them in good repair, and the interest on the investment and the depreciation in the value of the range and equipment must also have consideration.

An enumeration of the foregoing factors is given not with a view to discouraging any one, but they should be seriously considered before launching into the business of vegetable forcing. They call for the exercise of sound judgment and the application of dependable knowledge relating to the various problems of greenhouse cropping. But the chief motive in calling attention to them here is to emphasize the fact that the most intensive cropping plans must be employed in greenhouse management if maximum profits are to be realized. Certain expenses are constant, regardless of whether houses are handled poorly or skillfully. The interest on the investment, cost of maintaining the buildings, cost of fuel, water, manure, fertilizer, tools, labor, etc., remain fairly constant.

Now, the all important question to the grower is, how can he make every foot of ground yield maximum profits? All of the problems relating to the production of various crops, which have been discussed in previous chapters, should have the most careful consideration. But attention must also be given to the whole matter of cropping plans. What crop or crops should be grown? Will one vegetable, grown throughout the forcing season, pay the largest earnings, or will it be more profitable to grow two or more different classes of vegetables? Should the crops follow one another in close succession, or will it pay best to practice companion cropping? These are some of the questions which will be discussed in this chapter.

Selection of crops.—A number of factors should be taken into account in deciding upon the crops to be grown. Among them may be mentioned the following as being the most important:

(1) Demand. There is always a great demand for lettuce, cucumbers and tomatoes, although prices are at times low. Generally speaking, it is best to grow the vegetables which are most largely consumed, though there are many exceptions. It is possible, sometimes, to work up a good trade for a special crop, as witloof

chicory, for example. But the question of demand should be carefully considered before planting any crop.

(2) Character of the houses. Low, poorly constructed houses would not do at all for winter cucumbers or tomatoes, while they might give at least fair results when planted with lettuce or radishes.

(3) Character of the soil. This is not so much of a factor as might be supposed, unless one desires to grow head lettuce, when the soil should contain a large percentage of sand. Any good agricultural soil may be made to yield profitable greenhouse crops, but the lighter types are preferred.

(4) Ease with which the crop may be grown. Some crops are much more difficult to grow than others. It would be folly for an inexperienced grower to make any attempt to produce melons under glass. As experience is gained, the more difficult crops may be tried and, if desired, they may be grown at midwinter, when the greatest skill is required.

(5) Labor supply. Some crops require more work than others. Winter cucumbers or tomatoes, for instance, require far more attention than lettuce.

(6) Personal preference. Farmers succeed best with the class of livestock which they like the best, and growers of greenhouse vegetables obtain the best results from crops which appeal to them the most.

Single cropping.—It is unnecessary to enter into a lengthy discussion here of the disadvantages of a one-crop system of farming, whether in the open or under glass. It is never economical in the utilization of the applied or natural sources of fertility, and fungous and insect pests are likely to be much more destructive than when a rotation of crops is followed. When one crop is grown from early fall until August 15 of the following year, advantage cannot be taken of differences in light and temperature due to seasonal changes. Not one of the vegetables is adapted to culture under glass throughout the forcing period. This factor in itself is a strong argument in favor of growing more than one crop. It is not unusual, however, to find a grower, operating in a comparatively small establishment, growing one crop, often tomatoes or cucumbers, for 10 or 11 months of the year.

Succession cropping is popular with a majority of American greenhouse growers. At least 90 per cent of them believe that the largest profits may be realized by growing either two or three crops. Lettuce is the favorite crop during the late fall and winter, when there is so much dull, cloudy weather. Tomatoes and cucumbers generally do well early in the fall, but they are much more successful in the spring and early summer.

Succession cropping plans.—The following are the most important succession cropping plans for the entire forcing season, beginning September 1 and continuing until August 15 of the next year:

(1) Three or four crops of lettuce followed by cucumbers.

(2) Three or four crops of lettuce followed by tomatoes.

(3) One crop of tomatoes or cucumbers, one or two crops of lettuce and one crop of tomatoes or cucumbers.

Various other plans of succession cropping are less common. Among them may be mentioned the following: Lettuce, cauliflower and tomatoes or cucumbers; cauliflower, radish and tomatoes or cucumbers; radish, two crops lettuce and tomatoes or cucumbers.

The cool crops of minor importance, such as spinach, beet, carrot, cress, mint, swiss chard, etc., may be used in the rotation, any time during the fall, winter and early spring.

Companion cropping.—Companion cropping in greenhouse culture is not so common, although used to a considerable extent. The fundamental principles involved are practically the same as for double cropping in the open ground, but attention should be called to a few additional factors, as follows:

(1) Land values under glass are much higher than out of doors, and this is an argument for intensifying operations by intercropping.

(2) Steam sterilization destroys weed seeds and the soils used are usually light, so that cultivation, hoeing and weeding are not so necessary, and close planting, therefore, is less objectionable from this standpoint than in the open ground.

(3) A higher standard of quality is required for greenhouse products, and companion cropping may be the means of lowering the quality, as when radishes and lettuce are crowded and shaded by larger plants.

(4) Soil adaptation must be carefully considered. It is a mistake to attempt to grow two crops together in the greenhouse unless both are well adapted to the soil.

(5) The question of temperature is the most important factor, and often the most serious handicap. A common practice is to plant cucumbers in beds of lettuce. Although the plan is successful to a greater or lesser extent, one or both crops usually suffer because of unsuitable temperatures. This condition is so serious in the opinion of some growers that they never attempt to grow crops together which have different temperature requirements.

(6) The manurial requirements of each crop should also receive consideration. This problem, however, is not serious, because a soil that contains sufficient manure to produce a good crop of lettuce will also be satisfactory for tomatoes and cucumbers.

(7) The size of each kind of plants at the time of setting should be given the closest attention. For example,

small tomato plants might be greatly injured by setting in beds of large lettuce, while large ones would be damaged only slightly.

Ideas and planting distances for greenhouse companion cropping are so variable that it is impossible to present definite plans which are standard in the culture of crops under glass. It is hoped, however, that the following will be suggestive to those who are interested in this subject:

1. Cauliflower (C), Lettuce (L).

C 10 in.	L	C	L	C	L	C
10 in.						
L	L	L	L	L	L	L
10 in.						
C	L	C	L	C	L	C

Large, vigorous plants of cauliflower and lettuce set at the same time. The lettuce should be harvested in about five weeks.

2. Same as No. 1, except rows of radishes are planted between the solid rows of lettuce and the rows of lettuce and cauliflower. Eleven or 12-inch spaces instead of 10 inches are desirable.

3. Cauliflower (C), Radish (R).

C 20 in.	C	C	C
Radish	. . . .	. . . .	
Radish	. . . .	. . .	
Radish	. . . .	. . . .	
Radish	. . . .	. . . .	
C	C	C	C

Cauliflower plants 20 by 24 inches apart. Radish rows 4 inches apart. Less space may be allowed for cauliflower if desired. Radish seed sown in drills at the time the cauliflower is planted. The radish seed is sometimes sown broadcast instead of in drills.

4. Tomatoes (T), Lettuce (L).

T 9 in.	L	T	L	T	L	T
9 in.						
L	L	L	L	L	L	L
L	L	L	L	L	L	L
T	L	T	L	T	L	T

If desired, lettuce may be planted several weeks in advance of tomatoes and the plants cut and sold at a sacrifice when the tomatoes must be set in the permanent beds. Planting distances, time of planting and size of plants vary greatly in the management of different commercial establishments.

5. Cucumbers (C), Lettuce (L).

C 14 in.		C		C		C		C		C
9 in.										
L 7 in.	L	L	L	L	L	L	L	L	L	L
8 in.										
L	L	L	L	L	L	L	L	L	L	L
L	L	L	L	L	L	L	L	L	L	L
C		C		C		C		C		C

It is an advantage to plant the lettuce several weeks in advance of the cucumbers, and to sell the small plants and replant the spaces with large cucumber plants. In some instances growers plant small cucumber plants, but small plants are usually injured by the crowding of the lettuce.

6. Carnations (C), Tomatoes (T).

CT 10 in. 10 in.	C	CT	C
C	C	C	C
CT	C	CT	C

This plan is used largely at Kennett Square, Pennsylvania. Tomatoes are planted in place of the carnations whenever the carnations indicate rapid decline very early in the spring. The remaining plants of carnations are permitted to remain in the beds until the tomatoes need all of the space or the carnations fail to yield any considerable return. Sometimes large tomato plants are set between carnations without the immediate removal of the latter.

7. Fig. 48 shows potted cucumber plants being grown between gladioli on a raised bench. Both classes of plants were thriving when the photograph was taken.

8. Florists sometimes plant tomatoes or cucumbers with various kinds of flowers, whenever the latter become exhausted as the weather becomes warmer in the spring or early summer. For example, tomato or cucumber plants may be set between rows of sweet peas when the producing period of the latter is approaching an end.

CHAPTER XXII

FRAME CROPS

Frames vs. greenhouses.—It is generally conceded that greenhouses, especially in northern sections, possess, for the forcing of most vegetables, distinct advantages over frames. This subject was discussed more fully on page 13. It would be folly, however, to take the stand that there is no place for the use of frames in the forcing of vegetables, for this is far from the truth. Even many of our most successful and extensive northern greenhouse vegetable growers have large areas of frames. They are adapted to the growing of certain crops, especially the cool ones, such as lettuce, radish, cauliflower and other hardier classes, as, for instance, the dandelion. They find a most useful place in the operations of gardeners living near the seashore, particularly southward, where the extremes of temperature are not so great as in farther inland northern districts. In the warmer sections of the country, some crops, as head lettuce, thrive much better in frames than in superheated greenhouses.

Gardeners with limited capital can engage in vegetable forcing by purchasing only a few sash. As the profits increase, additional sash may be obtained, so that in the course of a few years an important enterprise may be established. Frequently the sash are used in the construction of cheap greenhouses, and in these greenhouses the process of evolution is followed by large modern ranges.

Importance of frame forcing.—Very large areas in various parts of the country are devoted to frame crops. The most extensive plantings are in North Carolina, though frames are used on a large scale in all of the South

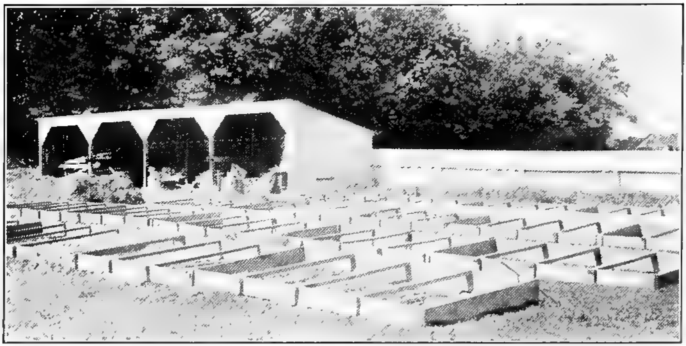

Fig. 132.—Well-protected wooden coldframes.

Atlantic coast states, whence shipments are made in carload lots. The industry has attained a high degree of perfection near Norfolk, where there is a special frame-growers' association. Thousands of sash are used in Philadelphia County, Pa. Rather unusual development of frame forcing has occurred in the northern part of New Jersey. For example, there are about 150,000 sash within an area of one square mile near Richfield, N. J. Market gardeners and truckers throughout the country employ hotbeds and coldframes to a great extent for the forcing of vegetables.

Location of frames.—The frames should be located near the buildings where the tools and supplies are kept. There should be an ample supply of water with pipe outlets at convenient intervals. Protection of some kind, as afforded by buildings, board fences, hedges or woods, is necessary. Fig. 132 shows an ideal arrangement, the shed nearby being convenient for the storage of sash, manure, sand and supplies.

Construction of frames.—When frames are used on a very large scale, they are usually portable or temporary. They may be put up in sections, as shown in Fig. 132, when it is possible to remove and store them in any convenient way until wanted again. The commoner method is to use, for the sides, boards which are nailed to stakes, as shown in Fig. 133. Between seasons, the boards may be used for the blanching of celery if desired. Most of the extensive frame growers do not use cross bars for the support of the sash, though they are an advantage in some respects and a disadvantage in others. It is largely a matter of preference.

There is a marked tendency to use concrete in the construction of frames. The walls need not be more than 3 inches thick. When banked on the outside with manure, they are practically as serviceable in protecting the plants from cold as are wood side boards. Light T-iron,

Fig. 133.—An extensive flat of coldframes. Note method of ventilation and side-boards nailed to stakes.

inverted, may be used for cross bars, if these are desired. The durability of this type of frame appeals to growers who have found the frequent renewal of wooden frames an expensive proposition.

Cloth-covered frames.—In North Carolina, South Carolina and other southern sections where the climate is not severe, the frame is usually covered with cloth instead of glass. Beattie gives, in Farmers' Bulletin 460, the following description of a typical cloth-covered frame:

"The covering of cheap, unbleached muslin is supported on strips of wood 1 inch thick and 2½ or 3 inches wide, which are raised in the center by being carried over the top of a stake; the ends are held down by nailing to the sides of the bed. The lumber for the sides is usually 1 by 12 inches by 16 feet of the cheaper grades of cypress or a good grade of common shortleaf pine. The stakes for holding the boards in place are 1 by 3 or 2 by 3 inches in size, and are driven about 1 foot into the ground. These cloth-covered beds are usually 14 feet in width, but some growers prefer them 10, 12 or 20 feet wide. The length of the frames varies greatly, but the longer ones generally run from 90 to 100 yards, depending entirely upon the space available and the evenness of the ground. The frames usually run east and west, with the cloth fastened to the north edge of the frame. Most of these frames are temporary and are taken apart and stored during the summer months.

"Before placing the frames in position in the autumn the soil is plowed, thoroughly fitted, and given a liberal dressing of well-rotted stable manure and commercial fertilizers. The placing of the boards will cause some trampling of the bed, and before putting in the ends and nailing on the rafters or strips to support the cloth it is desirable to loosen the soil again by means of a harrow or cultivator. The stakes for supporting the cross strips or rafters are then driven through the center and the strips nailed in place at intervals of 4 feet. The ends are inclosed by means of 12-inch boards, and the bed is then ready for the cloth cover. The cloth is stitched, with the strips running lengthwise of the bed, into one great sheet large enough to cover the entire bed. This sheet is fastened on the north side of the frame by nailing over it plastering laths or similar strips of wood. The cloth should not be fastened to the top edge of the board, but on the side 1 or 2 inches below the top. For fastening the sheet on the south side of the frame short loops of string or cloth are attached to its edge, and these are looped over nails driven into the side of the bed. In some cases brass eyelets, such as are used in tent flaps, are inserted in the edge of the cloth and hitched over nails or pins. Another method is to hem the cloth on one edge and run a ⅜-inch rope through the hem. The addition of the rope makes it comparatively easy to fasten the cloth to the side of

FIG. 194.—COLDFRAMES WELL PROTECTED BY THE GREENHOUSE. NOTE RYE STRAW MATS

the bed and also prevents tearing the sheet in handling. The cost of these frames, including lumber and muslin, together with the necessary facilities for supporting and fastening the cloth, will be from 35 to 50 cents a running foot for a bed 14 feet wide.

"If it is necessary to refit the land while the frames are in place, the cloth is turned back into the alleys between the frames, the strips that support the cloth are removed, and a 1-horse plow is taken into the inclosure. After the land is plowed and thoroughly fitted, the strips are again put in place. As the work of cultivating the crops must all be done by hand, it is essential that the soil be well prepared before planting."

Sash-covered frames.—Various plans are followed in the North for the making of sash-covered frames. De Baun describes the following plan, which is used at Richfield, N. J.:

"The soil is previously prepared by being leveled, heavily manured and sometimes plowed. The frames are usually made of spruce boards, 16 feet long, 1¼ inches thick and 10 inches wide. They are run northeast and southwest with a 5-inch pitch toward the southeast, so that the full benefit of the morning sun may be had. Each frame is usually made 25 sash long and the patch between the frames is usually about 20 inches wide. The frame boards are nailed to 2 by 3 chestnut stakes, 2½ feet long, driven into the soil on the outside of the frames. Bolts an inch in diameter and 23 inches long, provided with large washers, are run across the path to hold the boards securely in place. The paths are filled with coal ashes, covering the rods so that the latter cause no inconvenience to the workman when walking in the alleys, and the ashes help also to keep the cold out of the frames and prevent the paths from becoming muddy. Frames well made will last five years."

Frames of the type just described are fairly common in the North, except that the bolts in the alleys are not generally employed. Standard sash, 3 by 6 feet in size, are used by most growers. Though thousands of sash are glazed with very small panes of glass, it is desirable to use larger sizes, preferably the 10 by 12 size. If the sash are painted every other year, kept in repair, stored or stacked when not in use, they will last 15 to 20 years.

Mats and shutters.—In very cold weather, sash alone will not keep frost out of the frames; additional protection, therefore, is necessary at times. Probably no other covering is more effective in guarding against cold than rye straw mats (Fig. 134), though the sea grass mats, seen in Fig. 135, are most excellent. If better protection is required, board shutters placed over the mats and manure banked around the outside of the frames will take care of the plants when the weather is very cold. Growers in the coldest parts of the North, who use various methods of heating the frames, often employ mats

Fig. 135.—Frame cauliflower following a companion crop of lettuce. Note mats which are being thoroughly dried before they are stored for the summer.

and occasionally shutters to conserve the heat. It is not uncommon to see both mats and shutters on steam-heated frames during the daytime, when there are high winds and extremely low temperatures.

Heating frames.—It is impossible to give any rule for the heating of frames. Thousands of frames are used without any artificial heating. In the South, the muslin or sash-covered frames will keep the plants growing throughout the winter. In the North, they may give the necessary winter protection to certain crops, and rapid growth is not expected until March or even April, when the sun furnishes the required heat. Crops may be practically matured in the fall, when they are covered with sash merely as a matter of protection until the vegetables are sold.

Again, sash may be used for a period more or less definite in the spring, simply to advance the crops until no protection of any kind is needed, and if desired both the glass and the frames may be removed and all of the ground devoted to the crops. This plan is generally used from Norfolk southward.

In the colder parts of the country it is often an advantage to heat the frames. Ordinary hotbeds (Figs. 136 and 137), varying in depth of manure from a foot to 3 feet, are in common use for a great variety of purposes. A coil or two of steam or hot water pipes are often placed in frames, and this plan is gaining friends every year over the old plan of heating with manure. The temperature of the frames may be better controlled with steam than with manure, and the cost of heating the frames is often less.

Fertilizing.—The principles involved in the feeding of greenhouse crops (Chapters IV and V) are the same as

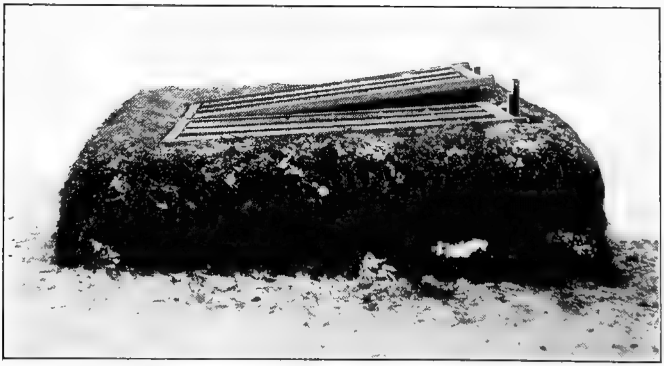

Fig. 136.—Surface hotbed. Note notched block for supporting sash.

for the growing of the various classes of vegetables in coldframes. In many instances it is not so convenient to apply manures and fertilizers in frames as in greenhouses, and perhaps greater care should be taken to have the soil fully and properly enriched before the crops are started.

Watering.—All that was said in Chapter X about watering applies to the moisture problem of frame crops. Success or failure hinges on this operation more than on any other factor. Evaporation is often very rapid, and constant alertness is required in order that the plants do not suffer at any time from an insufficient supply of soil moisture. It is also important to avoid over-watering and to maintain suitable atmospheric conditions for each

Fig. 137.—Pit or hotbed, showing drainage basin.

crop. The overhead system of irrigation is often employed for frame crops.

Ventilation.—Sash-covered frames may be ventilated in various ways. When there are cross bars the sash may be shoved either way so as to give as much ventilation as may be necessary. As a rule, the opening is made on the side away from the wind, so that the wind will not blow into the frame. If only a small amount of ventilation is needed, every other or perhaps every third or fourth sash, moved only an inch or two, will admit sufficient air.

When there are no cross bars, blocks of wood may be placed under the ends of the sash or at some distance from the ends of them, as shown in Fig. 138. This system is somewhat objectionable on account of its tendency to warp the sash. In warm, sunny weather the sash may be entirely removed during the day and replaced on the frames in the evening. A careful study of the appearance of the plants will enable the gardener to determine whether they are being properly ventilated.

Cloth covers are removed from the frames whenever the weather will permit. While they conserve heat they also exclude sunlight, and if they are kept on too much of the time the plants will become weak and spindling and subject to disease.

Control of pests.—For methods of controlling various insect and fungous enemies, see Chapters VII and VIII, and notes on different classes of vegetables.

VEGETABLES GROWN IN FRAMES

Asparagus may be forced at any time during the winter in heated frames. The roots from which the shoots are to be grown are dug late in the fall and stored in a cool, moist place until wanted for use. The details of culture are essentially the same as when the crop is forced in the greenhouse. See Chapter XII for particulars.

Bean.—This vegetable is sometimes grown in frames as a spring crop. The covering of cloth or glass should be used for about a month, or longer in the coldest sections, and then no further protection need be given. An excellent plan is to plant bush beans at proper intervals, in rows not less than 22 inches apart, between rows of

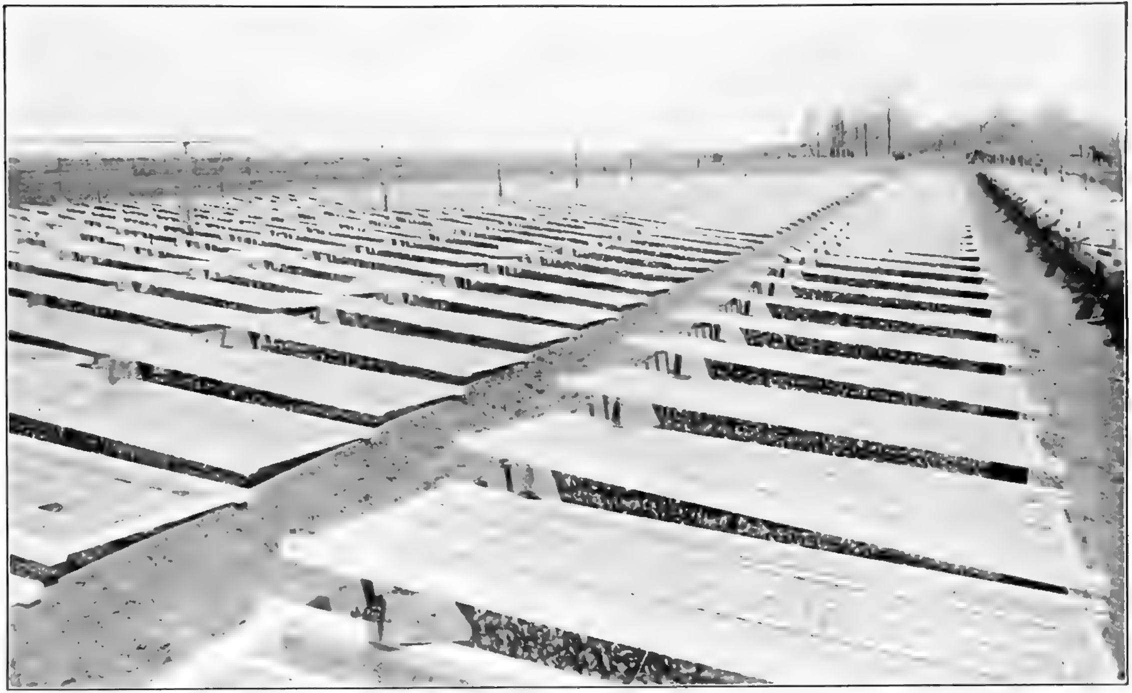

FIG. 138. AN EXTENSIVE PLAT OF COLDFRAMES. NOTE METHOD OF VENTILATION AND IRRIGATING LINES.

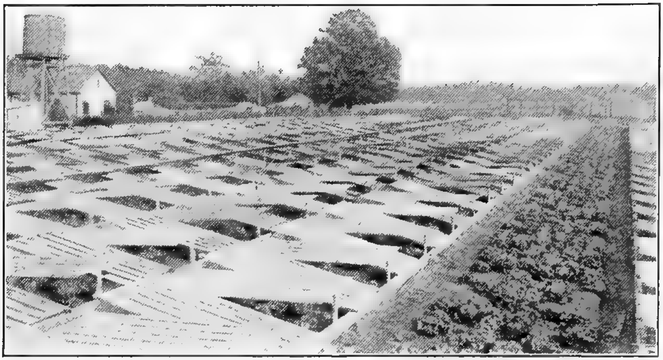

Fig. 139.—A coldframe plat near Norfolk, Va. Note method of ventilating.

spring lettuce when the latter crop is well advanced. After the lettuce is cut, all of the ground is devoted to beans. Any of the bush or snap varieties may be used. The wax-podded type is generally most popular.

Beans as a commercial frame crop do not offer great possibilities, though it is much better to grow them than to have the frames idle.

Beet.—Though the beet as a frame crop is not generally regarded as so profitable as the radish and lettuce, it is a favorite crop with some growers. It is usually grown without the employment of artificial heat. Sometimes the seed is sown in the summer and the crop protected in frames until Thanksgiving or later, if the climate is not too severe.

At Norfolk it is a common practice to sow from December 15 to January 15, and to protect the plants with glass until about April 1, when the sash are transferred to cucumber frames. The seedlings may be started in separate beds and transplanted into the frames. The early maturing varieties, such as Early Egyptian and Early Model, are employed for forcing. See page 359 for additional notes.

Carrot.—The carrot is extensively grown in frames. The small, early maturing varieties are employed. They may be grown as a fall crop or all winter if the climate is not too severe, but the greatest profits are generally derived from spring sowings. In the Richfield, N. J., section, seed is sown in the frames about August 1. Nantes is the most popular variety in this section on

Fig. 140.—Frame crop of Nantes carrot.

account of its good color, thriftiness in growth, sweet flavor and its certainty in producing good roots.

The fall frame carrots are usually planted in double rows only an inch apart, with 10-inch spaces between the pairs of rows. This method of planting is said to allow ample soil space for the development of good roots, and it insures the free circulation of air among the tops. Sash are placed on the frames in November and the carrots will be ready to bunch for the holiday trade. Fig. 140 shows a spring crop of carrots, the seed of which was sown March 1 between rows of lettuce.

Cauliflower (Fig. 141) is grown to a considerable extent in frames on Long Island. The principles involved are the same as when the crop is grown in greenhouses. It

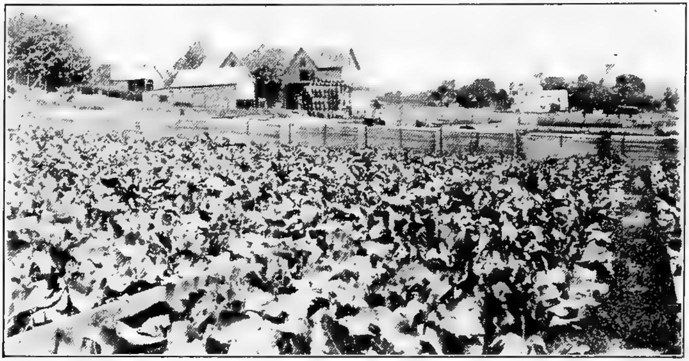

Fig. 141.—Frame cauliflower ready to head.

may be grown both as a fall and as a spring crop. See Chapter XV for data on the forcing of this crop.

Celery is grown occasionally as a spring frame crop. The plants should be started as explained in Chapter IX and transferred to the frames, when there will be no uncertainty about the possibilities of maintaining proper temperatures. All the notes on celery as a greenhouse crop, page 362, apply equally well to its culture in frames. It is possible to mature the crop six weeks earlier in frames than in the open ground.

Chinese cabbage may be grown in frames as a spring crop with entire success, provided careful attention is given to watering, ventilation and the removal of the sash when the temperature becomes very high. See page 360 for additional notes.

Corn salad, when given careful attention, is a profitable frame crop. It is sown in rows about 8 inches apart. Free ventilation and skillful watering are required to prevent the ravages of damping-off fungi.

Cress may be grown in frames in the same manner as that explained for greenhouse culture, page 361.

Cucumber (Fig. 142).—The cucumber is one of our most important spring frame crops. In the Norfolk region, thousands of sash are devoted to this vegetable. The seed is sown in greenhouses or hotbeds about March 1, and as soon as the plants are up they are transplanted into veneer boxes 6 by 6 by 6 inches in size. Five or six plants are set in each box and the plants are finally thinned to three or four. About April 1, one box or hill

Fig. 142.—Frame cucumbers near Norfolk.

of plants is set under each 3 by 6-foot sash, and from May 15 to 20 the sash and frames are removed.

The cucumber plants are set in every other frame, and when they need no further protection, May 15 to 20, the alternate beds of beets are ready to market; the cucumber vines are then trained over ground occupied by beets only a few days before. Stable manure is used in liberal amounts and supplemented by complete fertilizer. Top-dressings of fertilizer are also employed if additional growth is desired. When the frames are removed, the ground between them is thoroughly cultivated and the cucumber vines are turned up, the soil cultivated and usually top-dressed with fertilizer, and the vines replaced. Spraying is also practiced.

In New England and other northern districts the plants are generally started in pots in greenhouses or hotbeds, and transferred to coldframes late in the spring, when the sash alone will give all the protection that is needed. This method will produce a crop of cucumbers four to six weeks earlier than is possible by planting seed in the open ground. See Chapter XVIII for complete notes on forcing cucumbers.

Dandelion may be forced from seed sown in the frames or from crowns which have been grown in the open and

Fig. 143.—Soil in coldframe, after sowing seed of dandelion, carrot, parsley, etc., for the fall crop, is covered with salt hay to conserve moisture and to prevent the soil from baking. When seedlings are up, the hay is removed.

transferred to the frames. (See page 364.) Seed should be sown about July 1. Sash may be placed over the frame at any time during the winter, and if a little heat is provided the plants can be forced to marketable size in three or four weeks. If desired, the frames may be left uncovered until March, when the sash alone, without any artificial heat, will force a satisfactory growth. The demand for dandelion is increasing, and with good management it makes a profitable frame crop.

Eggplant.—The eggplant is grown to some extent as a frame crop. A good hotbed or warm greenhouse is required to start the plants. They should be first transplanted into small pots, and shifted until they are in 4 or 5-inch pots, and thence to the frames. After the season is well advanced and there is no danger of chilling the plants, the sash may be removed. See page 365 for additional notes.

Kohl-rabi.—Kohl-rabi is easily grown as a spring frame crop. The most economical use of the ground will be

Fig. 144.—Coldframes ready for seeding in August with carrots and other fall crops.

obtained if the plants are started in beds and then transplanted into frames. (See page 366.)

Lettuce (Fig. 139) is unquestionably the most important frame crop. It is extensively grown in frames in all parts of the country. As a hotbed crop it has been grown from the earliest days of vegetable forcing in the United States. As a frame crop in the South, whether the frames are covered with sash or muslin, it receives much more attention than any other crop. In the North hundreds of frames in which lettuce is grown are heated by steam or hot water.

Big Boston is the main forcing variety, especially in the Atlantic coast states. It is extremely hardy and will stand a large amount of exposure without serious injury. All of the varieties mentioned on page 207 are also grown to some extent in frames.

Seed for the fall crop is generally sown from August 15 to 20. If the plants for the spring crop are to be wintered in the frames, the seed should be sown about October 1 in the South, and the plants set in the frames later in the fall and covered with sash or muslin. In the North the

Fig. 145.—Choice heads of lettuce saved for the production of seed.

plants may be wintered in the frames or started in hotbeds or greenhouses in January or February, and then set in the frames in March, or even as late as April 1. The date of sowing and transplanting may depend largely on the uses of the sash and frames for other crops. Big Boston is set at various distances, probably 9 by 10 inches apart being the average.

Muskmelons may be grown in frames by the same methods as were explained for cucumbers (page 400). General questions relating to the forcing of muskmelons are discussed in Chapter XIX.

Mustard is easily forced in frames. See page 367 for directions.

Onion.—Onion sets may be forced in frames by the employment of methods described on page 367.

Parsley is easily forced in frames by the use of methods described on page 369 for growing it in greenhouses. It is a profitable crop wherever good markets are available.

Pepper.—The pepper is a satisfactory spring crop for frame culture. It pays well unless southern competition is too severe. The plants are started in pots and transferred to the frames whenever it is possible to maintain proper temperatures. See page 370 for notes on culture.

Radish.—The radish is one of the most profitable and satisfactory frame crops. It is easily grown and gives quick returns. As a companion crop with lettuce and

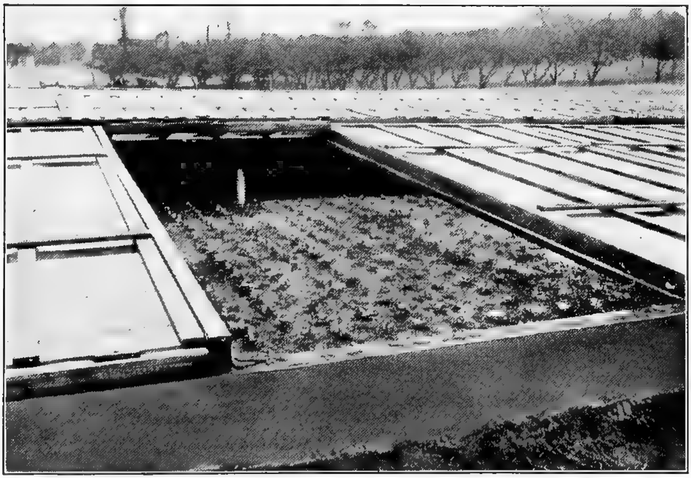

Fig. 146.—Double frames are sometimes used for forcing purposes.

cauliflower, it has no equal. See Chapter XVI for cultural notes.

Rhubarb may be forced with success in frames heated by manure or steam. If the roots are not planted until early spring, no artificial system of heating will be required. On account of the length of the leaf stalks, it is necessary to use frames deeper than those which will do for lettuce and other plants that do not attain a height of more than 10 inches. For cultural details, see Chapter XIII.

Spinach is easily grown in frames without any artificial heat. A fall crop may be harvested, and early spring cuttings may be made of plants started in the fall, or perhaps from January or February sowings, depending upon the severity of the climate. With proper attention spinach will yield about as large returns as lettuce, and it may be the means of avoiding a market glut of lettuce. (See page 372.)

Swiss chard may be sown in January in frames, or started in hotbeds or greenhouses and transplanted into the frames. In the milder sections of the country, pickings may be made from frames throughout the winter.

Turnip.—The early varieties of turnips are sometimes grown in coldframes, though this crop does not offer special financial inducements as a forcing proposition. (See page 373.)

Witloof chicory or French endive claims attention as a frame forcing crop. For further paticulars see page 373.

CHAPTER XXIII

MUSHROOMS

Hundreds of greenhouse vegetable growers are interested in the culture of mushrooms, and this volume would not fulfill its mission without a brief discussion of the most important phases of the subject.

Importance.—The gardeners of all civilized countries have long been interested in the growing of mushrooms. In England and France the industry has been of large commercial importance for over a hundred years. Extensive areas are also devoted to the crop in Germany, Belgium, Italy and other European countries.

In the United States the business did not assume large proportions until about 1900. The production of pure spawn, which has made the growing of this edible fungus a much more certain financial venture, has stimulated the enterprise until special sections of the country have attracted much attention for the magnitude of the mushroom business. The Kennett Square region of Pennsylvania is particularly famous, though large plantings are made near all of our great centers of population. Individual growers may have two acres or more of bed space devoted to the growing of mushrooms. Duggar estimates that about 5,000,000 pounds were sold during the season of 1913 and 1914.

Most of the crop is generally sold locally, though there is an increasing tendency to develop a trade with distant points. Practically all the mushrooms grown in the United States are sold in the fresh state. Large quantities of the canned product have been imported from Europe, particularly France, and a limited supply has been dried for commercial purposes, the latter being used mainly for flavoring and for gravies.

Fig. 147.—Wooden mushroom houses at Kennett Square, Pa.

Botanical characteristics.—The cultivated mushroom so familiar to growers in the United States is botanically known as *Agaricus campestris.* It consists of a stalk or stipe, varying in height from 2 to 5 inches, and in diameter from ½ inch to 1 inch. The top or expanded part of the mushroom is known as the "cap" or "pileus"; this varies greatly in thickness and diameter, according to variety, stage of growth and condition under which it is grown. Varietal variations are rather marked, the caps of some being whitish, while others are creamy white or perhaps brown. The leaflike or gill-like projections on the under side of the cap are termed gills or "lamellæ"; these, for a time, are pink in color in the white or cream-colored species, but they subsequently turn brown or brownish black. The dark-colored spores are borne on the gills, and they serve as the reproductive bodies of the mushroom.

Spores are the normal propagative bodies of this fungus, but growers do not use them directly in the production of mushrooms, although under favorable conditions they will germinate and ultimately produce a threadlike growth termed the "mycelium."

Where to grow mushrooms.—The most extensive mushroom plantations in the world are in France. The city of Paris, built of stones largely taken from quarries under its streets and properties, is the center of this great mushroom industry. Subterranean quarries near the city contain immense plantings, thousands of beds. In fact, the quarries are responsible for the tremendous development of this enterprise in France. The underground chambers are extremely variable in shape and dimensions. They may be 5 to 20 feet or more in height and width, and they may have entrances which are easily accessible, or it may be necessary to provide narrow openings above the quarries, with windlasses for the

Fig. 148.—A modern commercial mushroom range at Kennett Square, Pa. Built of concrete and tile. Frostproof and fireproof.

handling of manure and other materials. Ventilation is provided by means of special openings or ventilating devices of various descriptions.

In England, caves, cellars and specially constructed houses are employed. In the United States, the bulk of the commercial crop is grown in special houses such as are shown in Figs. 147, 148 and 149. The majority of the American mushroom houses are cheap, wooden structures, but in recent years more expensive buildings have been erected by experienced growers. Wood is unquestionably the most common material used in the construction of American mushroom houses, although many growers are employing the more durable materials, such as tile, brick and concrete, with air chambers in the walls. In most instances the houses are comparatively narrow,

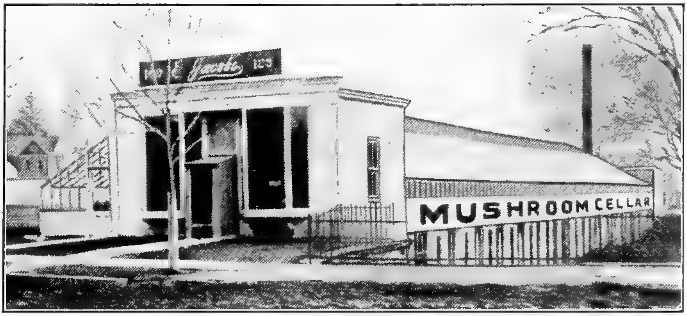

Fig. 149.—A New Jersey double duty house. Mushrooms are grown in the cellar and plants and flowers in the greenhouse above.

12 to 20 feet, but many of the modern ones are of much greater width, and they may be hundreds of feet in length.

The most economical use of the space is to construct tiers of beds. The old houses seldom contained more than two or three beds, while some of the new ones have as many as five beds. Most growers prefer single beds of about 3 feet or double ones of 6 or 7 feet in width. (See Fig. 150.) The alleys should be at least 2 feet wide, and many of them allow more space, for the convenient handling of manure and other material. When the tiers contain several beds, each 8 to 10 inches deep, provision must be made for strong supports; 2 by 4 and 2 by 6 scantling are generally employed, or heavy gas pipe makes a stronger, more durable and more sanitary frame, and the boards are easily removed at any time the beds are not in use.

Mushrooms are grown in a few large caves in America. Pits, small caves, cellars and barns are often used by amateur growers. Florists and sometimes vegetable gardeners grow mushrooms under greenhouse benches. In fact, any place can be used which provides proper cultural conditions, with special reference to heat and moisture. There must be perfect drainage and the temperature requirements are rather exacting. Special piping is necessary in mushroom houses in order to maintain sufficient heat.

Material for beds.—Various kinds of organic materials have been used for the growing of mushrooms, but there seems to be a consensus of opinion that fresh horse manure gives the best results. Most growers prefer that it contain considerable straw, although good results are sometimes obtained from manure with a small proportion of bedding. If sawdust or shavings have been used for litter, more time will be required to effect proper fermentation, and it is likely that such manure does not give as uniformly good results as strawy manure. The French growers prefer manure from grain-fed animals bedded with rye straw. Any of the cereals grown in America used for bedding grain-fed animals will produce manure which is entirely satisfactory for the growing of mushrooms. It is desirable that the manure be fairly open and porous after it has fermented, and the cereal straws seem to bring about this condition. The large commer-

Fig. 150.—Mushroom beds in a modern house.

cial growers buy the usual supplies of city stable manure, which is often shipped in carlots.

In many instances the manure is placed in large piles out of doors, as shown in Fig. 151, and allowed to ferment. There are advantages in keeping the manure under cover where there will be no loss from leaching and where it will not dry out rapidly, but the objections to open air composting are not serious.

Certain essential chemical changes occur during the process of fermentation, which also materially alter the physical properties of the manure. Fire-fanging should be avoided as much as possible. To encourage the proper kind of fermentation it is necessary to keep the pile uniformly moist and fairly compact. The supply of moisture in the compost should be watched carefully

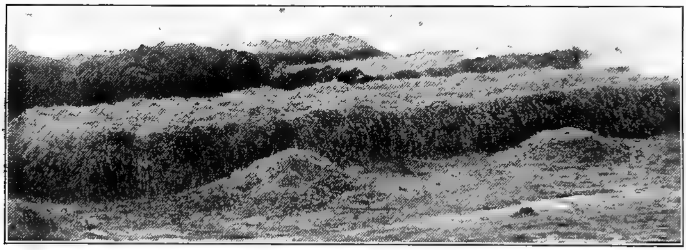

Fig. 151.—Composting manure for the growing of mushrooms.

from day to day. Copious applications of water or sufficient amounts to soak the manure are necessary when it is placed in piles, and the latter should not be more than 4 or 5 feet deep. It is generally customary to turn or fork over the piles from two to four times during the process of fermentation, which lasts about four weeks. This operation is essential in order to secure uniform fermentation throughout the compost and to make the manure shorter or finer in texture. Water should be added whenever necessary while the manure is being forked over, in order to keep all parts of the pile equally moist. Manure hauled from the cars nearly always requires a large amount of water when it is placed in a pile. The temperature will rise to possibly 150 degrees, but in three to four weeks it should drop to about 130 degrees, and if the manure has lost its unpleasant odors, and the straw has become dark brown in color, and the material friable and containing the right amount of moisture, the beds may be filled. Four large wagonloads of manure will generally be sufficient for 1,000 square feet of beds.

Preparation of beds.—As stated in the previous paragraph, the manure may be placed in the beds after the temperature has receded to about 130 degrees. If the beds are to be made on the ground, there should be no uncertainty about them being perfectly drained.

Practically all American growers prefer to make flat beds rather than ridged ones. Flat beds are the simplest to make, and they are more economical of space where tiers of beds are constructed. Ridged beds are about 2 feet wide at the base, they taper gradually to the top and are 12 to 15 inches high. They are generally arranged in groups of twos with approximately 12-inch alleys between each pair of beds. This plan is followed in the French caves, where it possesses distinct advantages, especially in providing a larger total area of bed surface when all of the beds are made on the ground. This system is sometimes seen in low commercial houses of America, or in private cellars and pits.

When flat beds are made in cellars or caves, some growers prefer a total depth of 12 to 14 inches, several inches or perhaps the lower half of this depth being composed of fresh, hot manure and the upper half of specially composted manure. The hot manure furnishes some heat after the beds have been planted or spawned, and this is thought to be of value in locations which are not adequately heated. Growers operating large commercial houses make beds 10 to 12 inches deep sometimes, but this is of doubtful expediency. The more generally approved plan is to use only the specially composted manure, making beds with a total depth of 8 to 10 inches, after the manure has been firmed or compressed by the use of a board or other convenient device. A certain amount of compacting of the manure is necessary to prevent it from becoming too loose and dry.

After the beds have been filled, the temperature of the manure may rise for a few days and then it will begin to decline, but there should be no spawning until it is down to 75 degrees or preferably 70 degrees. The moisture of the beds between filling and spawning should also be carefully watched. If the manure has been properly prepared and the beds and houses are well constructed, there should be very little trouble in this connection. However, light sprinkling is sometimes necessary in order to maintain proper moisture conditions. A practical test is to squeeze the compost in the hand at the time the beds are filled. If no drops of water are squeezed out and the hand remains distinctly moist, additional water is not required. But too much emphasis cannot be placed upon the importance of having perfect moisture conditions when the beds are filled. Skillful growers never water the manure in the beds.

Spawn.—Success in growing mushrooms depends very largely upon the use of good spawn. English spawn was used almost exclusively in this country until a few years ago, and although it was regarded as the best, results from its use were very uncertain. Great credit is due Duggar for his work in developing pure culture spawns which have placed the whole proposition on a more certain, scientific and satisfactory basis, thus making it comparable to other lines of horticultural production.

The making of pure culture spawn is in itself a special enterprise requiring skill and laboratory equipment, and it is not feasible or practicable for every grower to produce his own spawn. Those who are interested in this phase of the industry should study Duggar's "Mushroom Growing," Chapter VIII. It is gratifying, however, that there are reliable American firms from whom pure culture spawn may be obtained at reasonable prices, so that no one need take chances in planting ordinary commercial spawn, whether it is made in the United States or in foreign countries. Growers will do well to make a thorough investigation of the sources of good spawn before making purchases. Different varieties may be obtained and tested just as gardeners test different sorts of tomatoes or lettuce.

The pure cultures are generally sold in the usual commercial brick forms, as seen in Fig. 152. The bricks

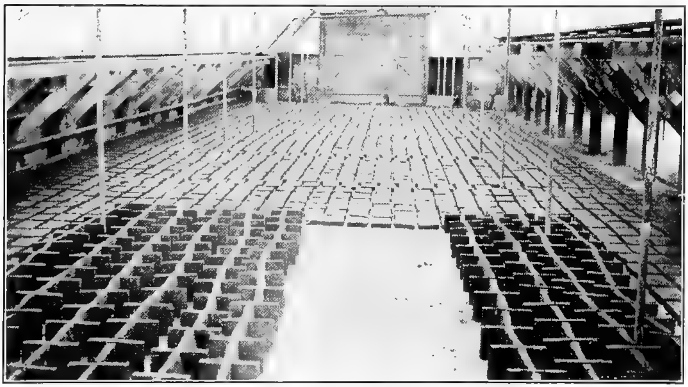

Fig. 152.—Drying bricks of mushroom spawn.

measure about 5½ by 8½ by 1½ inches. They pack readily for shipment and are easily broken for spawning the beds. It is exceedingly important to use fresh spawn. That which is a year old seldom gives good results. Duggar recommends that growers use spawn not more than six or eight months old, and they will do well to make arrangements with manufacturers several months in advance of the date when it will be wanted for planting. But it is safer to have delivery arranged for only a few weeks before the beds are spawned in order to avoid storage risks.

Spawning the beds.—As previously stated, a temperature of about 70 degrees, which may be determined by a thermometer plunged into the manure, is probably best for the spawning of the beds, though this is often done at temperatures ranging from 10 to 15 degrees higher. The beds may be spawned at 55 to 60 degrees, but the mushrooms will grow much less rapidly if the spawning is done at lower temperatures than 55 degrees.

There are no rules regarding the best distances for inserting the spawn. Ordinarily, a brick is broken into 10 or 12 pieces, sometimes more, and one piece is considered sufficient for about a square foot of bed. The pieces may be planted in check rows a foot apart, or at closer intervals if desired. A little manure is raised and a hole made where each piece of spawn is to be inserted; the spawn is covered with an inch or two of the manure and pressed firmly with the hand. If the bed seems too loose after the work of spawning has been completed, the entire area may be firmed with a board or a block of wood.

Casing the beds.—Mushroom beds are always covered with an inch or two of fine, rich, moist, loamy soil and this operation is termed "casing." Its purpose is to conserve moisture, give support to the mushrooms and presumably to improve the quality of the product. The casing is usually placed on the beds in 10 days to two weeks from the date of spawning. If conditions have been right, the mycelium will then appear as a moldy growth on the pieces of spawn. It is an interesting feature of mycelium growth that as it runs through the manure, the casing acts as a check on vegetative development, thus forcing the reproductive development, and to case too soon is a disadvantage. During the intervals some sprinkling may be necessary to keep the beds moist.

Moisture conditions.—Proper moisture conditions at all times after the beds have been started are of the greatest importance. Excessive humidity in the house should be avoided, but the atmosphere should be moist enough to prevent rapid evaporation from the surface of the beds. Molds and foreign fungi may develop if too high humidity is maintained. The best mushroom houses are provided with means of ventilation by which temperatures may be regulated and the humidity of the houses controlled to a great extent.

Mushrooms require a certain amount of soil moisture, just as do the higher classes of plants. There is always some daily loss of moisture from the beds by evaporation, and the harvesting of a successful crop also removes a considerable quantity of water. Some of the old growers claimed that the beds should never be watered after the mushrooms began to appear, and no doubt this was often responsible for light crops. Drenching and over-watering should be carefully avoided, but there can be no doubt about the value or necessity of light sprinklings whenever the casing seems to indicate the need of such treatment. If the casing is kept moist, but not wet, there will be no danger of the compost or manure becoming too dry. Contrary to the best practice in vegetable forcing, it is desirable to water frequently but lightly, but application should never be made unless there is assurance that water is really needed. So much water should never be applied that it will penetrate the casing and run into the manure, for this invariably weakens the mycelium, especially in the early stages of growth. No rule can be given concerning the frequency of watering any more than for the watering of greenhouse crops.

Temperature.—An atmospheric temperature of about 55 degrees is considered as ideal for the growing of mush-

pests are sometimes responsible for total crop failures.

Small flies or gnats of various descriptions are among the most common pests. They are invariably present in untreated manure, and under favorable conditions multiply very rapidly and soon become a great nuisance. High temperatures are especially favorable for the breeding of these pests, and therefore they are most likely to damage mushrooms in beds which have been spawned early in the autumn or before the advent of cold weather, for the flies are practically inactive at temperatures below 55 degrees. The damage is caused by the larvæ of maggots passing up through the stipes and riddling the caps. Fumigation with tobacco (page 105) at the strength generally employed in greenhouses will kill the adult flies. Hydrocyanic gas (page 109) may be employed before the beds are spawned. Bulletin 155, U. S. Bureau of Entomology, gives a description and life history of the various insects which feed on mushrooms.

The mushroom mite *(Tyroglyphus linteri)* is always present in stable manure, and it may cause serious damage to the crop if the manure has not been properly composted. It multiplies most rapidly at high temperatures and in dry manure; this is an important reason for maintaining an adequate supply of moisture in the compost pile. Apparently there is no practical means of eradicating the pests when they appear after the beds have been spawned. They feed both upon the spawns and upon the mushrooms.

Springtails are very minute, grayish-black insects, which sometimes appear in great numbers upon the surface of the beds. These pests are most likely to be troublesome in damp, poorly ventilated houses or caves. They generally attack the mushrooms through the gills. Thorough ventilation, applications of pyrethrum powder, and the dusting of the beds and floors with quicklime are among the remedies recommended.

The common sowbug is also an enemy of the mushroom. It may multiply in decaying wood, or gain an entrance to the house through the manure or compost. This pest, if uncontrolled, will destroy many pounds of mushrooms in a very short time. An effective remedy is to place poisoned slices of raw potatoes over the beds. If only a few sowbugs appear, a little handpicking may be all that is required.

Diseases.—Duggar believes it highly probable that the chief types of disease affecting cultivated mushrooms are due to one species, *Mycogone perniciosa,* which possesses two spore stages, and grows upon both the spawn and the mushrooms. The disease causes an enlargement of all parts of the mushroom, and usually covers it with a mold-like coating. In the second stage of the disease, the stem is greatly enlarged and the cap poorly developed. In this stage the mushrooms are very soft, and often decay before they attain normal size, though specimens of abnormal proportions occur in diseased beds. A 2½ per cent solution of lysol is recommended for spraying diseased beds, though fumigating with the vapors of formaldehyde is considered more effective. See "Mushroom Growing," by Duggar, page 139.

Diseases and insect enemies are not likely to cause serious losses in the growing of mushrooms if proper attention is given to sanitation. The soil, compost and lumber should be removed annually and all interior parts of the house thoroughly treated for the destruction of insect pests and disease germs.

Picking and marketing.—The beds generally begin to produce in 6 to 8 weeks from the date of spawning, though 10 to 12 weeks may elapse, if the temperatures are abnormally low or if shavings manure has been used for the compost. The period of production is extremely variable, but it should continue for several months.

It is necessary to look over the beds every day, so that

is used for the forcing of vegetables or the growing of flowers. A fair idea of its fertilizing value is given by a number of analyses of such manures made at the Pennsylvania Experiment Station, under the direction of Frear. For comparison the average of a number of analyses of fresh horse manure, with litter, is added.

ANALYSES OF MUSHROOM MANURES (Per cent)

Mushroom manures	Moisture	Organic matter	Mineral matter	Nitrogen	Potash	Phosphoric acid
1	30.97	15.99	53.04	.626	.93	.64
2	4.45	25.31	70.24	.80	1.47	.85
3	52.94	[47.06]		1.22	1.41	1.14
4	45.52	12.30	42.18	.32	.16	.26
5	38.32	30.10	31.58	1.21	.25	1.06
6	57.05	29.84	13.11	1.17	.45	1.05
7	22.42	40.12	37.46	1.60	.32	1.31
Average	33.12	25.61	41.27	.99	.71	.90
Fresh horse manure	72.33	23.47	4.20	.61	.565	.37

Frear says of these analyses:

"No detailed information accompanied the first four samples. No. 5 represented many different beds, filled with manure that had been watered and turned three to five times before benching; No. 6, six beds filled with manure that was well rotted, extremely short and very wet when benched, and that became so pasty and sticky that it had to be turned up to dry before spawning was attempted; No. 7, manure benched directly from the car, in a very wet state, and watered heavily two or three times before spawning.

"It is not known, in any instance, whether the casing earth was at all separated from these samples. The high mineral content, at least of all but No. 6, indicates the presence of such earthy admixture.

"The mushroom manures are much drier than the fresh stable manure. This accounts in part for their comparative concentration, but only in part. The relative composition of the dry matter of the fresh horse manure and of the average for the seven mushroom manures shows:

	Horse manure per cent	Mushroom manure per cent
Organic matter	84.60	40.37
Mineral matter	15.40	59.63
Nitrogen	2.20	1.67
Potash	2.04	1.15
Phosphoric acid	1.34	1.51

"The potash in the mushroom manure is relatively low, the phosphoric acid high, as compared with horse manure. The mushrooms do use much more of potash than of phosphoric acid, but their consumption is very small in proportion to the supply given. One hundred cubic feet of manure, underlying 100 square feet of the beds, would weigh, in the fresh state, and compacted, approximately 3,500 pounds, and would furnish about 77 pounds of nitrogen, 71 of potash and 47 of phosphoric acid. One hundred pounds of mushrooms harvested from 100 square feet of beds contain only 0.58 pounds of nitrogen, 0.23 of potash and 0.07 of phosphoric acid.

"The changes the horse manure undergoes, during its preparation for and use in the mushroom beds, are little, if at all different, from those which would attend its quite complete rotting under other conditions, with the exception that all but samples Nos. 2 and 3 indicate some loss by leaching away of the potash either during composting or at some earlier time. The result is a relative depression of the soluble potash and, in some measure, of nitrogen and a corresponding increase in the proportion of the phosphoric acid, which is present in forms not soluble in water.

"All in all, the mushroom manures are somewhat richer in nitrogen and potash, and much richer in phosphoric acid than an equal weight of fresh horse manure. It is probable, however, that their values for agricultural use are like those of other well-rotted manures, as distinguished from fresh manures holding the soluble urinary constituents little changed."

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