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# DISEASES OF TRUCK CROPS

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## CONTENTS

# DISEASES OF TRUCK CROPS

RALPH E. SMITH[1]

## INTRODUCTION

Discussed in this circular are diseases of truck crops (vegetables), including all forms of such crops as beans, beets, corn, and crucifers, which are grown partly as vegetables and partly as field crops. Similar circulars on diseases of fruits and nuts, diseases of flowers and other ornamentals, and diseases of field crops are being issued. The main purpose of these four circulars[2] is to give a brief, popular account of the nature of and control methods for the important plant diseases in California, as far as such information is available; a further purpose is to mention, under each plant, all the specific diseases which have been observed on it in this state so that the work may serve as a check list of California plant diseases. Mere records of parasitic fungi on various hosts, however, are not included. Certain diseases of much importance in other parts of the United States which do *not* occur or flourish in California are also mentioned to aid those who want to obtain disease-free seed or plants, or to help in identifying new diseases which may appear in this state.

Diseases and failures of plants are due to a great variety of causes. For this reason the problem of understanding and controlling them is often a complicated one. Some diseases are caused by definite parasites which can be fought with sprays and other devices similar to those used in the struggle with insects. Other troubles arise from the existence of conditions which are unfavorable to the plant in some way but which may be difficult to determine or change. In the latter respect, it should be remembered that all kinds of plants naturally do not thrive equally well in all places or under the same conditions; some do better under certain circumstances than others and consequently can be more easily brought to perfection in any given locality. When conditions are too difficult for a particular kind of plant, the experienced grower may give up trying to fight adverse conditions and change to some other kind of plant that is easier to grow on his particular place.

Plant diseases may be divided into two types, parasitic and nonpara-

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[2] These circulars supersede portions of Circular 265, *Plant Disease and Pest Control,* by W. T. Horne, E. O. Essig, and W. B. Herms. The portions dealing with insect pests have been superseded by Extension Circular 87, *Insects and Other Pests Attacking Agricultural Crops,* by E. O. Essig and W. M. Hoskins. The other members of the present series are Extension Circular 118, *Diseases of Flowers and Other Ornamentals;* Extension Circular 120, *Diseases of Fruits and Nuts;* and Extension Circular 121, *Diseases of Field Crops.*

sitic. In the former group are included fungus, bacterial, insect, and nematode attacks. Fungi are microscopic organisms that cause diseases like mildews, rusts, and smuts, as well as molds and rots. In most cases their threadlike filaments, invisible to the eye, grow inside the plant (on the surface in the case of powdery mildews) and weaken or injure it by absorbing food and destroying the tissues. Most fungi spread and reproduce themselves by means of bodies called "spores," which in typical cases like the molds (fig. 1, p. 6), mildews (fig. 4, p. 11), smuts, and rusts (fig. 2, p. 8) are visible in mass to the eye as a dusty powder. These spores may blow in the air or be carried on the bodies of insects, living plants, bulbs, or seeds, or by other modes of transportation. Bacteria are microörganisms even smaller than fungi and are only visible in certain cases as a slimy exudate. They are spread in a manner similar to fungi and are of the same general nature as bacteria or germs which cause human and animal diseases.

Nematodes (eelworms) are organisms of the animal kingdom whose attacks are included here in a number of cases because these creatures (fig. 42, p. 95) are so small as to be practically invisible to the eye and their effects upon plants are similar to many others which are listed as diseases. A few insect effects are also included for similar reasons, although in such cases descriptions of the insects themselves will be found in Extension Circular 87, to which reference is made in each case.

Nonparasitic diseases are mainly the effects of soil and climatic conditions such as moisture, temperature, and chemical substances. Direct, obvious, or easily diagnosed injuries like those caused by frost, wind, excess water, drought, or chemical salts (alkali) in most cases are not described as diseases under specific hosts.

Viruses are foreign substances which invade, spread, and increase in the bodies of plants, often causing specific diseases and great injury. Many human and animal diseases (measles, smallpox, rabies, foot-and-mouth disease) are of a similar nature. The virus itself is invisible even under the strongest microscope and, while in many respects it behaves like a parasitic living organism, has other characteristics which make it seem a nonliving chemical substance. Most plant-virus diseases are spread by aphids, thrips, or leafhoppers which feed on affected plants and then on healthy ones.

If there is difficulty in diagnosing a disease, help can be obtained from the county farm advisor or it may be desirable to send specimens to the Division of Plant Pathology, University of California, Berkeley. In case of plant diseases or troubles in which no insects can be found, an effort should be made to select specimens which seem to be typical of the dis-

ease. If it is necessary to include fresh leaves, stems, roots, flowers, or fruit, these should be packed in such a way that they will not dry out. Fresh plant material can be kept in good condition in waxed paper without adding any moisture, or, if it seems better, the samples may be wrapped in moist newspaper and this again enclosed in a tight covering. A screw-top mailing tube makes a good container for fresh vegetation without adding any moisture. Plant-disease samples should be addressed to the *Division of Plant Pathology, College of Agriculture, Berkeley.* Requests for information about insects should be addressed to the *Division of Entomology, College of Agriculture, Berkeley.* In parts of the state where it is more convenient, information may be obtained from the same divisions at the College of Agriculture, Davis, or at the Citrus Experiment Station, Riverside. A letter fully describing the trouble should always be written and mailed to the same address at the time the specimens are sent.

The California Agricultural Experiment Station has issued many bulletins and circulars which discuss certain individual plant diseases much more fully than can be done in this publication. There are also bulletins upon insect pests and upon culture of important crops including their principal pests and diseases. A list of the available Experiment Station publications, which are sent free on request, may be obtained by addressing the *Publications Office, College of Agriculture, Berkeley.* Consultations, publications, and other services of the College of Agriculture are free as far as possible.

Other bulletins upon plant diseases and insects, as well as on numerous other subjects, are published by the experiment stations of other states and by the United States Department of Agriculture, Washington, D. C. Many of these may be obtained free or for a small charge or may be seen at the offices of the local county farm advisors.

References are given throughout this circular to useful publications on various topics. Bulletins which are out of print may be consulted in public libraries. Several books on insects or plant diseases are of general interest in California.[3]

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[3] Among these may be mentioned:

Essig, E. O. Insects of Western North America. 1025 p. 766 figs. The Macmillan Company, New York, N. Y. 1926.

Heald, F. D. Manual of plant diseases. 2d. ed. *xii* + 953 p. 59 figs. McGraw-Hill Book Co., New York, N. Y. 1933.

Heald, F. D. Introduction to plant pathology. *xi* + 579 p. 200 figs. McGraw-Hill Book Co., New York, N. Y. 1937.

Owens, C. E. Principles of plant pathology. *v* + 629 p. 222 figs. John Wiley and Sons, New York, N. Y. 1928.

## DISEASES BY CROPS

### ARTICHOKE (GLOBE)[4]

**Bud Rot, Mold.**—The common gray-mold fungus, *Botrytis cinerea,* sometimes attacks artichokes in the field or in shipment, just as it affects heads of lettuce, bunches of grapes, ripe fruit, and other fleshy material. The bud scales are rotted and covered with a brownish-gray, dusty

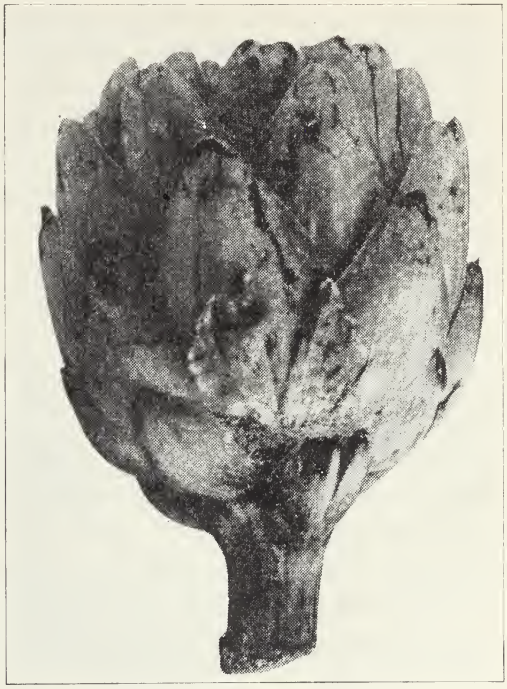

Fig. 1.—Bud rot of artichoke.

growth of mold (fig. 1). This disease is greatly favored by rain, fog, or high humidity. The fungus is not a very active parasite under average conditions.

Bud rot cannot be prevented by any specific treatment. It is advisable, however, to practice such sanitary methods as the prompt removal of all affected buds from the plants and care in culling out all which show the slightest trace of the disease before shipment.

**Leaf Spot.**—The leaves attacked by this disease are disfigured with large dead spots. Any of various fungi, including a species of *Cladospo-*

[4] For further information about artichoke culture, with descriptions and illustrations of diseases see: Tavernetti, A. A. Production of the globe artichoke in California. California Agr. Ext. Cir. 76:1–24. 14 figs. 1933.

*rium, Cercospora obscura,* and *Ramularia cynarae,* may be responsible. The trouble is not serious enough to require treatment.

**Powdery Mildew.**—The leaves and buds occasionally show a white mildew caused by the fungus *Erysiphe cichoracearum.* The disease is not important on artichokes.

**Root Rot.**—Affected plants wilt and die on account of a rotting of the main root and lower stem caused by a fungus, *Phytophthora megasperma.* It occurs mostly in wet spots in the field. This disease can be prevented by proper leveling and surface drainage so that there are no low spots where water stands.

**Yellows.**—In this disease, small, yellow, spindling shoots with undersized, worthless heads develop in place of the vigorous, normal growth. The plants do not die but remain stunted and sickly. If the diseased shoots are cut off, similar ones come up again. The roots appear sound and normal. This disease appeared in at least two different places in the coast district and seemed to spread locally to a certain extent but has not increased during a period of several years. The cause is not known, but this has the characteristics of a virus disease. It is evidently spread by using sprouts from diseased plants for propagation and may also be transmitted by some insect. Artichoke yellows has considerable resemblance to aster yellows, but tests by H. H. Severin indicated that the diseases are not identical.

In districts where this disease occurs, great care should be taken to avoid using offshoots from affected plants for planting new fields. Diseased plants in old fields should be destroyed as soon as they are found.

## ASPARAGUS[5]

**Cercospora Spot.**—This fungus disease, caused by *Cercospora asparagi,* has been observed only in the southeastern part of California. Dead, gray spots, the largest about 1/8 inch long, develop on both stalks and smaller stems of the bushy tops. No control treatment has been attempted.

**Phytophthora Rot.**—Soft, watery spots appear on the asparagus shoots in the market or in transit and these break down into a foul-smelling decay. The cause is a fungus, a species of *Phytophthora,* which lives in the soil and produces there the spores that infect the asparagus shoots, either by direct contact or by infesting the water in which the crop is washed. The same fungus, when conditions are favorable, also

[5] For further information about asparagus culture, with descriptions and illustrations of diseases see:

Hanna, G. C. Asparagus production in California. California Agr. Ext. Cir. 91:1–32. 22 figs. 1935.

Smith, Ralph E. Asparagus and asparagus rust in California. California Agr. Exp. Sta. Bul. 165:1–99. 45 figs. 1905. (Out of print.)

infects the underground parts of the growing plants and sometimes greatly reduces the yield.

This fungus is one of the water-mold type, which flourishes under conditions of high soil moisture. The occurrence of the disease is correlated with high water table, poor drainage, and similar situations which must be corrected in order to avoid this trouble. (See "Root Rot" under "Arti-

Fig. 2.—Spore pustules of rust on asparagus tops.

choke," p. 7; "Wet Rot" under "Beet," p. 23; "Root Rot" under "Crucifers," p. 42; and other diseases caused by species of *Phytophthora.*) A satisfactory method of disinfecting the water used for washing asparagus has not been found.

**Rust.**—The principal symptom of this disease is a dusty, red rust of the bushy tops which grow up each year after the asparagus cutting stops (fig. 2). Such tops when disturbed give off clouds of red dust, which consists of spores of the fungus *Puccinia asparagi.* The rust pustules afterward turn black. The tops die prematurely and the plants are weakened more and more each year, which reduces the yield and shortens the

life of the field. This fungus disease is also seen sometimes on young asparagus plants in spring, in the form of oval, yellowish patches with pustules of spores on the stems.

Dusting or spraying with sulfur is effective in control of rust, but resistant varieties are available which make such treatment unnecessary under most circumstances. Of such varieties, the Martha Washington is usually considered the most resistant to rust. Mary Washington is also highly resistant. Palmetto, while more susceptible than the Washington varieties, is less affected than the older white varieties of the Conover's Colossal type, which are very susceptible. In case it is necessary to control rust, thorough applications of high-grade dusting sulfur to the bushy asparagus tops, beginning when the first traces of the disease are seen, should be made. Volunteer or wild asparagus should not be allowed to grow in the vicinity of commercial plantings, for the rust may get a start on such growth early in the season and thus be ready to infect the new tops as soon as they come up after the cutting season.

**Stain.**—The white shoots which are cut for market sometimes show a reddish stain or discoloration caused by the fungus *Corticium vagum,* but the trouble is not very serious.

## BEAN[6]

**Anthracnose.**—Bean anthracnose is very rare and unimportant in California and has been observed in only a very few instances near the coast. This is of importance to those seeking anthracnose-free districts for growing seed beans. The symptoms of this fungus disease, caused by *Colletotrichum lindemuthianum,* consist in dark-colored, rough, scabby spots up to 0.4 inches in diameter, usually with a red border and pinkish in the center, on the leaves, stems, and pods.

**Bacterial Blight.**—Small, water-soaked spots appear on the underside of the leaves of plants affected by bacterial blight. These gradually increase and form large, dead areas. In the center may be seen a dried incrustation surrounded by a yellowish zone. Dead, sunken, red spots develop on the stems and pods. In time, the plants become defoliated and the seed may be completely destroyed. Beans from affected plants may contain the causal organism, *Phytomonas medicaginis* var. *phaseolicola* or *P. phaseoli,* and when these are planted the disease is again produced.

Bacterial blight of beans is rare in California and seed grown in the interior valleys is free from infection.

**Cottony Rot.**—In cottony rot, the stems, and sometimes the leaves and

[6] For further information about bean diseases, see: Harter, L. L., and W. J. Zaumeyer. Bean diseases and their control. U. S. Dept. Agr. Farmers' Bul. 1692:1–28. 14 figs. 1932.

pods, are affected by a soft rot covered with a fluffy white mold containing small, round, black bodies called "sclerotia." This fungus, *Sclerotinia sclerotiorum,* is most apt to develop in heavy, matted vegetation where there is an abundance of moisture. See "Cottony Mold" (p. 90).

**Curly Top.**—Curly-top plants are stunted and the leaves deformed and curled in a peculiar manner. This is the same virus disease as curly

Fig. 3.—Bean mosaic.

top of beets (p. 15) and is transmitted by the beet leafhopper, *Eutettix tenellus.* It is not often serious on beans in California.

**Downy Mildew.**—A white, downy mold (*Phytophthora phaseoli*) sometimes develops on the pods of lima beans, as well as in the young shoots and blossoms, and deforms and stunts them. The fungus infection is carried inside the seed.

This disease was reported in California in early times but has not been

observed for many years. This fact is of importance to those wishing to grow clean seed.

**Dry Root Rot.**—Affected plants are dwarfed and yellow and many

Fig. 4.—Powdery mildew of bean.

die. The fibrous roots rot off, the taproot turns a dark-red color and gradually dries up. New lateral roots sometimes grow out above the dead part. This fungus disease, caused by *Fusarium solani* var. *martii* f. 3, is worst on poorly drained soils.

Good soil preparation, proper irrigation and cultivation, and crop rotation are the only control measures which can be used against diseases of this type. Resistant varieties of different types of beans may in time be developed but none are available at present.

**Mosaic.**—The leaves of plants attacked by this virus disease are much puckered and cupped downward at the edges. In color they are darker green than normal or mottled with green and yellow patches (fig. 3). Early-affected plants bear little seed. The infection is carried in the seed and spread by aphids.

Control measures for this disease lie in obtaining clean seed. Plantings for seed production should be made in places well isolated from other bean fields and with seed from fields which are as free from mosaic as possible. The seed field should then be carefully rogued by pulling out every plant which shows mosaic as soon as it can be detected. Resistant varieties of certain types of beans are available. For further information, address the Division of Plant Pathology, College of Agriculture, Berkeley.

**Powdery Mildew.**—A gray mildew, *Erysiphe polygoni,* sometimes develops on the foliage of beans in cloudy weather or in the fall when humidity increases (fig. 4).

Dusting with sulfur (p. 104) is the most effective control measure if any is needed for this fungus disease.

**Rhizoctonia Stem Rot, Rhizoctonia Canker.**—Symptoms of this disease are dark-red or brick-red, dead areas or cankers that develop on the lower part of the stem (fig. 5) and kill or stunt the plant. The same fungus, *Corticium vagum,* attacks potatoes and many other plants and causes damping-off of seedlings.

No control is possible except good soil preparation and proper irrigation and cultivation to keep the plants growing vigorously.

**Root-Knot Nematode.**—Galls or swellings, larger and of a different appearance from the nitrogen-bearing nodules, appear on the roots (fig. 6) of plants attacked by the root-knot nematode, *Heterodera marioni.* The plants are badly stunted and killed.

Infested soil should be avoided for beans and other susceptible crops but may be used for winter cereals with clean summer fallow. See "Nematodes, Eelworms" (p. 94).

**Rust.**—In affected plants, red, dusty pustules of rust spores break out in great abundance on the leaves, mostly on the lower surface. In bad cases, the plant is greatly injured and the crop ruined. This fungus disease, caused by *Uromyces phaseoli* var. *typica,* is common in the state but causes the most serious damage on winter string beans, particularly

the Kentucky Wonder variety, grown in frostless districts of southern California.

Dusting or spraying with sulfur (p. 104) at the first appearance of rust

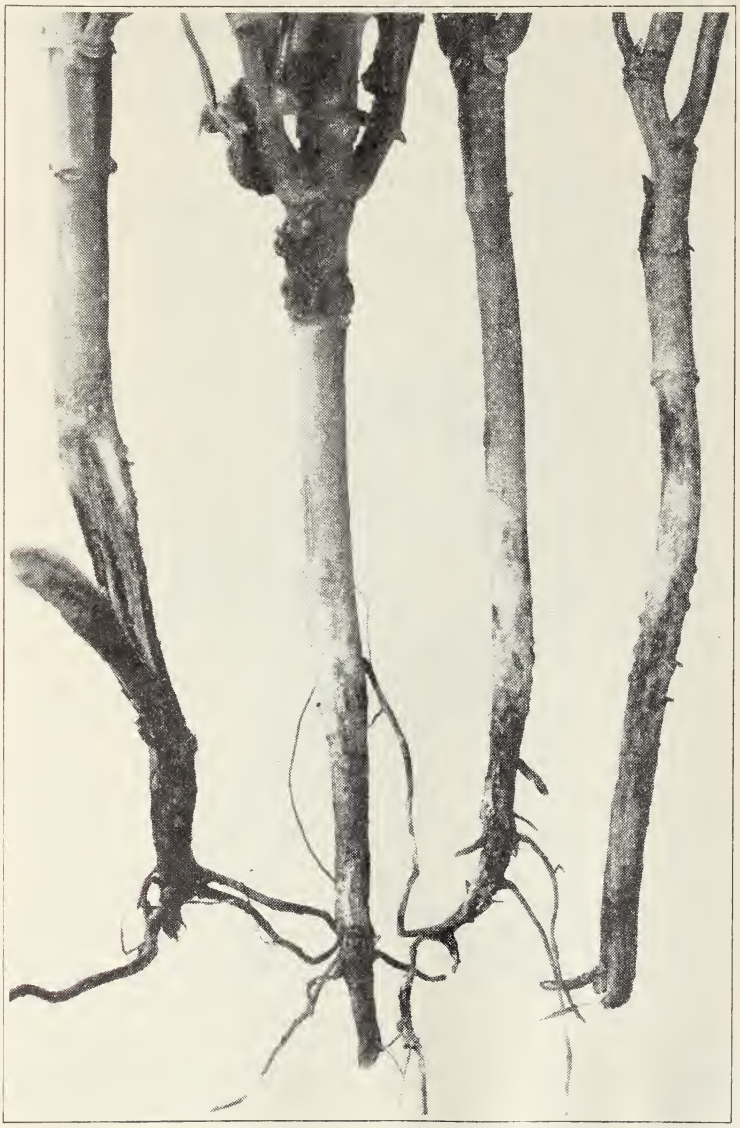

Fig. 5.—Rhizoctonia stem rot of bean.

is of some value in control but has never proved entirely satisfactory. Seedsmen now offer rust-resistant strains of the Kentucky Wonder and other bean varieties. This is the most satisfactory method of control.

**Southern Root Rot.**—The plants attacked by this disease die prematurely and the roots are rotted. Small, brown sclerotia (fig. 9, p. 21) resembling mustard seed may be produced in the soil near the surface of roots. These bodies keep the fungus, *Sclerotium Rolfsii,* alive in the soil. They are much less abundant on beans than on sugar beets or other hosts.

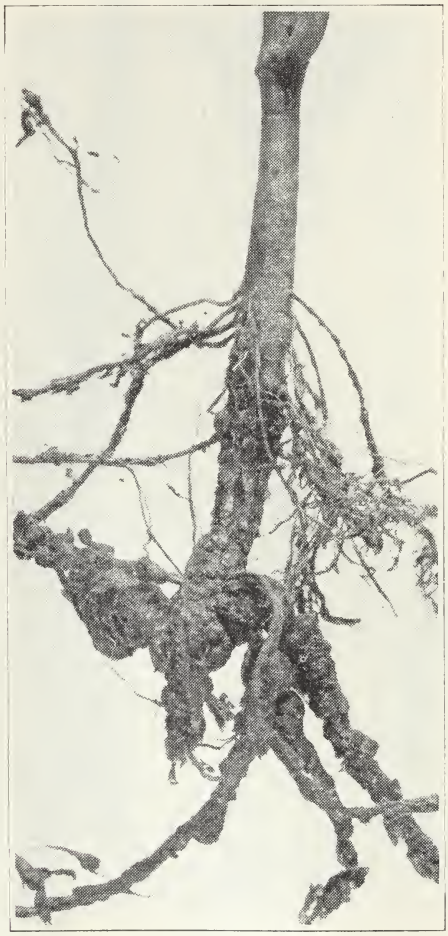

Fig. 6.—Root-knot nematode on bean roots.

In California the fungus attacks many other plants, of which the sugar beet is one of the most important.

Land which is badly infested with this fungus should be summer-fallowed as much as possible for several years. Cereals or vegetables may be grown in the winter. Summer-irrigated crops like beets, tomatoes, carrots, and beans should not be planted.

**Stem Blight, Charcoal Rot.**—This disease causes the death of seedlings that come up during hot weather and also attacks older plants. Dark-brown cankers are formed on the stems of the seedlings, which are usually killed soon after emergence from the soil. On the stems of older plants, the fungus, *Rhizoctonia bataticola,* produces light-gray cankers, speckled with numerous minute black dots. The same fungus attacks the roots of sugar beets, sweet potatoes, strawberries, and other crops, and persists in the soil.

## BEET[7]

### (Sugar Beet, Garden Beet, Swiss Chard, Mangel-Wurzel)

**Bacterial Pocket Disease.**—This bacterial disease has been seen in California on sugar beets but is not serious at present. Large, rough, fissured galls or tumors occasionally develop near the top of the root. This condition, caused by *Phytomonas beticola,* may easily be mistaken for that caused by crown gall, but the galls are inclined to be rougher than those produced in the latter disease and in cross section show pockets containing brown, rotting substance instead of solid, white tissue.

**Charcoal Rot.**—The leaves of affected plants wilt, turn brown, and die. The roots show a brownish-black rot starting at the top of the beets (fig. 7) which reduces them to a mass of dry fibrous tissue, covered by a thin, dry, papery surface layer. This disease is caused by a soil fungus, *Rhizoctonia bataticola,* which also attacks corn, beans, sweet potatoes, and other crops, and which is active only at high temperatures. Consequently its principal importance is in the interior valleys, where it makes its greatest progress in midsummer when extremely hot weather prevails.

Crop rotation is advisable when this or any other root disease of sugar beets becomes prevalent. See Extension Circular 95.

**Crown Gall.**—Beets sometimes show large, smooth galls, or swellings, on the sides of the main roots. This condition is the same as crown gall on fruit trees and is caused by the same bacterial organism, *Phytomonas tumefaciens.* Somewhat similar galls of a more irregular nature are characteristic of the bacterial pocket disease, previously described, which is also caused by a bacterial infection. This trouble is not serious on beets and does not require control.

**Curly Top.**—Beet plants affected by curly top are stunted, dwarfed, and deformed in a characteristic way, the edges of the young leaves roll inward, and the veins are translucent when held toward the light. A rough, warty condition develops on the backs of the leaves. The main roots show a mass of hairy secondary roots and pronounced black rings in

[7] For further information on sugar-beet production, with descriptions and illustrations of certain diseases, see: Robbins, W. W., and Chas. Price. Sugar-beet production in California. California Agr. Ext. Cir. 95:1–78. 35 figs. 1936. (Out of print.)

cross section. All the various plants of the beet family, including sugar beets, table beets, and Swiss chard, are affected by curly top. Many other kinds of plants are also susceptible, the most important being the tomato, in which the disease was first called "western yellow blight." For other

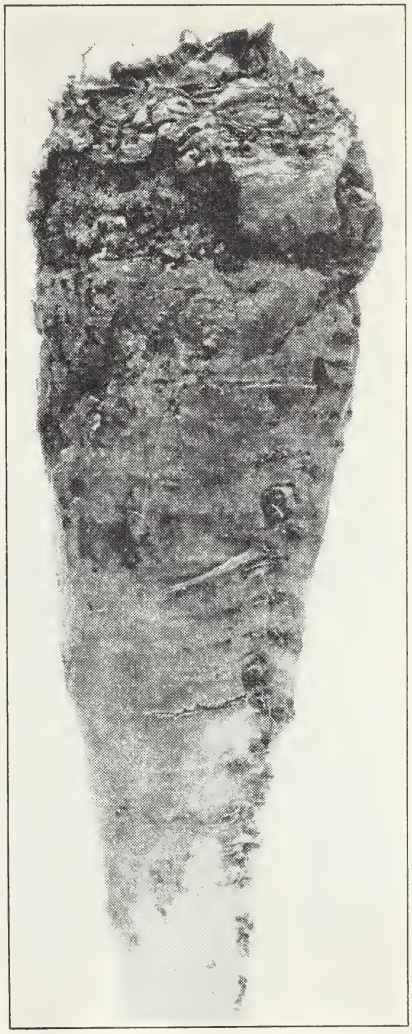

Fig. 7.—Charcoal rot of sugar beet.

hosts, see "Curly Top" (p. 91). Curly top is an extremely sporadic disease, being very abundant and destructive some years and again almost absent. The cause of the disease is a virus. As a rule it is more common in the warmer interior valleys and less troublesome in cool foggy districts near the coast. These facts are explained by the habits of the beet leaf-

hopper, *Eutettix tennellus,* an insect which comes from native vegetation in the foothills and spreads curly top in feeding on the beet plants. This insect is described in California Extension Circulars 87 and 95.

Experience has shown that curly top may be avoided to a certain extent by planting beets in places where the leafhopper is not common, or at times of year when it is not abundant. This varies with different localities but usually means planting as early as possible in the spring. Resistant varieties of sugar beets have been developed and are now being generally planted. Information about these may be obtained from the United States Department of Agriculture Bureau of Plant Industry, Sugar-Beet Investigations, Riverside; or from the Division of Botany, College of Agriculture, Davis; or from the beet-sugar companies. Work is also being done by large beet-sugar companies in destroying the leafhoppers in their winter breeding grounds in the foothills by spraying the native vegetation. Sugar-beet growing on a commercial scale should not be undertaken in any locality without first getting complete information as to the curly-top situation.

**Damping-off.**—Unsatisfactory stands of sugar beets are frequently caused by the attack of various soil fungi upon the germinating seed and young seedlings. The term "damping-off" is used to describe all stages of infection upon seedlings and includes the rotting of seed in the soil, the killing of seedlings before or just after they emerge from the soil, and the infection of older seedlings, usually referred to as "black root" or "blackleg." Damping-off is most commonly caused by species of *Pythium* or *Rhizoctonia* that live in the soil or by a seed-borne fungus, *Phoma betae,* that is found on many samples of European-grown beet seed. With the relatively heavy rate of seeding (15 to 20 pounds per acre) now in general use, satisfactory thinned stands are usually obtained, even where damping-off fungi destroy a high percentage of the seedlings.

Replanting has been the only method of overcoming this trouble. Recently the practice of treating the seed with chemical dusts for control has come into common use with excellent results. The beet-sugar companies in some cases treat the seed for their growers who request it, and several commercial operators make a business of treating seed. The grower may, if he wishes, treat his own seed by rotating it with the correct amount of the dust in a drum mounted on an axle, or in any other device that provides a thorough and uniform coating of the seed. Under most conditions, satisfactory control of damping-off (p. 92) can be secured by treating the seed with Ceresan (p. 104) at the rate of 1 or 1½ pounds for 100 pounds of seed, the larger amount being recommended only when the infestation is severe. New Improved Ceresan (at the rate

of 0.5 pounds per 100 pounds of seed) is, in most cases, equally effective; and where *Pythium* is the chief organism responsible for the seedling infection, red copper oxide (p. 102) at the rate of 3 pounds for 100 pounds of seed will provide adequate protection.

*Caution:* To avoid the possibility of seed or seedling injury, it is suggested that treated seed should not be permitted to become damp or be stored for any length of time before planting. Operators should avoid inhaling or consuming any quantity of the dust. Poultry or farm animals should not be permitted to eat treated seed.

**Downy Mildew.**—In this disease, the inner leaves and seedstalks become curled, dwarfed, and covered with a violet-colored mildew, *Peronospora Schachtii.* Heavily attacked plants are stunted or killed. The disease shows up during the rainy season on sugar and garden beets and is especially bad on fall-planted root beds (stecklings). Newly infected young plants show light-green spots on the upper side of the leaves with mildew on the underside. Usually a few plants here and there in the bed show the first cases, and then the disease spreads through the field. The original cases may come from spores blown in from infected plantings, from overwintering spores that survive in the soil for several years, or from infected seed. In this disease the fungus grows all through the plant and penetrates some of the seeds while they are developing on the mother plant. In stecklings which become infected in the seedbed, the fungus grows down into the root and up again into the new leaves and seedstalks in the field, stunting the plants, reducing the yield of seed, and infecting some of the seed.

In places where beet seed is grown and downy mildew is common, the original infected stecklings in the root bed should be watched for and destroyed. Infected stecklings should also be eliminated at the time of transplanting to fields for seed production. The young stecklings may be sprayed with bordeaux mixture 4–4–50 (p. 100) as soon as the disease appears. Early-planted sugar beets in coastal districts and portions of the interior valleys may be severely injured by downy mildew during seasons of moist weather. Later-planted fields are less affected. No direct control measures can be recommended but some varieties are much less susceptible than others. Information regarding this can be obtained from the Division of Plant Pathology, College of Agriculture, Davis.

**Dry Rot and Leaf Spot.**—This disease is often very destructive on sugar beets grown in places where there is rain in summer; it has caused some rotting of beets in California in certain seasons, but is not important in this state. The fungus, *Phoma betae*, produces light-brown, dead spots on the leaves and a dry rot of the crown of the beet. The fungus is

seed-borne and is found on many samples of European seed but as yet has not been found on American-grown seed. This is one of the causes of damping-off (p. 17).

**Dry Rot Canker.**—See "Seedling Root Rot" below.

**Leaf Spot.**—Leaf spot is not serious in California but sometimes becomes abundant on the leaves of beets growing in moist weather. The leaves of affected beets are marked with gray, dead spots about 1/16 to 1/8 inch in diameter with borders of brown or purple. Moisture and high temperature are favorable to this disease, and it sometimes ruins the foliage of sugar beets grown in places with rain in summer. *Cercospora beticola,* the fungus which causes this disease, is carried on the seed. Another leaf spot on beet, ascribed to the fungus *Alternaria tenuis,* has been reported from southern California. Control treatment is not necessary in California.

**Powdery Mildew.**—Powdery mildew, caused by the fungus *Erysiphe polygoni,* has been reported on sugar-beet leaves but is not serious.

**Root-Knot Nematode.**—The roots of sugar beets are affected by two distinct species of nematodes, the root-knot nematode (*Heterodera marioni*) and the sugar-beet nematode. The latter is discussed on page 23. The former causes good-sized galls or swellings on the main or branch roots of the beet. The same parasite attacks roots of most of the common vegetables, ornamentals, trees, and weeds. It is most destructive in light, sandy soils, but is also abundant in peat soils, where it is frequently referred to as the "potato nematode."

Land badly infested with root-knot nematode should be avoided for planting sugar beets. For further information see page 94.

**Rust.**—Powdery, dark, reddish-brown pustules of spores of the fungus *Uromyces betae* occasionally break out in abundance on the leaves, usually in the wet season or late in the summer. The plants are sometimes stunted, and the leaves of Swiss chard may be made unfit for use by this fungus disease. No method of control has been tried.

**Seedling Heat Injury.**—In this nonparasitic trouble, young beet seedling fall over and die much as in damping-off. The stem just above ground is killed and shriveled (fig. 14, p. 28). This injury is caused by high temperature which burns the tender young stem at this point during periods of hot weather. There is no remedy except replanting.

**Seedling Root Rot.**—A black, dry rot sometimes attacks the roots of young seedlings. In some cases the plants are killed while in others only the lower part of the main root is destroyed and a malformed, fork-rooted beet develops.

The fungus which is responsible, *Corticium vagum,* may also cause a

dry-rot canker of mature beets. This usually starts at cracks or around the bases of secondary roots toward the lower part of the beet, where the brown, dead, woody tissue is marked with fine, concentric, circular, sur-

Fig. 8.—Dry rot canker of sugar beet.

face markings (fig. 8). Beets which have been injured or weakened in some way are more likely to be affected by this disease. The same fungus attacks many other hosts.

This disease is in part the same as that described under "Damping-off" (p. 17). Unless seed treatment is effective in preventing serious injury,

not much can be done except to replant fields that have been badly attacked by the seedling form of the trouble.

**Southern Root Rot.**—In this disease, the roots of growing plants in the field become affected with a rot which spreads from beet to beet. The fungus, *Sclerotium Rolfsii,* develops an abundant white mold on the beets and soil and on this growth are seen a great many small, round bodies of

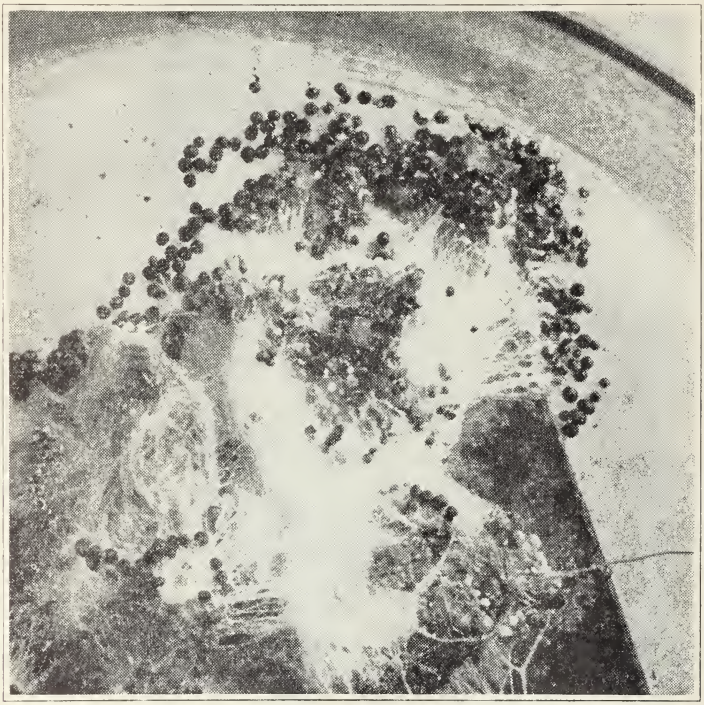

Fig. 9.—Fungus growth and sclerotia of *Sclerotium Rolfsii.* (From Ext. Cir. 118.)

about the size and color of mustard seed. These are the sclerotia (fig. 9), which act as the seeds of the fungus and help to spread it. This fungus attacks many different kinds of plants and persists for years in the soil after it once gets started. It requires rather high temperature and does not develop on plants grown in the winter in California.

Land and crops infested with *Sclerotium Rolfsii* should be handled very carefully to prevent the further spread of the fungus. Bulbs, roots, or rooted plants which have grown in infested soil should not be planted in clean land. The dump screenings and trash and the wash water from sugar beets are also important means of distribution. Dump screenings should not be returned to the fields but should be piled on nonagricul-

tural lands. Wash water should not be run onto clean land. In small areas of land that are already infested, it may be possible to eradicate the fungus by saturating the surface of such spots with formalin, 1 pound to 12½ gallons of water at the rate of 1 gallon or more for each square foot.

Fig. 10.—Wet root rot of sugar beet.

Where there is too much land infested for this to be practical, nothing can be done except to use cropping methods. Badly infested soil may be kept fallow and clean of vegetation for one or more years, or may be planted to alfalfa or some nearly immune crop such as asparagus, or to winter crops such as peas, lettuce, or spinach, winter cereals, or corn. Carrots, beans, potatoes, and lettuce for seed are susceptible. By examining

soil samples collected under the supervision of the sugar companies or the farm advisor, it is possible to estimate the population of the fungus and to predict with reasonable accuracy the amount of disease which can be expected if the field is planted to sugar beets. Nitrogenous fertilizers applied at rates approaching 100 pounds of nitrogen per acre usually provide a partial control, but are recommended only where such applications are also stimulating to the crop. For further information on this subject, consult the Division of Plant Pathology, College of Agriculture, Davis.

**Sugar-Beet Nematode.**—The plants are badly stunted by the attack of this parasitic worm, *Heterodera schachtii,* upon the roots. This species produces no root galls upon its host. In this case the tiny, lemon-shaped, white, female worms can be seen clinging to the roots. Some of the females die while still filled with eggs and become brown, sac-like cysts in which the eggs may lie dormant for many years, a few hatching every year and the larvae escaping from the cyst. The attack of this species of nematode is limited to beets, spinach, Swiss chard, and related weeds, and to cultivated and wild species of the mustard family. It is spread by irrigation water, cultivation, factory waste water, by particles of soil or roots mixed with seed, and by the return of dump screenings to the land.

In land infested with beet nematode, sugar beets should not be grown oftener than once in five years, with alfalfa, barley, beans, or some other nonsusceptible crop between. Weeds which might carry over the pest should be eliminated. Dump dirt and wash water should be handled as advised in the preceding section, "Southern Root Rot."

**Wet Root Rot.**—Sugar beets sometimes show a soft, wet, brown rot of the main roots (fig. 10), starting at the lower end. This is due to a fungus, *Phytophthora Dreschleri,* but usually develops only in low spots in the field where water stands for a long time or where water penetration is impeded by a compact layer of subsoil. Similar fungus diseases caused by species of *Phytophthora* are described under "Crucifers" (p. 42), and other hosts.

Spots where this trouble occurs should be releveled, and overirrigation should be avoided.

## BROCCOLI

See "Crucifers" (p. 36)

## BRUSSELS SPROUTS

See "Crucifers" (p. 36)

## CABBAGE

See "Crucifers" (p. 36)

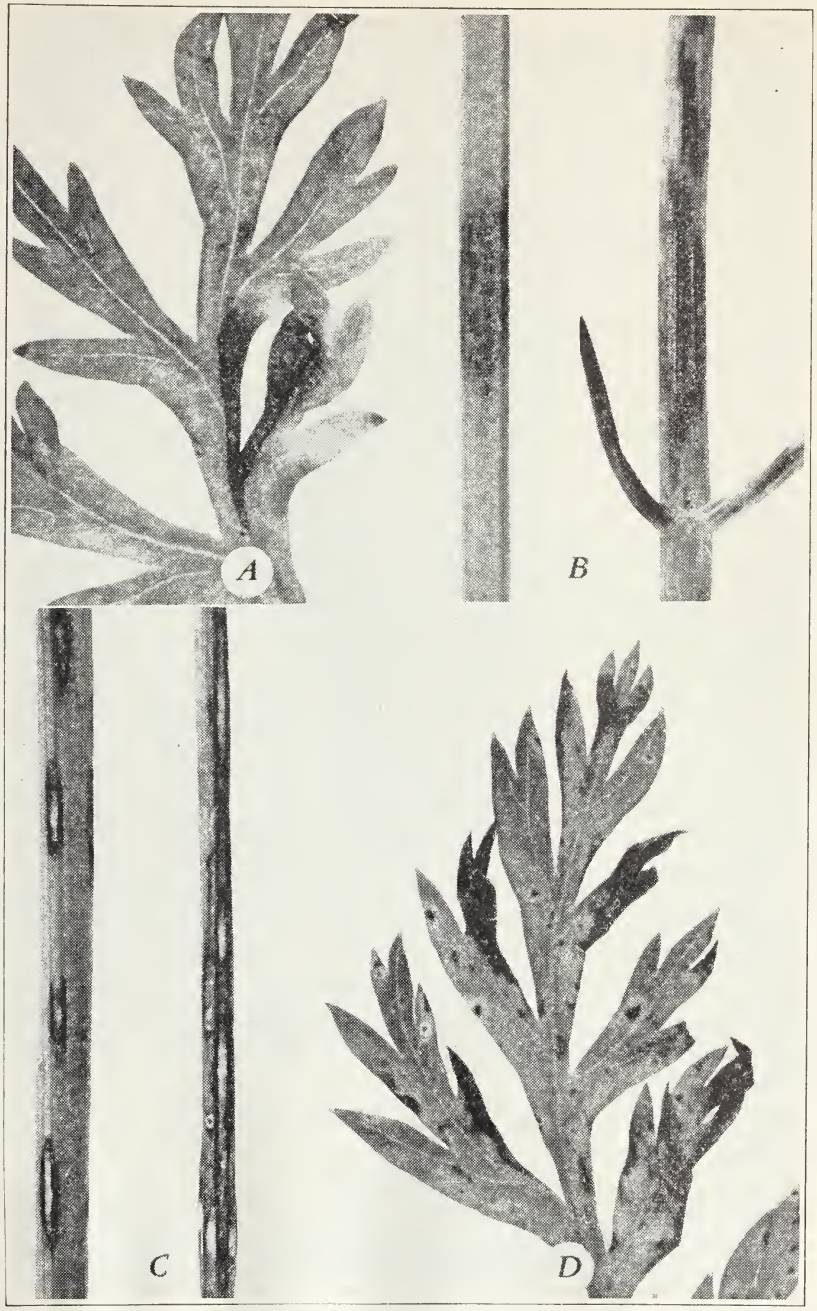


Fig. 11.—Carrot blight: *A*, early (*Cercospora*) on leaf; *B*, same on stem; *C*, late (*Macrosporium*) on stem; *D*, same on leaf. (All enlarged.)

## CANTALOUPE

See "Cucurbits" (p. 45)

## CARROT

**Bacterial Blight.**—In this disease, the principal damage is caused in the flower heads of carrots grown for seed, which may be entirely killed.


Fig. 12.—Spores of carrot-blight fungi: *A*, *Cercospora* spores; *B*, *Macrosporium* spores. (Greatly enlarged.)

Irregular, dead spots appear on the leaves, dark-brown lines on the petioles and stems, and a blighting on the floral parts. Sometimes this bacterial infection, caused by *Phytomonas carotae,* is confined to one side


Fig. 13.—Late (*Macrosporium*) blight of carrot: *A*, on mature leaf; *B*, on cotyledons of very young plants.

of the head, or dark-brown, dead branches occur irregularly. These floral infections cause a contamination of the seed with germs of the disease. Crop rotation and use of clean seed are suggested as possible control measures.

**Blight.**—This is really two distinct fungus diseases, of which one, caused by *Cercospora apii* var. *carotae* (fig. 11, *A* and *B*; fig. 12, *A*), may be called "early blight," while the other, caused by *Macrosporium carotae* (fig. 11, *C* and *D;* fig. 12, *B;* and fig. 13) is correctly described as "late blight." The latter has been much more serious in California, reaching its peak in November upon carrots planted in August. In both, the leafy tops in the field are spotted, blighted, and more or less completely killed, the disease working from the outer leaves inward. In shipment the leaves of affected plants become decayed and "slimed."

In districts favorable to this disease, late (*Macrosporium*) blight can only be controlled in the manner practiced with celery blight, that is, by keeping the tops continuously covered with bordeaux mixture throughout the growing season. Using a 5–5–50 mixture (p. 100), the plants should be thoroughly sprayed about 4 weeks after sowing (since the very young seedlings become infected; see fig. 13, *B*) and thereafter every 7 to 9 days for a total of at least 4 or 5 applications. Dusting with 20–80 copper-lime dust (p. 102) is fairly effective but less so than liquid spraying. Crop rotation is advisable to keep down the disease. Extensive testing of all obtainable carrot varieties has thus far shown none to be resistant.

Early (*Cercospora*) blight is controllable by the same methods, but the disease has not been serious enough to warrant the expense of spraying. In packing carrots for shipment, all blighted leaves should be removed.

**Mosaic.**—Carrots affected with western celery mosaic (p. 31), a virus disease, have been reported in California, but the trouble is not common.

**Root-Knot Nematode.**—This injurious pest (p. 94) often attacks carrots.

**Scab.**—Rough pits and spots sometimes develop on the surface of the roots. This is caused by *Actinomyces scabies* and is the same fungus disease as scab of potatoes. It has been reported on carrots in California in rare instances. Planting carrots on land where scabby potatoes have grown is not advisable.

**Seedling Heat Injury.**—In hot weather, young plants sometimes shrivel and turn brown just at the surface of the ground (fig. 14) and may wilt and collapse as in damping-off. Unlike damping-off, this is a purely physical effect caused by high temperature.

**Soft Rot.**—The roots of affected plants decay with a soft, slimy, bacterial rot caused by *Erwinia carotovora.* This usually follows some injury and may occur either in the field or in storage. In California, market carrots grown as bunch vegetables rarely develop this disease, but carrots transplanted to the field during the fall and winter months for seed production often show serious losses from soft rot. Wet weather after

Fig. 14.—Seedling heat injury of carrot.

transplanting favors the disease. Only sound, healthy carrots, free from injuries, should be used for seed growing.

**Southern Root Rot.**—Carrots are very susceptible to this disease, which is of great importance on sugar beets and other crops (p. 21). The growing plants are killed by a rather firm rot of the roots, the fungus, *Sclerotium Rolfsii,* being visible on and about the affected plants as a whitish mold bearing numerous little mustard-seed-like sclerotia (fig. 9, p. 21). This fungus persists in the soil when susceptible plants like beets or carrots are grown upon it. Carrots should not be planted on land infested with *S. Rolfsii.*

**Watery Soft Rot, Cottony Rot.**—The well-known cottony-rot fungus, *Sclerotinia sclerotiorum,* sometimes attacks carrots growing in the field and causes a rotting of the roots at the surface of the ground. The snowy-white mold growth spreads from plant to plant so that all the carrots are

destroyed in spots or areas where the fungus gets a start. Roundish, solid, black bodies (sclerotia) are seen in the white mold. It is from these bodies that the spores of the fungus are produced. They also serve to perpetuate the organism in the soil, since they are able to remain dormant for considerable periods. See "Cottony Mold" (p. 90) for further discussion.

All the carrots should be pulled out in spots where this fungus is seen, to prevent it from spreading. In land where this disease has been very abundant, neither carrots or celery nor any other very susceptible crop should be planted the following year. When carrots are grown for seed production, cottony rot sometimes becomes abundant in roots held in sacks on account of bad weather. Such carrots should be carefully sorted and all diseased ones discarded. The planting stock should then be dipped in Improved Semesan (p. 104) 1 pound to 7½ gallons of water or Semesan 1 pound to 50 gallons. New solution should be prepared when the old becomes very muddy or half used up.

**Yellows.**—In this virus disease, which is occasionally seen in carrots, the leaves are twisted, stunted, and yellow. The leaflets may be reduced to short scales. This is the same disease as aster yellows; affected parsnips and parsley plants have also been observed. It is not often serious.

## CASABA

See "Cucurbits" (p. 45)

## CAULIFLOWER

See "Crucifers" (p. 36)

## CELERY AND CELERIAC

**Aster Yellows.**—Affected plants are light yellow and stunted, and the stalks, instead of growing upright and close together, branch out in a horizontal position and become very much curled and twisted. This is the same virus disease as aster yellows and rabbit ear of lettuce and is spread by the six-spotted leafhopper, *Macrosteles divisus*. Destroy affected plants if not too abundant.

**Blackheart.**—The inner leaves and heart of affected plants turn black and are often destroyed by a soft rot, which ruins the heads. No bacterial or fungus parasite has been found to be the primary cause of this trouble, but it seems to be connected with irregular moisture conditions like sudden flooding when the soil is dry. Blackheart is avoided by keeping up good, uniform soil moisture to maintain regular growth of the celery, and harvesting as soon as the crop is mature.

**Blight, Late Blight.**[8]—In this disease, the leaves and stems are blighted and have dead areas dotted with small, black, spore pustules (fig. 15). This disease, if not controlled, causes much loss to celery in California, both by stunting the growth of the plants in the field and by causing slimy rot ("slime") of the heads in shipment. It is caused either by *Septoria apii* or by a closely related fungus, *S. apii-graveolentis*. There is a

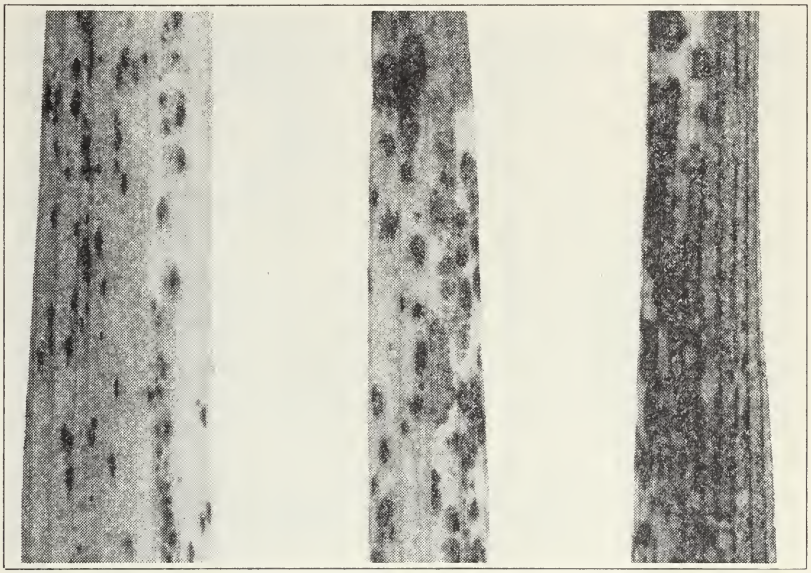

Fig. 15.—Celery blight caused by a species of *Septoria* on stalks.

somewhat similar disease called "early blight" (caused by *Cercospora apii*), which is much less important.

To prevent blight, celery must be sprayed repeatedly with 5–5–50 bordeaux mixture (p. 100) beginning in the seedbed. In places where conditions are very favorable to the disease, it may be necessary to spray once a week. Spraying in the seedbed and early in the season is especially important to keep blight from getting started. In spraying celery, the matter of spray residue must be kept in mind, for there is much prejudice at present against anything which looks like chemical spray materials on articles used for food. On this account it is desirable for celery growers in any given district to learn by experiment the minimum amount of spraying needed to control blight and also to determine the least amount of lime which may safely be used in the mixture.

Dusting with a dry copper-lime dust (p. 102) is also practiced some-

[8] For further information and illustrations see: Rogers, S. S. The late blight of celery. California Agr. Exp. Sta. Bul. 208:83–115. 17 figs. 1911. (Out of print.)

times for control of celery blight, but ordinarily this method is not as satisfactory as spraying. A mixture of 20 pounds of monohydrated copper sulfate with 80 pounds of hydrated lime is commonly employed.

**Cottony Rot, Pink Rot.**—The plants sometimes wilt and die on account of a soft rot of the stems and roots, usually starting near the crown on the outer stalks. At this point, a white, cottony fungus, *Sclerotinia sclerotiorum,* grows out over the surface and may spread from plant to plant. In this are seen the black bodies called "sclerotia." Often, affected tissues show a light-pink color. See "Cottony Mold" (p. 90) for more complete description of the fungus.

There is little which can be done to prevent the occasional development of cottony rot in celery fields when humidity and temperature conditions are favorable. It is not advisable to plant celery on land where this rot was serious the previous season. Affected plants should be removed from the field as soon as detected.

In shipment of celery, this disease, often referred to as "watery soft rot," is sometimes very destructive. Temperatures below 40° Fahrenheit retard growth of the fungus. Great care should be exercised to avoid packing any heads affected with cottony rot.

**Fusarium Yellows.**—As with aster yellows, plants affected by fusarium yellows are stunted and yellow, but usually more so on one side. There is a brownish discoloration of the woody tissue of the stems. This is a fungus disease caused by *Fusarium orthoceras* var. *apii.* When it gets started in a field, the soil becomes infested with the fungus so that susceptible varieties of celery can no longer be profitably grown.

If yellows develops in the seedbed, the soil should no longer be used for growing celery plants. Good varieties of celery resistant to yellows are now available. In general, green varieties are less susceptible than yellow ones. But Florida Golden and Golden Pascal are highly resistant yellow varieties and another called "Michigan Golden" has recently been developed. For latest information, write to the Division of Plant Pathology, College of Agriculture, Davis.

**Hollow Stem.**—The stems, especially the outer ones, sometimes become pithy and hollow so that the head is worthless or requires stripping off of all the outer stalks. This condition appears to be caused by irregular growth of some sort, such as checking caused by cold or drought.

**Mosaic, Western Celery Mosaic.**[9]—The young leaflets of plants attacked by this virus disease are mottled with green and yellow areas (fig. 16) and in advanced stages become narrow, twisted, and cupped.

[9] For a technical discussion of this disease, see: Severin, Henry H. P., and Julius H. Freitag. Western celery mosaic. Hilgardia 11:493–558. 9 figs. 8 pls. 1938.

The plants are stunted, the central leafstalks being shortened and the outer ones assuming a horizontal position. The disease is most prevalent during the summer months and is spread by aphids from plant to plant. No wild host plants are known, but carrots and celeriac are susceptible.

Several other mosaiclike diseases of celery are distinguished in Cali-

Fig. 16.—Western celery mosaic.

fonia, including those called "calico," "yellow spot," and "ring spot," as well as aster yellows (p. 29) and spotted wilt (p. 33). These are much less important than western celery mosaic, which is a serious disease in most celery-growing districts of the state.

Spraying to control aphids may help to prevent the spread of mosaic. For this purpose, nicotine may be added to the sprays used for blight (p. 30). In one part of the state, the control of mosaic has been attempted by the legal establishment of a "celery-free period" of 3 months, during which time no celery plants are allowed to exist in the district.[10] Such

[10] See: Milbrath, D. G., and Harold J. Ryan. A method of control of western celery mosaic. California State Dept. Agr. Bul. 27:290–95. 1938.

a period is expected to eliminate the principal source of mosaic infection: growing celery plants. It is thought that much benefit has been obtained by this procedure, which comes within the jurisdiction of the county agricultural commissioners and the State Department of Agriculture. In any district which is free from this disease, no celery plants should be brought in from outside.

**Root-Knot Nematode.**—The roots attacked by this pest are covered with galls or swellings and the plants are stunted. This is the common garden nematode, *Heterodera marioni,* which has a great variety of host plants.

In places where celery is troubled with nematode, great care should be taken that the soil of the seedbed is free from anything which might introduce the pest. Infested fields should not be planted to celery or any other vegetable or susceptible host but may be used for summer-fallowed winter cereals for one or more years. The soil must be kept clean of all plant growth in summer, to starve out the nematode. See page 94.

**Root Rot.**—A black rot, caused by the fungus *Phoma apiicola,* sometimes attacks the crown, leafstalk bases, and roots of the plant, usually near the ground level. The plants are stunted and the outer leaves or the whole plant killed, or the roots may rot off so that the plant falls over or maintains itself only by sending out a few new roots (fig. 17).

Where this disease is of serious consequence, fresh soil should be used for the seedbed, and celery should not be grown again immediately in infested soil.

**Soft Rot, Slime.**—This is a bacterial disease of celery in transit in which the leaves, stalks, and crowns go down with a soft, mushy rot. This is caused by *Erwinia carotovora* but usually starts in dead spots caused by blight or cottony rot, sometimes in cuts or bruises.

To prevent soft rot in transit, fungus diseases like blight should be controlled in the field by spraying. In celery being packed for shipment, all leaves or stalks showing spots or blemishes should be stripped off. Thorough icing helps greatly to keep down soft rot.

**Spotted Wilt.**—In this virus disease, the leaves show yellow areas, which turn brown and die. Prominent dead streaks or pockets of dead tissue develop on the stalks and ruin the heads for sale. This serious disease (see p. 97) of tomatoes, lettuce, and other plants sometimes develops on celery in the close vicinity of other affected hosts but cannot be considered common on this crop. No control is known except to avoid planting in areas where spotted wilt is prevalent.

**Yellows.**—See "Aster Yellows" (p. 29) and "Fusarium Yellows" (p. 31).

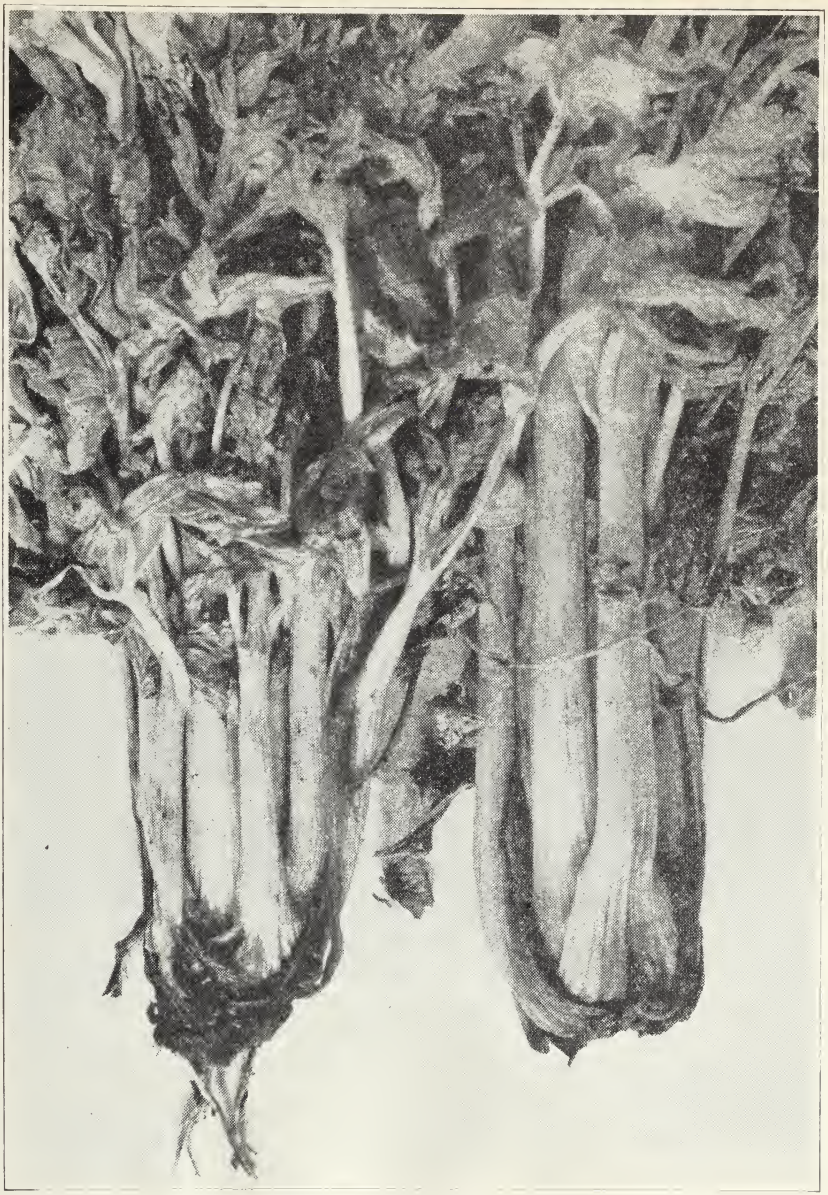

Fig. 17.—Root rot of celery.

## CHARD

See "Beet" (p. 15)

## CHINESE CABBAGE

See "Crucifers" (p. 36)

## CITRON

See "Cucurbits" (p. 45)

## CORN[11]

**Bacterial Stalk Rot.**—This disease has been found in California only in districts near the coast. The lower leaves of affected plants turn yellow and rot off where they join the stalk. The same dark-brown, soft, bacterial rot affects the stem, usually starting near the first joint above ground. In severe infections, the whole stalk rots off and topples over. The disease is caused by *Phytomonas dissolvens* but is favored by high temperatures and humidity.

Land in which this disease has occurred should not be used again for corn for several years. Seed should not be taken from an affected field. Seed corn may be disinfected with corrosive sublimate solution (p. 103) or one of the proprietary organic mercury dusts like Ceresan or Semesan (p. 104). If this disease, which is new in California, becomes serious, one should write to the Division of Plant Pathology, College of Agriculture, Berkeley, for the latest information on control.

**Bacterial Wilt, Stewart's Disease.**—In this disease, the plant gradually withers, usually beginning with the lower leaves. A cross or longitudinal section of the stem shows a yellow slime oozing from the fibrous vessels. This is composed of the bacteria—*Phytomonas Stewartii*—which cause the disease. Golden Bantam sweet corn is very susceptible but a variety called "Golden Cross Bantam" is said to be resistant.

To control, destroy all infected plants and refuse. Do not grow sweet corn on the same land the next year.

**Brown Spot.**—Brown spot has but recently been observed in the state. Reddish-brown spots and blotches appear on the leaves and stalks, which sometimes become blighted and killed. The cause of the disease is a fungus, *Physoderma zeae-maydis,* which lives in the superficial plant cells.

[11] For further information on corn diseases see:

Brown, J. G., and R. B. Streets. Diseases of field crops in Arizona. Arizona Agr. Exp. Sta. Bul. 148:85–228. 58 figs. 1934.

Mackie, W. W. Diseases of grain and their control. California Agr. Exp. Sta. Bul. 511:1–87. 46 figs. 1931. (Out of print.)

Melchers, L. E. Smuts of cereal and forage crops in Kansas and their control. Kansas Agr. Exp. Sta. Bul. 279:1–37. 17 figs. 1938.

Corn should not be planted the following year on land where this disease has been abundant.

**Dry Rot, Stem Rot.**—Affected plants are weakened and mature prematurely, which causes lodging and reduction of yield. The fungus, *Rhizoctonia bataticola,* develops inside the stem near the surface of the ground and may be recognized by the small, black specks which develop in the pith. This disease is not serious enough to require treatment.

**Ear Mold, Pink Rot.**—This disease causes the ears to mold in the field, the kernels becoming crusted together with fungus growth. It ruins the corn or impairs germination the following season. It occurs especially in late-maturing corn, in seasons of early rain, or in fields heavily irrigated late in the season. Any of several fungi may be responsible, especially *Diplodia zeae* and *Fusarium moniliforme.*

Early-maturing varieties are advisable in places where ear mold is likely to occur. Overirrigation should be avoided; harvesting and curing done as early as possible. Seed corn is best selected in the field, only sound ears being used; and it should be stored in a dry place. Each ear should be tested by germinating several kernels and all ears not showing good germination rejected. When the disease is very troublesome, seed may be treated with one of the mercury dusts like Semesan Jr., Merko, or Ceresan (p. 104) with good results. Old debris of the preceding crop in the field should be burned or plowed under.

**Rust.**—Symptoms of this disease are long pustules of dark-red, dusty, rust spores on the leaves. This fungus disease, caused by *Puccinia sorghi,* is not a very serious one in California, and no treatment is required.

**Smut.**—Two fungus smuts attack corn. In boil smut, caused by *Ustilago zeae,* large, fleshy, irregular swellings appear on the stems, ears, and heads. These are at first covered with a whitish membrane which bursts at maturity and sets loose a mass of dusty, black, spore powder. In head smut, caused by *Sorosporium Reilianum,* the plant is stunted and the tassels and ears are transformed into masses of dusty smut spores. This disease also attacks sorghum, but on corn is not seen so frequently as boil smut.

Diseased plants or parts should be destroyed and not mixed with the soil or manure. Seed treatment is not effective for either disease.

## CRUCIFERS

**(Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Chinese Cabbage, Kale, Kohlrabi, Raddish, Rutabaga, Turnip)**

**Alternaria Leaf Spot, Black Leaf Spot.**—Gray or black, dead spots of considerable size, mostly on the outer leaves, are a symptom of this disease. The heads of cauliflower are sometimes attacked. This fungus

disease, caused by *Alternaria brassicae,* is not usually serious, and no control method is practiced.

**Bacterial Spot.**—The leaves of affected cauliflower or cabbage are peppered with small brown or purplish spots. The most serious phase of the disease, caused by *Phytomonas maculicola,* takes the form of brown, de-


Fig. 18.—Cauliflower injured by bacterial spot.

cayed spots on the white heads of cauliflower (fig. 18), lowering their value or ruining them entirely for market. This is sometimes abundant especially on overripe or frost- and rain-damaged heads. During protracted rainy periods, considerable damage is caused to cauliflower plants intended for seed purposes. Many growers produce their own seed. Some winters this disease is extremely serious and damaging since the decay progresses rapidly and ruins the plant. There is no practical control method for this disease.

**Black Leg.**—Light brown, dead areas or cankers on the main stem are the early symptoms of black leg; later these spread to the leaves and stalks. Numerous tiny, black spore dots of the fungus, *Phoma lingam,* appear on

the surface of the dead areas. The stem cankers finally turn black, girdle the main stem, rot the stem and root, and kill the plant. This fungus disease is mentioned here because, like cabbage black rot and yellows, it is one of the most destructive diseases of cabbage and related plants in many parts of the United States, but in California it is unknown.

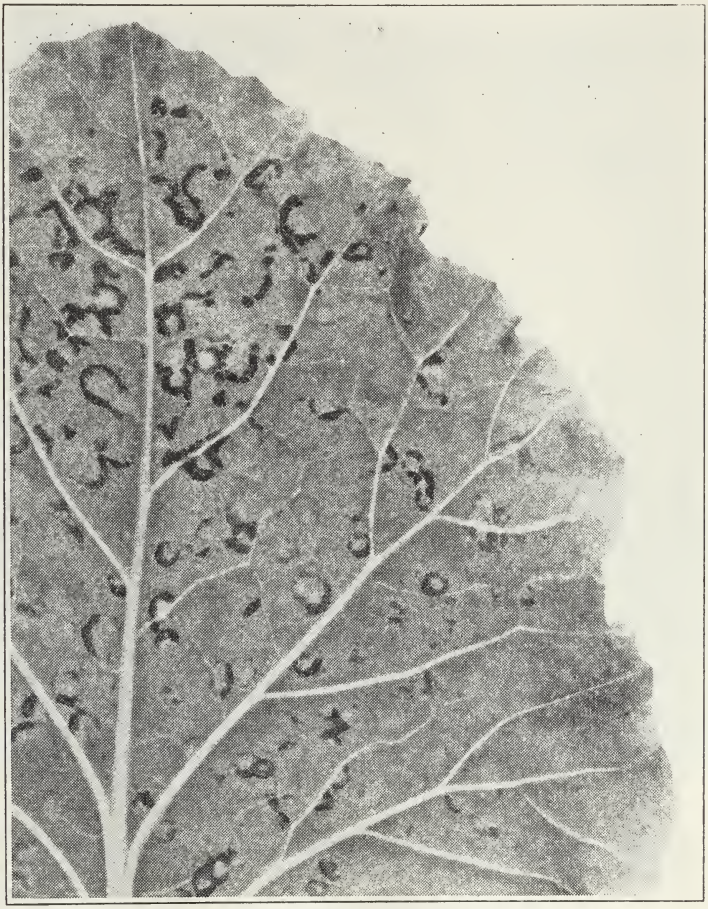

Fig. 19.—Cabbage black-ring disease.

Black leg is controlled by the methods of seed treatment given under "Control of Crucifer Diseases" (p. 44).

**Black Rot.**—Withered leaves, with dry, leathery tissue and dark-brown discoloration in the veins running down into the woody part of the stem are an indication of black rot. This disease, caused by *Phytomonas campestris,* does not itself produce a soft rot or offensive odor, but it is usually followed by secondary effects of this nature. After soft rot sets

in, the head of the plant may drop off and leave a bare stump. Black rot is a very serious bacterial disease of cabbage in many parts of the United States but is rare and unimportant in California. This may be due to the fact that cabbage and cauliflower are grown here mainly during the winter or in places near the coast; the disease is favored by high temper-

Fig. 20.—Cauliflower mosaic on seedling and older leaves.

atures. Black rot is controlled successfully by seed treatment and other precautions given under "Control of Crucifer Diseases" (p. 44).

**Cabbage Black Ring.**—Infected plants are sometimes dwarfed, but the principal damage from this virus disease results from necrotic spotting of the outer or older leaves which must be removed before marketing. When the spots first appear, they are green and vary from 1/16 to 1/8 of an inch in diameter; later a brown ring surrounds the green centers; finally the spots turn dark-brown to black, with fusing of several or more spots not uncommon. The disease is destructive on cabbage (fig. 19) grown during the winter months in the coastal and inland valleys. Cauliflower is also affected: on this host the disease has been called "ring mosaic" and "necrotic ring mosaic."

The cabbage aphid is responsible for dissemination of the virus and

can be controlled by dusting or spraying with nicotine (Black Leaf 40). (See Extension Circular 87.)

**Cauliflower Mosaic.**—The leaves of mosaic plants are mottled, distorted, and frequently covered by small, dead areas (fig. 20). Plants are stunted and seldom produce heads of marketable size unless infection

Fig. 21.—Club root on turnip.

occurs very late. All commercial varieties of cauliflower grown in California are susceptible. Cabbage and peach aphids, which breed naturally on this host, readily transmit the causal virus to healthy plants after feeding on diseased leaves.

Losses could be materially reduced by dusting or spraying with nicotine for aphid control while the plants are young, with applications at 10-day intervals (see Extension Circular 87). Plants showing visible symptoms (fig. 20, top) should not be put out in the field.

**Club Root.**—This is another important fungus disease which, for some unknown reason, is extremely rare in California. It is caused by *Plasmodiophora brassicae*. Affected plants are yellow and sickly and wilt

during hot days. The roots develop large, irregular galls or swellings (fig. 21) which finally rot with a foul odor.

Seed treatment is not effective. The use of clean seedbed soil is of greatest importance so that the plants may be free from infection when put out in the field. Heavy applications of lime are beneficial on infested soil.

**Cottony Rot.**—The fungus *Sclerotinia sclerotiorum,* which is mentioned under "Celery," "Lettuce," and other hosts, sometimes attacks cabbage, cauliflower, and other crucifers. A rotting of the stem and head is produced, with the typical cottony, white fungus and black sclerotia described under "Cottony Mold" (p. 90). This disease occurs very sporadically and is not subject to control.

**Downy Mildew.**—This common disease of cabbage, cauliflower, and related plants produces on the older leaves spots which are at first yellow and later turn brown with bluish-black, lacelike markings. A velvety, white, fungus mold, *Peronospora parasitica,* develops on the surface at the edges of the spots in moist weather. With age, infected leaves turn brown and the plants in the field appear to have been scorched by fire. Heavy infection seriously affects marketing.

The injury in most seasons is not sufficient to require treatment. Spraying with 4–4–50 bordeaux mixture (p. 100) or dusting with 20–80 copper-lime (p. 102) has been suggested. Bordeaux mixture is sometimes injurious to cauliflower.

**Powdery Mildew.**—The surface of infected leaves becomes covered with white mildew fungus (*Erysiphe polygoni*). It is most common on cabbage in coastal areas and also on turnips and other related plants.

This disease, like other powdery mildews, might be controlled by dusting with sulfur when it first appears, but such treatment is not often necessary in this case.

**Rhizoctonia Root Rot.**—Damping-off in seedbeds is sometimes caused by the fungus *Corticium vagum,* and the disease may persist in older plants. In the latter, the fleshy bark tissue of the stem below ground dies and dries down to the wood in a hard, dark-colored, leathery condition, either on one side or entirely girdling the stem. The plant is eventually stunted or killed. The same disease attacks sugar beets, potatoes, and other crops.

To avoid this disease, use plants which have not been affected by damping-off in the seedbed; see page 92.

**Ring Spot.**—The ring-spot fungus, *Mycosphaerella brassicicola,* causes round, dead spots on the leaves, from very small up to nearly ½ inch in diameter. Each spot is surrounded by a green ring and has minute black spore dots on the surface (fig. 22). This fungus disease attacks most of

the cruciferous crops in the coast districts of California but is not usually serious enough to require treatment. On broccoli, brussels sprouts, and cauliflower, it sometimes disfigures the leaves rather badly and increases during transit to market. Spraying with bordeaux mixture 4–4–50 (p. 100) when the plants are young and before the disease appears has been

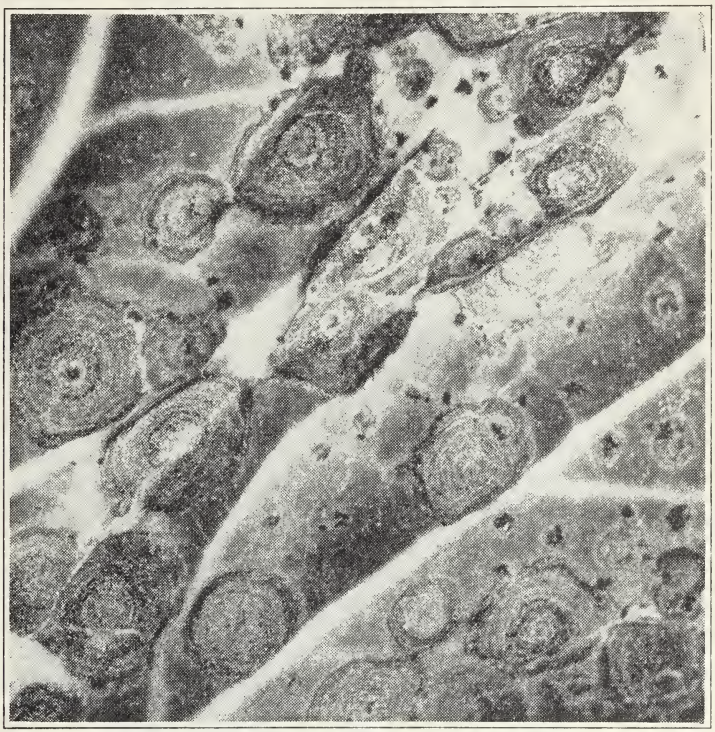

Fig. 22.—Ring spot on cauliflower leaf.

tried, but no very definite results have been observed. A spreader (p. 105) should be added to the spray.

**Root Rot.**—Diseased plants wilt suddenly (fig. 23), and the leaves turn red to purple, with a rotting of the underground part of the stem and root system. Plants of all ages are susceptible. This disease, which is caused by a fungus, *Phytophthora megasperma,* occurs in winter plantings of cauliflower, cabbage, brussels sprouts, and related plants in the coastal regions. Low, excessively wet or poorly drained areas and low temperatures favor infection.

This trouble can best be prevented by proper leveling of the field before planting to avoid low areas which are subject to waterlogging.

**Virus Diseases.**—In addition to the two crucifer virus diseases pre-

viously discussed (cabbage black ring and cauliflower mosaic), others occur in California and are destructive to cultivated crops of this group; among these may be mentioned the mosaic viruses of horseradish, radish, mustard, Chinese cabbage, and turnip.

Control of aphids (see Extension Circular 87) and destruction of af-

Fig. 23.—Cauliflower plants affected by root rot in a low, wet corner of the field.

fected plants is the only method known at present for holding these virus diseases in check.

**White Rust.**—In this disease, the stems, leaves, or flower stalks may be swollen and deformed. White, blisterlike, spore pustules of the fungus, *Albugo candida,* appear on the surface. The disease is not often serious, but is most common on radish and certain cruciferous weeds like shepherd's purse. Affected plants should be destroyed.

**Yellows.**—This is a very serious disease of cabbage in many parts of the country but, like several other cruciferous diseases, is practically unknown on this crop in California. It is common here in certain districts on kale, possibly on account of higher temperatures during the growing season. Affected plants have a yellow, sickly, dwarfed appearance, sometimes on only one side, and the leaves wither and drop off one by one, beginning with the lowermost. If the plant survives, it may become an elongated, naked stalk with a small tuft of leaves at the top. A

cross section of a stem affected with yellows shows brown, discolored, woody tissue. The soil becomes so thoroughly infested with the fungus, *Fusarium conglutinans,* that susceptible plants can no longer be grown in it. Most of the related crops are affected.

Cabbage yellows has been successfully controlled by the development of resistant varieties, so that in places where the disease formerly made cabbage growing almost impossible, it is no longer a problem. Seed of such varieties can be obtained from seedsmen in districts where this disease is important under the name "yellows resistant." For yellows in kale, resistant strains of this crop for poultry feeding have been developed by the Division of Plant Pathology at the College of Agriculture, Davis, where seed may be obtained. Susceptible crops should not be grown continuously on the same soil.

**Control of Crucifer Diseases.**—It is fortunate that in California, where cruciferous vegetable crops such as cauliflower, broccoli, cabbage, and brussels sprouts are grown so extensively, the most serious diseases of these crops like black leg, black rot, club root, and yellows are rare or unknown. All the more for this reason, however, growers should guard against the development of these troubles. With this in mind, certain precautions are advisable. In the seedbed, fresh land should be used and special care be taken not to mix any old plants or refuse of cabbage, cauliflower, or related plants into the soil.

Seed treatment may be advisable, especially if there is much danger of black leg or black rot. To prevent these diseases, the seed, in loose, cheesecloth bags containing not over ¼ pound of seed each, should be thoroughly wet and soaked for ½ hour in a solution of corrosive sublimate 1 ounce to ¾ gallons of water (1–1,000) in a wooden vessel. After this treatment, the seed should be rinsed in clean water and spread out to dry. This should not be done over a hot stove or in strong sunlight.

A more drastic treatment for seed-borne parasites which penetrate the inside of the seed is furnished by the hot-water dip method. The bags of seed are soaked in water at 122° Fahrenheit, the temperature being kept up by occasionally adding hot water and stirring with a thermometer to be sure that 122° is not exceeded. Cabbage seed should be soaked for 25 minutes and related seeds for 18 minutes. The seed should then be spread out to dry. This treatment will injure the seed more or less, especially if it is more than one year old. The usual methods for prevention of damping-off in the seedbed should also be applied. See page 92.

In pulling seedbed plants, any which show signs of disease should be rejected. If a seedbed contains large numbers of diseased plants, all

plants from it should be discarded; or at least that portion of it where the disease is abundant should be discarded, and the disease identified before putting out even the healthy-looking plants in the field. Land which has been in a cruciferous crop the previous year and where there have been any serious diseases like black leg, black rot, or yellows, should not be put back immediately into crops of the same kind, but may be used for tomatoes, celery, peas, beans, alfalfa, corn, grain, or any other noncruciferous crop. Spraying of crops like cabbage or cauliflower for the control of leaf diseases such as downy mildew or ring spot has never proved very successful. Bordeaux mixture 4–4–50 (p. 100) is sometimes recommended for this purpose. The addition of some sticker (p. 105) improves its effectiveness.

Control of aphids by spraying or dusting with nicotine is highly desirable, both on account of the direct injury caused by these insects and the fact that they are carriers of virus diseases. Treatment should begin in the seedbed. See Extension Circular 87 for details.

## CUCUMBER

See "Cucurbits," below

## CUCURBITS

**(Cantaloupe, Casaba, Citron, Cucumber, Gourd, Honeydew Melon, Muskmelon, Persian Melon, Pumpkin, Squash, Watermelon)**

**Bacterial Wilt.**—Leaves wilt and die and finally the whole plant is killed. On cutting across the petioles, a sticky ooze, consisting of millions of microscopic bacteria, *Erwinia tracheiphila,* can be seen exuding from the fibers. The infection is spread by leaf-biting insects but is not common in California. Most cucurbits except watermelons are susceptible.

Control is by destroying cucumber beetles and other insects, also by spraying with bordeaux mixture (p. 100) or dusting with copper-lime (p. 102) and nicotine.

**Cantaloupe Wilt.**—This serious disease has not yet appeared in California but is known in several other states. It is apparently seed-borne and may be introduced in this manner. Cantaloupe plants affected with this disease wilt, wither, and die at any age in a manner similar to that seen in watermelon wilt. The soil becomes infested so that cantaloupes can no longer be grown successfully. The fungus which causes this disease, *Fusarium bulbigenum* var. *niveum* f. 2, cannot be distinguished in culture from that of watermelon wilt (p. 49), but they are sufficiently different so that neither one has an effect upon the other

host. That is to say, watermelons are not affected in soil where cantaloupes are killed and vice versa. The Persian, Honeydew, Honey Ball, and Casaba types are reported to be relatively resistant to both types.

A disease of this type affecting an important California crop is significant enough to warrant some effort toward keeping it out of the state by guarding against the introduction of infected seed. When the disease is once established, the affected crop must be continuously grown on new land to avoid severe losses. Any crop except cantaloupes (even watermelons) will be safe on infested soil. The Minnesota Agricultural Experiment Station has been carrying on work for several years in breeding to develop resistant melon varieties. The basis of this work lies in crossing cantaloupes with the resistant melon types mentioned above.

**Cottony Rot.**—This disease causes plants to wilt and die and show a rotting in the stem at the surface of the ground. The fungus *Sclerotinia sclerotiorum,* may be seen at or may be cultured from this point. The same organism causes green rot of apricots, cottony rot of lemons, and many other diseases (see "Cottony Mold," p. 90). It is a white, cottony mold with small, black, tuberlike bodies or sclerotia imbedded in it.

This disease is not often serious enough in the open field to warrant any treatment. In the greenhouse it may be necessary to change or disinfect the soil (p. 92) on account of this and other diseases and pests.

**Curly Top.**—The young terminal leaves of curly-top plants become curled and stunted and are of a darker green than normal. The older leaves are yellow. This virus disease, which is the same as curly top of the sugar beet (p. 15), has been seen only in the vicinity of badly affected beet fields.

**Damping-off.**—When young plants wilt and die from a rotting in the stem, the disease is called "damping-off." It is caused by a number of fungi, including *Pythium, Phytophthora, Rhizoctonia,* and *Fusarium* species. With cucurbits, it is troublesome only in the greenhouse.

The control of this disease, so common in many kinds of seedlings, is a matter of care in watering and, to some extent, may be accomplished by chemical treatment of the soil (p. 93).

**Downy Mildew.**—This disease has been seen rarely in the southern coast regions of California but never in the interior-valley melon districts. It should not be confused with powdery mildew, which is an entirely different disease. In plants affected by downy mildew, spots, at first yellow, appear on the leaves; these enlarge and become dark-brown or black, and eventually kill the leaves. The spores of the fungus, *Pseudoperonospora cubensis,* develop on the underside of these spots and

are visible to the eye in moist weather as a violet-gray, delicate mold. First the center of the hill is defoliated and finally the whole plant.

No treatment is needed but in more humid regions applications of bordeaux mixture (p. 100) or copper-lime dust (p. 102) are made.

**Leaf Blight, Rust, Anthracnose.**—In these diseases, the leaves show black spots which enlarge and kill the whole blade, starting in the center of the hill. Finally most of the leaves dry up and the fruit is stunted and worthless. These fungus diseases and other leaf troubles are not always distinguishable from each other without the aid of a microscope unless one is familiar with their symptoms. In anthracnose, caused by

Fig. 24.—Squash mosaic.

*Colletotrichum lagenarium,* the melons may also be spotted, and may begin to rot. The name "rust" is sometimes applied to the leaf blight, or alternaria leaf spot, caused by *Macrosporium cucumerinum,* but there is no true rust on any of the cucurbits. None of these troubles occur in the interior valleys of California, but they are not unknown in the coast districts.

Thorough spraying with 4–4–50 bordeaux mixture (p. 100) as soon as any leaf spotting is seen is recommended for the control of all these diseases.

**Mosaic.**—The young leaves of mosaic plants are stunted and deformed, and mottled with yellow and green (fig 24). The fruit is also deformed and mottled in color. The disease, caused by a virus, is spread

by aphids. Transmission through the seed sometimes occurs. Where this disease occurs, affected vines should be destroyed.

**Powdery Mildew.**—The leaves become covered with white mold growth of the fungus *Erysiphe cichoracearum,* and the plants are stunted and weakened. This disease, which attacks all the plants of this family, is important on cantaloupes in Imperial Valley, and sometimes serious on cucumbers in all parts of California, but usually develops late in the season and does not cause much damage or require treatment on other crops of this group.

Good varieties of cantaloupe resistant to mildew have been developed, but there has been some indication that this resistance is breaking down. For further information, write to the Division of Truck Crops, College of Agriculture, Davis. Dusting with sulfur, the usual treatment for powdery mildew, cannot be practiced on cantaloupes because of injury to the plants. With cucumbers growing in fairly cool localities, light applications of sulfur give some control of mildew without serious damage to the leaves.

**Root-Knot Nematode.**—The plants are stunted and the roots covered with large and small, irregular, roundish swellings or galls (fig. 38, p. 87). Cucumbers and melons are very susceptible to this common pest, the root-knot or garden nematode, *Heterodera marioni.*

Cucurbits should not be planted in nematode-infested soil. In greenhouses such soil should be changed or disinfected (p. 92).

**Root Rot.**—In root rot, the lower leaves turn yellow and wilt, after which all the other leaves on the vine wilt and the plant dies. A soft surface rot of the stem is found at the surface of the ground. Squashes, pumpkins, watermelons, and gourds are affected. Fruits in contact with the soil may be attacked directly and caused to rot by this fungus, a species of *Fusarium.* The disease is readily transmitted by seed taken from affected fruit and is common in the coast counties of California.

Nothing can be done to prevent the development of this disease on susceptible plants in infested soil. Great care should be taken to avoid taking seed for planting from affected vines or fruit.

**Verticilliosis.**—The leaves wilt and wither and the plant dies. The fungus, *Verticillium albo-atrum,* first attacks the roots from the soil, then grows up through the woody tissue of the stem and produces there a black discoloration. Many other kinds of plants are susceptible to this fungus, which causes important diseases of tomato, apricot, raspberry, potato, chrysanthemum, and numerous others. Wilt diseases caused by *V. albo-atrum* have been reported on most of the cucurbits in various parts of the world, and in California on watermelon and Persian and

other melons. Thus far, however, the disease has not been a serious one. If such a disease should become abundant on watermelon, the situation would be complicated since varieties which are resistant to *Fusarium* wilt (see the next disease) might be very susceptible to *Verticillium*. For further information see under "Tomato" (p. 87).

Melons should not be planted for several years on land where this disease has appeared. Tomatoes should be avoided in the rotation. Cotton and potatoes may also be important carriers.

**Watermelon Wilt.**—Affected watermelon plants wilt, wither, and completely die, sometimes after reaching good size. The fungus, *Fusarium bulbigenum* var. *niveum,* increases in infested soil, so that if planted continuously, susceptible crops can no longer be grown in such areas. The watermelon is the only host of this disease in California.

Varieties of watermelons which are resistant to this disease have been developed in several parts of the country. Those interested in obtaining such seed in California should write to the Division of Truck Crops, College of Agriculture, Davis. Susceptible varieties should not be planted on infested soil.

## EGGPLANT

**Gray-Mold Rot.**—The fruit attacked by this disease rots on the plant and is covered with a dense, gray, fungus mold, *Botrytis cinerea,* usually beginning at the blossom end. Fruits develop the same mold in shipment.

To control the rot, destroy all affected fruit as soon as it can be seen, do not let moldy fruits remain in the field, and keep the fruit as dry as possible.

**Leaf Spot and Fruit Rot.**—A fungus, *Phomopsis vexans,* causes light-brown spots on leaves, with black spore pustules, also a light-brown, zonated rot of the fruit, dotted with black spore pustules.

All infected fruit and trash should be cleaned up and destroyed. Plants may be sprayed with 5–5–50 bordeaux mixture (p. 100) if disease is serious enough to warrant. The spray must be washed from fruit to be marketed.

**Verticillium Wilt, Verticilliosis.**—Plants affected with verticilliosis become stunted, wither, and die, often when fairly mature. The bark and outer tissue of the stem is green and sound, but the central woody portion of the lower stem and main root is dry and light brown, with darker streaks. The fungus *Verticillium albo-atrum* that causes this disease causes similar diseases in tomatoes (see p. 87), strawberries, apricots (blackheart), and many other plants.

Eggplant should not be replanted on land which has shown much of this disease or on that which has recently been in tomatoes.

## ENDIVE

**Cottony Rot.**—Endive plants affected with cottony rot wilt and die on account of a rotting of the roots and the stem at the surface of the ground. *Sclerotinia sclerotiorum*, a white, moldy fungus with black sclerotia, can be seen on the surface. See "Cottony Mold" (p. 90).

**Rust.**—Affected leaves are blighted and spotted with the dusty spore

Fig. 25.—Rust of endive leaves.

pustules of a rust fungus, *Puccinia hieracii* (fig. 25). Crops are sometimes ruined. No practical treatment for this disease has been suggested.

## GARLIC[12]

**Nematode.**—When this pest is present, the plants are stunted and killed and the bulbs decompose in certain spots in the field. These areas gradually increase in size as the nematode spreads. This is a strain of the same species—*Ditylenchus dipsaci*—as the bulb or stem nematode (p. 94). The variety of garlic called "Late" is much more susceptible than the "Early" variety.

Care should be taken in the selection of planting stock, to be sure that it is nematode-free. Infested soil should not be planted to garlic, especially the Late variety.

[12] For further information about garlic culture and diseases see: McCallum, Roy D. Growing and handling garlic in California. California Agr. Ext. Cir. 84:1–16. 13 figs. 1934.

**Pinkroot.**—The plants are stunted or killed, bulbs are small, and yields reduced when garlic becomes infected with pinkroot. The roots are rotted and show a pink color. This is the same disease as pinkroot of onions and is caused by the fungus *Phoma terrestris.* Infested soil should be avoided for onions and garlic.

**Rust.**—The tops of growing garlic plants are sometimes attacked by a rust fungus (*Puccinia porri*) which breaks out in small red or black spore pustules on the surface of the leaves and more or less injures the plants. In the few cases where this disease has been observed in California near-by onion plants were not affected.

**White Rot.**—Affected plants die from a rotting at the neck. At this point there is a surface crust of soil, small, black fungus sclerotia, and a thin web of white mold. Certain spots in the field covering several square yards may become infested with this soil fungus, *Sclerotium cepivorum.*

Garlic or onions should not be planted in spots where this disease has appeared. As soon as a spot is seen in the field, all the affected plants and the marginal normal ones should be dug out.

### GOURD

See "Cucurbits" (p. 45)

### HONEYDEW MELON

See "Cucurbits" (p. 45)

### HORSE-RADISH

**Powdery Mildew.**—The leaves sometimes become covered with a white fungus mildew, *Erysiphe polygoni.* Dusting with sulfur may be practiced if the disease seems serious.

### KALE

See "Crucifers" (p. 36)

### KOHLRABI

See "Crucifers" (p. 36)

### LETTUCE [13]

**Anthracnose.**—Small, dead, brown spots appear on the blades and midribs of affected leaves. The centers of the spots in the blades drop out and leave a black-margined "shot-hole" effect. This fungus disease, caused by *Marssonina Panattoniana,* is not usually serious in California

[13] For further information, with description and illustrations of diseases see: Tavernetti, A. A., and John B. Schneider. Head lettuce production in California. California Agr. Ext. Cir. 105:1–48. 1938.

except during unusually long periods of wet weather. Under such conditions, the outer leaves may be so badly blighted that they are broken off and blown away by the wind. Anthracnose has not been serious often enough to require treatment.

**Big Vein.**—In this disease, the veins become coarse and large and the heads loose and reduced in size. Big vein, a virus disease, increases year by year if lettuce is grown in the same ground. No method of control is known except crop rotation and developing resistant varieties.

**Brown Blight.**—Affected plants remain small, yellowish, and fail to head, and dead, brown streaks develop in the outer leaves. The disease infests the soil and increases so rapidly that susceptible varieties of lettuce can no longer be grown after brown blight appears in a field. The cause is unknown.

Strains of lettuce which are resistant to this serious disease have been developed by the late Dr. I. C. Jagger and are now widely planted. Advice should be obtained in local districts as to the best variety for any given season of year.

**Downy Mildew.**—The first symptom is light-colored areas on the older leaves, with a dense, grayish-white, fluffy growth of the fungus, *Bremia lactucae,* on the lower surface. These areas gradually enlarge and die, which causes a blighting and killing of the leaves. In shipment of lettuce, these dead spots on the leaves serve as starting points for decay and "slime."

Considerable attention has been paid in California to the control of lettuce downy mildew by some method of treatment, but no practical procedure has been found. Sulfur is not effective, and spraying with bordeaux mixture is unsatisfactory. The development of resistant strains of lettuce by I. C. Jagger has solved the downy-mildew problem to a large extent. The varieties called "Imperial C," "D," and "F" are highly resistant to both downy mildew and brown blight.

**Drop.**—Plants may be attacked by this disease at any age, but most often after the heads are formed. The older leaves wilt and fall flat on the ground, leaving the center leaves erect. Soon the entire plant wilts and collapses, often becoming covered with the common gray mold, *Botrytis.* The primary cause of this disease, however, is not *Botrytis* but the "cottony mold" soil fungus, *Sclerotinia sclerotiorum,* which is described on page 90.

In greenhouses this fungus sometimes infests the soil and makes it impossible to grow lettuce, tomatoes, or cucumbers until the soil is changed or disinfected (p. 92). In the open ground, "drop" is much less abundant, and the fungus does not build up in the soil, so that no treat-

ment beyond normal crop rotation is necessary to keep the disease in check.

**Gray-Mold Rot.**—Nearly grown heads of lettuce sometimes wilt and collapse and become covered with a dense, gray, moldy, fungus growth, *Botrytis cinerea.* In some cases *Botrytis* is the primary parasite, rotting the stem and leaf bases, but often it follows some other fungus (see preceding section) or injury. No control treatment is possible nor is the disease serious enough to warrant it.

**Mosaic.**—The leaves of mosaic lettuce are mottled with green and yellow areas, and the plants are somewhat stunted. This disease, caused by a virus, is not serious in California.

**Rabbit Ear, Rio Grande Disease, Yellows.**—The leaves of affected plants are dwarfed, yellow, and narrow, often turning outward instead of inward so that the plants are much stunted and fail to head. The disease is caused by the virus of aster yellows (see "Celery," p. 29) and is spread by the six-spotted leaf-hopper, *Macrosteles divisus.* Affected plants should be destroyed.

**Slime.**—Heads of lettuce, especially during shipment, often break down with a slimy, soft rot. This usually happens to heads which have been considerably injured before shipment by frost, downy mildew, spotted wilt, tipburn (the last three of which are discussed in preceding and following sections).

Heads showing much injury to the leaves at harvest, and any which already show slime, should not be packed for shipment. Lettuce should not be planted to mature in hot weather in any given district on acount of the danger of tipburn. Strains resistant to tipburn are less subject to slime. Lettuce should not be planted to mature during freezing weather.

**Spotted Wilt, San Pablo Disease.**—In this virus disease, large, irregular, dead areas develop in the leaves, the outer ones wilt down on the ground, and finally the whole head collapses, usually in a one-sided manner. Great damage is done to lettuce in certain districts by this disease, which also attacks many other plants. See "Spotted Wilt" (p. 97). In early stages its effects on lettuce resemble those of brown blight, but the two diseases are entirely different. Spotted wilt kills the plants; brown blight does not. Brown blight is spread entirely through the soil, which becomes so infested that susceptible strains of lettuce can no longer be grown; spotted wilt is spread by thrips from plant to plant and has no relation to the soil. Strains of lettuce resistant to brown blight have no resistance to the other disease. No specific method of control for spotted wilt in lettuce is known at present.

**Tipburn.**—Dead spots appear at the margins of the younger leaves

and these spread to form a dead, brown strip around the edges of the leaf (fig. 26). Although tipburn itself is nonparasitic, "slime" and gray mold develop from tipburn areas, especially in packed lettuce. Tipburn appears mostly during the warmest portion of the year and is popularly supposed to follow alternating periods of cloudy and hot, bright weather.

To avoid tipburn, the planting of lettuce in the various California dis-

Fig. 26.—Lettuce tipburn.

tricts is so regulated as to avoid having crops mature during very hot weather. Summer lettuce is grown in the cooler coast districts like Salinas and Guadalupe rather than in the interior valleys. Strains or varieties of lettuce have been developed which are considerably resistant, though not immune, to this disease. New York Number 515 is one of the most popular of these.

## MELONS

See "Cucurbits" (p. 45)

## MUSHROOM[14]

**Brown Blotch.**—Dark-brown patches develop on the surface of affected mushrooms. These spots, caused by *Phytomonas Tolaasii,* are usually not very deep and may be covered with slimy bacterial growth.

[14] For further information on mushroom culture and diseases see: Lambert, E. B. Mushroom culture in the United States. U. S. Dept. Agr. Cir. **251**:1–35. 18 figs. 1932.

Since this disease is favored by high humidity and surface moisture, care should be taken to ventilate thoroughly and avoid spattering water from the soil onto the mushroom caps.

**Bubbles.**—A white, mold fungus, *Mycogone perniciosa,* sometimes grows over and into the mushrooms and deforms them. A layer of brown spores develops on the surface of the affected mushrooms, which, as the disease develops, go down into a putrid mass with a very disagreeable odor.

Great care should be taken not to introduce this or any other disease in the spawn. While the crop is being picked, all mushrooms affected with disease should be carefully removed from the house and burned. After doing this, the men should thoroughly wash their hands in hot soap suds or disinfectant. After each crop, all traces of spent manure and refuse should be removed and disposed of so that none of it can get back into the mushroom house or be used on fields near by. Between crops the house should be fumigated with burning sulfur or formaldehyde fumes. When sulfur is used, it should be burned at the rate of 5 pounds to 1,000 cubic feet of air space. Fumigation with commercial formaldehyde is accomplished by vaporizing commercial formalin (40 per cent formaldehyde) at the rate of 1 quart to 1,000 cubic feet. The formalin is usually placed in buckets along the alley and vaporized by adding crystals of potassium permanganate at the rate of 1 pound per quart. The house should be tightly closed during fumigation, which cannot, of course, be practiced when a crop of mushrooms is growing.

**Plaster Mold.**—A grayish-white mold, *Monilia fimicola,* appears in patches on the compost and may run all through the bed and almost entirely prevent the development of mushrooms.

For treatment see under "Bubbles." Contaminated spawn and too much moisture in the manure are important factors in this disease. Mushroom culture is such a highly specialized art that no printed directions can guarantee success in handling these difficult problems.

## MUSKMELON

See "Cucurbits" (p. 45)

## OKRA

**Root-Knot Nematode.**—Roundish, rough galls and knots develop on roots attacked by the root-knot, or garden, nematode, *Heterodera marioni.* The plants are stunted and weakened. Okra is very susceptible to this worm, which attacks a great variety of plants (p. 94); nematode-infested soil should be avoided for this crop.

**Verticillium Wilt, Verticilliosis.**—Affected plants wither and die, with a discoloration and breaking down of the main root and stem. This disease, caused by *Verticillium albo-atrum,* attacks many other plants (see p. 99). No control can be suggested beyond avoiding infested soil.

## ONION[15]

**Black Mold.**—A black, powdery fungus, *Aspergillus niger,* sometimes develops in spots and streaks between the outer bulb scales, usually on onions in storage. Appearance and keeping quality are seriously injured. This is sometimes called "smut" but is not the true onion smut described below.

Affected bulbs should be discarded in harvesting. The onions should be thoroughly dried and, if kept in cold storage, held at 32° to 35° Fahrenheit.

**Downy Mildew, Blight.**—Good-sized spots or areas, with a violet-tinted fuzz, appear on affected leaves and seedstalks. The tissue at these areas rapidly collapses, fades, and dies, and in wet weather the fungus, *Peronospora destructor,* spreads rapidly. In California the worst effects are seen in seed fields where the large stalks become infected and spotted on the sides so that they droop and break over, and the seed heads are lost or do not develop. The disease is sporadic, being very destructive some seasons and almost entirely absent during other years. Its development depends mainly upon abundant moisture from rain or heavy fogs at the right time in the season.

Dead tops should be raked and burned, and badly infested fields should be put into some other crop for a few years. The disease may be effectively controlled by spraying at its first appearance with 2–2–100 rosin-soap lime-sulfur spray (see "Spreaders and Stickers," p. 105). Progress is being made in developing mildew-resistant onion varieties.[16]

**Leaf Mold.**—A black fungus, *Macrosporium porri,* appearing on the older leaves and flower stalks, frequently follows downy mildew and causes more or less injury. The bulbs are also sometimes affected. Control, if needed, is as for downy mildew.

**Neck Rot, Botrytis Rot.**—A gray, feltlike growth of fungus mold, a species of *Botrytis* appears at the neck of affected onions and softens and rots the tissue and gradually destroys the entire bulb. White onion varieties are more susceptible than colored ones.

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[15] For further information on onion diseases see: Walker, J. C. Onion diseases and their control. U. S. Dept. Agr. Farmers' Bul. **1060**:1–24. 15 figs. 1931.

[16] Jones, H. A., D. R. Porter, and L. D. Leach, Breeding for resistance to onion downy mildew caused by *Peronospora destructor.* Hilgardia vol. 12, no. 9, p. 531–50. 6 figs. 1939.

The prevention of neck rot depends mainly upon proper care in harvesting and curing the onions. The bulbs should be dried as thoroughly and rapidly as possible, should not be exposed to dampness, and should be stored in a cool, dry place. If necessary, the onions may be dried with artificial heat at 100° to 120° Fahrenheit with provision for ventilation to carry off the moisture.

**Pinkroot.**—The roots of affected plants shrivel and die and take on a pink color. The plant keeps sending out new roots and these in turn are affected. As a consequence, the plants are stunted and the bulbs small. The disease is caused by a fungus, *Phoma terrestris,* which lives in the soil.

Infested soil should be abandoned for onions or garlic for several years. Plants should be kept in as vigorous a growing condition as possible because this makes them less susceptible to the disease. Onions of the sweet Spanish type and the Japanese type called "Nebuka" are less susceptible than those of the Danvers type.

**Smudge.**—This disease attacks mostly the white varieties of onions. Circles or concentric rings of dark-colored dots, the spore pustules of the fungus, *Colletotrichum circinans,* appear on the outer scales just before harvest. The disease does not usually cause any great injury to the bulbs but gives them a dirty, unsightly appearance. Bulbs which have been poorly cured or stored may suffer considerable loss. This disease has not been observed in California but may appear at any time. It is often spread on onion sets.

White varieties of onions should be harvested and dried as rapidly as possible without exposure to moisture.

**Smut.**—Black, elongated blisters or pustules of spores that break out on the scales or leaves of young plants are a symptom of smut. Many plants die, others continue to be attacked and may show the black or brown smut pustules even on the cured bulbs and as deep as the third or fourth scale, usually near the base. The smut fungus, *Urocystis cepulae,* does not itself cause a rotting of onion bulbs, but smutted onions are more likely to be attacked by other fungi than normal ones. Where this disease occurs, the soil becomes infested with smut spores and the disease is worse on each succeeding crop of onions planted on the same land. For some unknown reason, onion smut has never been found in California although it is prevalent in other parts of the Pacific Coast.

Since this disease attacks only very young plants, onion seed may be planted in clean soil and the seedlings then transplanted to infested soil after they are a few inches high. Onions grown from healthy sets are also immune to smut. For growing field-sown onions on infested soil, a for-

maldehyde drip method is used, a solution of formaldehyde being applied in the furrow with the seed. This is done by a tank-and-drip attach-

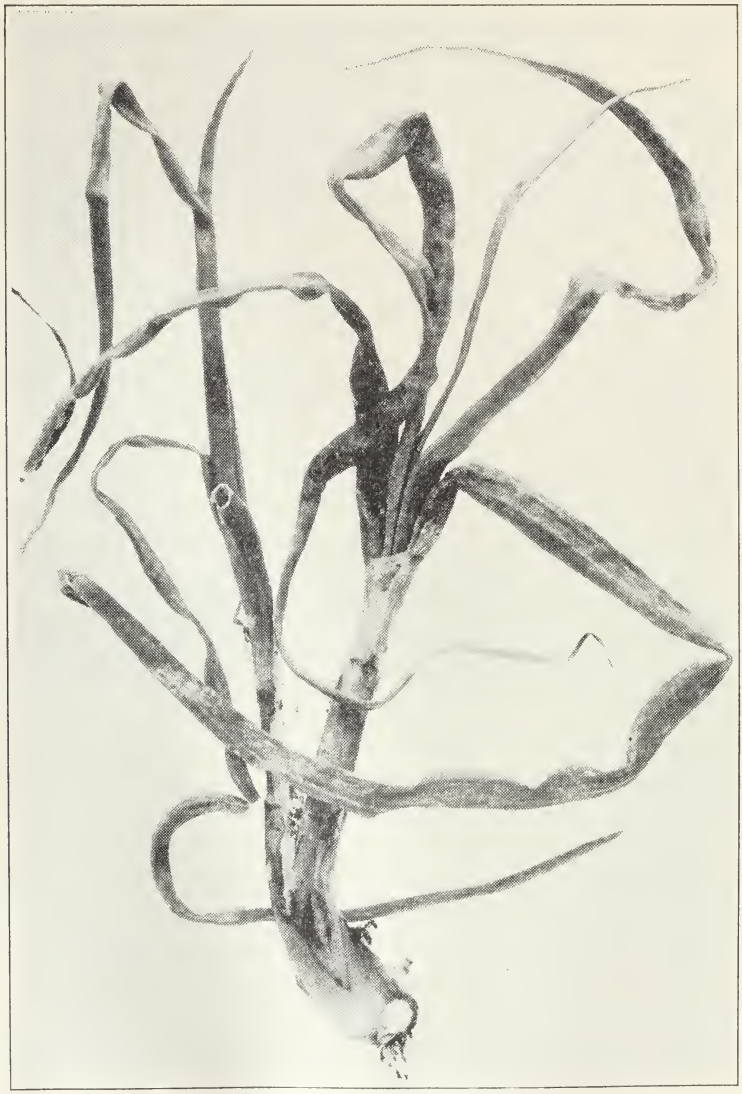

Fig. 27.—Onion yellow dwarf.

ment on the seed drill, using a solution of 1 pint of commercial formalin to 8 gallons of water. The total cost amounts to about $3 an acre.

**Southern Root Rot.**—The plants may be attacked and rotted off near the surface of the ground by a white fungus or mold, *Sclerotium Rolfsii,* in which are seen numerous small, round bodies about the size and color

of mustard seed (fig. 9, p. 21). This disease is described at more length under "Beet" (p. 21).

Onions are moderately susceptible to southern root rot and cannot be planted on infested soil without danger of loss.

**White Rot.**—See under "Garlic" (p. 51).

**Yellow Dwarf, Yellows.**—Affected plants are dwarfed and yellow and the seedstalks twisted and stunted in a peculiar manner (fig. 27). The cause is a virus. Affected plants should be immediately destroyed.

### PARSLEY

**Aster Yellows.**—See "Celery" (p. 29).

### PARSNIP

**Cottony Rot, Watery Soft Rot.**—The roots of affected plants decay and become covered with the typical white mold of this fungus, *Sclerotinia sclerotiorum*. See "Cottony Mold" (p. 90).

### PEA[17]

**Ascochyta Blight, Blight.**—In this disease, the stem becomes spotted with purplish-black blotches and the underground stem is blackened and shriveled (fig. 28). Spots which may be either dark or tan-colored also develop on the leaves and pods (fig. 29). In severe cases on young plants, the leaves are badly blighted, the stem and roots rot, and the plant is completely killed. This disease is especially bad in the coastal pea districts during a wet, cool spring and sometimes completely ruins entire fields. Several fungi, *Ascochyta pisi, A. pinodella,* and *Mycosphaerella pinodes* are all found singly or together on affected plants and produce very similar symptoms.

This disease is seed-borne, but the most severe outbreaks occur on land where peas have been grown for several years and the fungus carries over on litter from the old vines. Seed from clean fields should be used. Badly blighted fields should not be planted in peas again for at least three years, and the old diseased vines should be burned or ploughed under deeply and not be scattered on the land. Seed treatment is not effective. None of the varieties of market peas show much resistance to this disease. New, resistant varieties must be developed before satisfactory control of blight can be obtained.

**Bacterial Blight.**—Affected plants show extensive watery, olive-

[17] For further information on culture and diseases of peas, see: Talbot, Parker, and A. A. Tavernetti. Growing and handling market peas in California. California Agr. Ext. Cir. 85:1–36. 21 figs. 1934. Harter, L. L., W. J. Zaumeyer, and B. L. Wade. Pea diseases and their control. U. S. Dept. Agr. Farmers' Bul. 1735:1–25. 13 figs. 1934.

green blisters on stems and leaf bases and water-soaked, oily spots upon pods and leaves in this bacterial infection, which usually follows cold, wet weather and frost injury. These blisters, especially on leaves, dry down into brown, dead spots and the stem may be girdled. Healthy shoots sometimes spring up from below. The disease, caused by *Phy-*

Fig. 28.—*Ascochyta* blight of pea plants.

*tomonas pisi,* is seed-borne. The use of clean seed from healthy fields and crop rotation are the best methods of control.

**Cladosporium Leaf Spot, Scab.**—Leaves, stems, and pods are sometimes marked with dark-colored spots which in moist weather are covered with velvety mold of the fungus *Cladosporium pisicola.* The leaves become curled and twisted and the pods very much deformed and roughened. Sometimes the fungus penetrates the pod and forms mold growth on the inner surface and on the young seeds.

Crop rotation is advisable where this disease occurs. Seed from affected fields should not be used for planting since the disease is seed-borne.

**Downy Mildew.**—Affected leaves curl downward and show yellowing from above; a violet-colored fungus, *Peronospora viciae,* covers the

underside. In some cases a pod disease is caused by the same fungus. Affected pods may show but few external symptoms other than yellowish blotches, but on the inside there is seen a mealy, white substance which may cover the whole inner surface of the cavity. In addition, presence of the fungus in the pod may cause a mass of white hairs to develop on

Fig. 29.—Pea pods showing *Ascochyta* spots.

the inner pod wall, like the growth of a mold. Downy mildew is sometimes very abundant in the spring after cool wet weather, and may also appear in the fall crop in fields subject to heavy coastal fogs.

Spraying with bordeaux mixture 4–4–50 (p. 100) before downy mildew develops is said to prevent it, but in most districts it does not appear often enough to warrant doing this every year. No treatment is effective after mildew is seen.

**Fusarium Wilt.**—Plants affected by wilt become stunted and turn yellow, the leaves curl, and the plants die. The disease causes more or less circular, bare spots in the field, which enlarge year by year if peas are planted in the same land. High soil temperature is favorable to this disease, which is caused by *Fusarium orthoceras* var. *pisi*.

Varieties are available which are highly resistant to fusarium wilt.

More detailed information about them can be obtained from the Division of Plant Pathology, College of Agriculture, Berkeley, or from the county farm advisors in the principle pea-growing counties. It should be pointed out that a very similar disease, near wilt (discussed later), exists in this state and that varieties which are resistant to true wilt are susceptible to the other disease.

**Mosaic.**—There are several mosaic diseases of peas in California, all caused by viruses. The most common and important one is the pod-deforming mosaic. In this the plants are stunted, the leaves mottled with green and yellow or transparent areas, and the pods are rough and deformed. The disease is spread by the pea aphid.

Control is best obtained by keeping down the pea aphid (see Extension Circular 87). Various leguminous plants, including some of those naturally occurring as weeds about pea fields, are susceptible to this virus and may carry the disease.

**Near Wilt.**—This disease is very similar to true fusarium wilt but is caused by a different fungus—*Fusarium oxysporum* f.8. Varieties which are resistant to true wilt are susceptible to near wilt. Tests are under way to find varieties resistant to this disease. Infested land should not be planted to peas for several years.

**Powdery Mildew.**—Affected leaves become covered with the white fungus growth of *Erysiphe polygoni.* Mildew also develops on the pods and causes a discoloration which may lower their market value. The plants are often stunted and badly injured by this disease.

Dusting with powdered sulfur controls mildew. The first applications should be made before the disease appears, followed by others at frequent intervals.

**Root Rot, Damping-off.**—Some of the sprouting seeds die before the young plants get above ground. Other plants turn yellow, wither, and die from a rotting of the roots underground. This disease occurs mostly in land which has been used for peas for many years or in wet, poorly drained fields or after heavy rains, and may be caused by *Aphanomyces euteiches, Fusarium solani* var. *martii* f. 2, *Corticium vagum* (*Rhizoctonia*), a species of *Pythium, Thielaviopsis basicola,* or other fungi. Each of these causes a more or less specific disease.

Crop rotation, thorough preparation of the soil, maintenance of fertility, and good drainage help to reduce the damage caused by root rot. Seed treatment with red copper oxide (cuprous oxide) as recommended for spinach seed (p. 75) is becoming very common for peas. Mercury dusts (p. 104) are also recommended for the same purpose.

**Rust.**—The fungus, *Uromyces fabae,* which causes this disease, is a

true rust, and breaks out in small, red, spore pustules on the leaves and stems (fig. 30). It also attacks broad bean, but is not important.

**Septoria Leaf Spot, Leaf Blotch.**—The affected leaves become spotted with indefinite, yellow to brown blotches and are blighted much as in ascochyta blight. Pods and seeds may become infected with this fungus

Fig. 30.—Rust of pea; the same fungus also attacks broad bean.

disease, which is caused by *Septoria pisi*. It is common in winter or spring peas, especially on the lower leaves, but is not often important enough to require control.

**Spotted Wilt.**—The stems of plants affected by spotted wilt are marked with purplish-brown, elongated, dead streaks and brown spots develop on the leaves, which may die prematurely. This is caused by a virus and is identical with the disease of the same name which affects tomatoes, lettuce, and many other plants. So far as is known at present, spotted wilt is not of major importance on peas in California. For further information, see page 97.

**Stem Rot.**—The plants sometimes die from a rotting of the stems and

roots caused by the cottony mold fungus, *Sclerotinia sclerotiorum* (p. 90). The disease is not serious on peas.

**Streak.**—In this disease, the stems are marked with reddish-brown, elongated, dead streaks. There are several virus diseases which have this effect on peas in California. One of these is probably the same as spotted wilt, previously discussed.

## PEPPER

**Crown Rot, Cottony Rot.**—Pepper plants are sometimes killed by a rotting of the stem at the surface of the ground. A cottony, white mold, *Sclerotinia sclerotiorum,* is seen on the affected parts. See "Cottony Mold" (p. 90).

**Curly Top.**—See page 91.

**Fruit Spot and Pod Rot.**—Dead spots and rotting may appear on the pods, often after sun scald. A dark-colored fungus mold, a species of *Alternaria* or one of *Cladosporium,* develops on the affected parts. The only control usually needed is to destroy affected pods.

**Leaf Spot.**—The large, roundish, spots developed on the leaves in this disease are at first water-soaked, then have a dead, white center with a dark-colored border. In wet weather, the plants are sometimes seriously injured by leaf spot, caused by the fungus *Cercospora capsici.*

Spraying with bordeaux mixture would probably control leaf spot, but this would disfigure the fruit; so that, unless the disease were much worse than usual, the remedy would do more harm than the disease. No other control is known at present.

**Mosaic.**—In mosaic of pepper, the leaves are mottled and dwarfed as in some of the potato and tomato mosaic diseases. It may be confused with curly top or spotted wilt. True mosaic is spread by aphids. For control, see "Mosaic Diseases" under "Tomato" (p. 85).

**Root Rot.**—The plant wilts and dies from a rotting of the stem and root just below the surface of the ground, caused by a fungus, *Phytophthora capsici.* This effect is worst in wet soil and at high temperatures. The trouble can be largely prevented by having the land well leveled and avoiding overirrigation.

**Spotted Wilt.**—The leaves affected by spotted wilt show concentric, circular markings of green and yellow or dead tissue, the fruit is deformed and shows similar markings, dead streaks develop on the tips of the stems, and young leaves drop off. The cause is a virus. See discussions under "Spotted Wilt" (p. 97) and under "Tomato" (p. 86).

**Sun Scald.**—Occasionally one side of fruit, toward the point, shows a dead, scalded-looking condition apparently caused by sunburn.

**Verticillium Wilt, Verticilliosis.**—The lower leaves wither and fall and the whole plant wilts and dies from this fungus disease, caused by *Verticillium albo-atrum*. See page 99 for further discussion.

Peppers should not be planted again for several years on land where the disease has been troublesome. Crops following tomatoes or potatoes are likely to be affected. There are many other hosts.

### PERSIAN MELON

See "Cucurbits" (p. 45)

### POTATO[18]

**Bacterial Wilt, Brown Rot.**—This disease, caused by *Phytomonas solanaceara,* has never been serious in California but is most common in the southeastern states. Leaves of infected potato plants wilt, wither, and finally drop, leaving a naked stem which often falls over. The woody part of the stem shows black streaks. In the tubers a brown ring is seen about ½ inch beneath the skin. Often the tubers begin to rot before they are dug and in storage develop a soft, "leaky," ill-smelling rot.

Bacterial wilt is best controlled by the use of sound, disease-free seed, seed treatment, and crop rotation.

**Blackheart.**—When affected potatoes are cut across, the flesh in the center appears dark-colored or black (fig. 31) in definite areas. In advanced stages, the affected tissues may dry out and leave cavities. The trouble is caused by high temperature or lack of oxygen or the two combined. This usually occurs in storage, but may develop in the field if potatoes are exposed to high temperature in light soil or after digging, or if oxygen is excluded from the soil by waterlogging.

Potatoes should be kept at temperatures below 95° Fahrenheit and with plenty of ventilation. They should not be kept in piles more than 6 feet deep. Tubers should not be allowed to remain in hot, light soils after the vines are dead, or in waterlogged soil, or to lie long exposed to the sun after digging.

**Blackleg.**—The most obvious characteristic symptom of blackleg is a black, slimy, foul-smelling rot of the stem just above the seed-piece. As a result of this, the leaves near the top of the stem become curled upward, stunted, and yellow. Aerial tubers may form in the leaf axils. Later the stem weakens and the plant falls over. The new tubers on affected plants

[18] For further information on potato culture, with descriptions and illustrations of diseases see:

Porter, D. R. Potato production in California. California Agr. Ext. Cir. **61**:1–63. 20 figs. Revised 1939 by D. R. Porter and John B. Schneider.

See also: McKay, M. B., and T. P. Dykstra. Potato diseases in Oregon and their control. Oregon Agr. Exp. Sta. Cir. **127**:1–84. 60 figs. 1938.

become infected and, when used for seed, perpetuate the trouble by producing diseased plants and also by contaminating the cutting knife and spreading the organism, *Erwinia atroseptica,* to healthy tubers. Potatoes in storage may develop a soft rot from this cause, usually starting near the stem end. The bacteria which cause blackleg may survive in the soil from one season to another. They are also spread by certain insects from diseased to healthy tubers.

Where blackleg is serious, diseased plants should be rogued from the

Fig. 31.—Blackheart of potato.

field, care being taken to remove and destroy any tubers which have formed. Seed treatment for other diseases like scab and rhizoctonia, together with crop rotation, will help to control this.

**Dry Rot.**—Potatoes in storage often show a dry, powdery or leathery type of decay which usually starts from bruises on the surface. High temperature and humidity and poor ventilation favor this, since these conditions are favorable to the fungus, a species of *Fusarium,* which causes dry rot.

Careful handling, cold-storage rooms at a temperature between 36° and 40° Fahrenheit and with good ventilation, and control of other tuber-rotting diseases, help to reduce losses from dry rot.

**Early Blight.**—Brown, circular, dead areas develop on the leaves, blighting and killing them and defoliating the plants. This fungus disease, caused by *Alternaria solani,* is sometimes seen in California but is not often serious.

In places where control seems necessary, the plants may be sprayed with bordeaux mixture (p. 100).

**Internal Necrosis, Brown Streak.**—The affected tuber shows light brown streaks running through the flesh, sometimes forming a ring just beneath the surface. This is usually found in potatoes grown in light, hot soils and is nonparasitic. Affected seed may produce a clean crop, but the use of seed potatoes with discolored flesh from any cause is not advisable.

**Jelly End.**—In the pointed stem end of the Netted Gem variety, a characteristic rotting often occurs in certain districts of northeastern California and adjacent states. The rotted tissue is at first nearly white and of a jellylike consistency, but gradually dries out and becomes brown and hard. The common *Corticium* (*Rhizoctonia*) *vagum* fungus, the cause of rhizoctonia disease of potatoes (p. 68), is present and appears to be the cause of the trouble, although the potato soils of the affected district are typically alkaline, which should be unfavorable to this organism. Deficiency of starch in the point of the tuber has been suggested as the reason for the susceptibility of this tissue.

Search for a satisfactory, nonsusceptible variety of potato might be advisable if this trouble becomes too severe. Heavy applications of potash fertilizers have been recommended.

**Knobby Tubers.**—Knobs or secondary tubers growing out from the sides and ends of the normal potatoes may sometimes result from disease attacks or may be due to secondary growth caused by irregular soil-moisture conditions.

**Late Blight.**—This trouble, which is the most world-wide potato disease, is not general in California but sometimes occurs in cool, foggy districts near the coast. Large, brown, dead areas develop in the leaves and, under favorable conditions, the entire foliage and tops of the plants may be blighted and killed by the fungus *Phytophthora infestans* within a short time. A delicate, white mold appears on the underside of affected leaves. The tubers, if attacked, show dark-colored, slightly sunken, rotted areas on the surface. In storage, or if left in the ground, tubers may rot badly. Tomatoes are similarly affected but the fungus appears to be a distinct strain.

To control late blight in districts where it is common, care should be taken to use seed free from any signs of discoloration or rot. Spraying the foliage thoroughly with 5–5–50 bordeaux mixture (p. 100) beginning just before the time when the disease usually appears or at the first sign of its development, prevents the development of blight on the leaves. If foggy weather continues, two or more applications may be

advisable unless the tops are so dense that spraying is not feasible. Under such circumstances, dusting with 20–80 copper-lime mixture (p. 102) may be more practical and of some value.

Efforts are being made in several places to develop potato varieties having resistance to late blight. Sebago is one of these and others no doubt will follow.

**Leak.**—Affected potatoes rot with a very soft, watery type of decay from which a yellowish or brown liquid runs off when tubers are crushed or pressed. No fungus growth is visible, but the cause is a fungus, *Pythium Debaryanum.* Infection by this soil fungus takes place through digging or other wounds. The same fungus also causes damping-off of many kinds of seedlings.

To avoid this disease, care should be taken to prevent injuring the potatoes in digging. Modern harvesting machinery helps greatly in this objective.

**Net Necrosis.**—This name is applied to a network of fine brown or black lines which occasionally runs through the flesh of the potato. It is probably the effect of some virus or other disease or harmful condition; sometimes it is caused by frost. Such tubers should not be used for seed.

**Powdery Scab.**—This disease is not present in California. Small discolored pimples or pustules appear on the surface of the tuber, in patches or scattered over the surface. As these enlarge, they split open in a star-shaped manner, and the epidermis curls back and exposes a brown, powdery mass of fungus spores. The spores fall out and leave shallow pits less than ⅛ inch in diameter. In storage, a dry, sunken rot may develop about the pits. The fungus is *Spongospora subterranea.* Where the disease occurs, the use of clean seed, seed treatment, and crop rotation keep it well in check.

**Rhizoctonia Disease, Black Scurf.**—Small, black particles of fungus tissue up to ⅓ inch in diameter may be seen on the tubers at digging. Young sprouts in the soil are rotted, marked with dead spots on the sides, or burned off below the surface of the ground. Similar spots may develop on the shoots which form the tubers. The roots may also be corroded by the fungus. The leaves of affected plants have a tendency to roll upward and may turn yellow. Small, aerial tubers often develop in the axils of the leaves on severely affected plants. "Jelly end" rot of the tubers, caused by the same fungus, *Corticium vagum,* has been referred to on page 67. Many plants other than potato are attacked.

Crop rotation and seed treatment are the principal methods of avoiding this disease. For methods of seed treatment, see the last section under this crop (p. 72).

**Root-Knot Nematode, Eelworm.**—The tubers affected by root-knot nematode, *Heterodera marioni,* have a pimply or warty surface, with small brown channels just beneath the skin. Such potatoes are worthless for market and should by no means be used for seed. Clean potatoes cannot be grown on land infested by nematodes. See "Nematode" (p. 97) for further information.

**Scab.**—Brown, roundish, rough areas are seen on the surface of the tuber. These may be few in number or numerous enough to cover the whole surface. The scab fungus, *Actinomyces scabies,* is favored by high temperature and alkaline or only very slightly acid reaction of the soil.

Control of scab depends on use of clean seed, thorough seed disinfection, and planting in clean soil. The latter may be accomplished by crop rotation when no new potato lands are available. For methods of seed treatment, see the last section under this crop (p. 72). When planting new land to potatoes, it is advisable to treat all the seed very carefully, even that which does not show much scab. This will help to keep down the infestation of the soil and prevent scabbing of future crops.

**Secondary Tubers.**—Seed potatoes sometimes produce no tops but send out only shoots which develop into clusters of small, secondary tubers. This weakness is apparently due to some unfavorable condition during the growth or storage of the seed potatoes.

**Seed-Piece Decay.**—The potato seed-pieces rot in the ground, either before the sprouts start or before they become established as independent plants. No specific method can be given for prevention of this trouble, except proper preparation of the soil and the use of good seed. Losses from seed decay may be reduced by keeping seed-pieces moist after they are cut and by planting immediately in moist soil.

**Silver Scurf.**—The surface of affected potatoes is covered with brownish blotches which show a silvery sheen, especially when placed under water. This condition, caused by a superficially growing fungus, *Spondylocladium atrovirens,* is seen occasionally in California but has never been serious.

**Spindling Sprout.**—The shoots are slender, wiry, and weak and usually more than normal in number. This may be the effect of one of the virus diseases or may be an indication of some weakness in the seed potatoes.

**Virus Diseases.**—In the potato virus diseases, of which at least 10 have been recognized in California, the foliage is more or less mottled, dwarfed, crinkled, and distorted, and the vigor and yield of the plants are reduced. These diseases are transmitted in the seed tubers of the potato and are spread from plant to plant in the field by aphids and other

insects. Bulletin 587 gives the following list and description of potato virus diseases which occur in California:

In general, potato virus diseases naturally fall into two groups, according to the presence or absence of mottling in the individual leaflets of infected plants. For the sake of clarity, these groups are herein designated as mosaic and nonmosaic. The diseases of the mosaic group are characterized primarily by mottling, in which irregular, light yellowish-green or yellowish patches appear in place of the normal green color of the leaflets. With nonmosaic diseases, this mottling is absent, but infected plants manifest other symptoms of abnormality, as indicated below. Although as many as 16 potato virus diseases have been described, only 10 have been found in California. The virus diseases of the mosaic group found here to date are mild mosaic, crinkle mosaic, leafrolling mosaic, rugose mosaic, and calico; of the nonmosaic group, leafroll, spindle tuber, witch's broom, curly top, and giant hill.

*Mild mosaic* symptoms are manifested by mottling in the green leaflet, in which irregular yellowish or light-colored areas alternate with the normal green. Infected plants are slightly dwarfed, and the leaves usually are tender in texture. Sometimes the leaflet margins become slightly ruffled. *Crinkle mosaic* resembles mild mosaic but, in general, produces more prominent mottled areas and more pronounced crinkling in the leaflets. *Leafrolling mosaic,* as the name implies, is characterized both by foliage mottling and by leafrolling. Unlike true leafroll, infected leaves are tender, not leathery or tough. *Rugose mosaic,* probably the most severe and most easily recognized disease of the group, causes numerous mottled areas and intense ruffling of the leaflets and resembles an advanced stage of crinkle mosaic. *Calico* is recognized by irregular spots of brilliant-yellow, yellowish-white, or gray color, usually unaccompanied by any distortion in the leaflets. *Potato leafroll* causes upward rolling of the leaflets so that the midrib remains at the middle of the trough thus formed. Infected leaflets become brittle, tough, or even leathery. *Spindle tuber* is one of the few virus diseases that may be detected in the tuber. Infected potatoes are elongated, often pointed at one or both ends, with more numerous eyes than healthy specimens of the same variety. The plants are usually somewhat darker green than normal and are often erect, rigid, or spindling with an acute angle between the leaves and the main stem. *Witch's broom* —not often seen in the field in California—is characterized by numerous spindling stems produced from one seed-piece, giving the plant a bushy appearance, with very small rounded leaflets. *Giant hill*—rarely encountered—is manifested by rank, coarse growth and by large, irregular tubers. Infected plants appear more frost-resistant than healthy ones.[19]

Virus diseases are controlled by planting seed which is free from these troubles. The potato grower can accomplish this either by producing healthy seed himself or by buying from a reliable source certified seed or stock which he knows to be clean. No one can tell by looking at potatoes whether or not they are affected with virus diseases. Only by inspection of the growing plants can these troubles be detected. The following quotation is from a recent publication:

*Control of Potato Virus Diseases.*—The seed plot should be started with either *certi-*

[19] Porter, D. R. Relation of virus diseases to potato production in California. California Agr. Ext. Sta. Bul. 587:1–32. 19 figs. 1935.

*fied* or *tuber-indexed* seed stock, although progress can be made with uncertified stock which is not heavily infected with virus diseases. All tubers should be planted in the seed plot by the tuber-unit method; that is, all the sets of one tuber should be planted in succession in the row and about 4 feet left vacant before the sets of another tuber are planted. Some growers prefer to mark each tuber unit with a wooden stake set in the row. The object of tuber-unit planting in the seed plot is to facilitate roguing during the growing season. If one plant of a tuber unit is diseased, the entire unit should be removed, even though some plants of this unit may appear healthy. Evidently, then, tuber-unit planting makes roguing easier and much more accurate than promiscuous planting of sets in the seed plot. Roguing of diseased plants should begin as soon as any disease is evident and should continue at intervals depending on growing conditions. As insects spread virus diseases from plant to plant, the necessity of prompt removal of diseased plants is evident. The prevalence of insect vectors of virus diseases likewise increases the importance of isolation of the seed plot from the main field by at least 300 feet. A quarter of a mile is preferable.

The value of *tuber-indexing* of stock before planting the seed plot has been demonstrated not only in California but in many other states. This practice is nearly ideal, but requires facilities not generally available to the average grower. Tuber-indexing involves the growing of one eye from each tuber . . . well in advance of the planting season. The eye which is planted is numbered to correspond with the mother tuber; those which index as diseased are discarded, so that only healthy-appearing tubers are planted. Even with the precaution of tuber-indexing, some diseased plants may appear in the seed plot, and one must usually rogue a few units. Growers may have access to a greenhouse where seed stock may be tuber-indexed during the winter months, and growers who live in frost-free districts may be able to index in the open field or in cold frames which may be covered in case of frost danger. Growers in Oregon have accomplished nearly as good results by ordinary tuber-unit planting as by tuber-indexing. Either method, if intelligently used, will tend to rid seed stock of virus infection.[20]

**Wart.**—This fungus disease, caused by *Synchytrium endobioticum,* is common in England and other European countries and has been introduced into Newfoundland and certain parts of Pennsylvania. It has never been found in California, and, on account of this disease, potatoes from affected districts are excluded by quarantine. Prominent, warty outgrowths develop on the stem around the crown of an infected plant and from the eyes of the new tubers. Some of these are as large as the potato itself. At harvest time they become black and resemble crown galls on fruit trees.

**Wilt.**—The symptoms of the wilt diseases caused by two soil fungi, *Fusarium oxysporum* f. 1 and *Verticillium albo-atrum,* are practically identical. The leaves lose their bright-green color, curl upward, turn yellow, and dry up. The plant is stunted and finally killed. Brown discoloration is seen internally in the woody portion of the stem; this extends into the tuber and often forms a dark ring in the flesh at the stem end. This is

[20] Porter, D. R. Potato production in California. California Agr. Ext. Cir. **61**:61–63. Revised 1939 by D. R. Porter and John B. Schneider.

not a soft rot as in the next disease. Verticillium wilt is more common in the coastal sections, and the fungus also attacks tomatoes, apricots, strawberries, and other crops (see under "Tomato," p. 87).

Crop rotation, use of clean seed, and seed treatment contribute to the control of this disease.

**Wilt and Soft Rot.**—This is a comparatively new and serious potato disease which has only recently been identified as occurring in California. On plants affected with this bacterial disease, caused by *Phytomonas sepedonica,* leaves and individual stems wilt; affected leaves show chlorosis and dying of the tissue between the veins and gradually wither. The young tubers attached to affected stems show an internal decay which starts in the vascular region and thence extends into the middle of the tuber, forming a white or cream-colored rot. Often the entire center disintegrates, which leaves a hollow shell. There is no bad odor unless other bacteria get in. Tubers of an affected plant sometimes show a characteristic surface cracking.

This trouble, like many others, may be spread in seed potatoes and cannot always be detected by external seed inspection. Great caution should therefore be used in bringing in seed potatoes from other districts. Examination of the tissues of the potato with the microscope furnishes an accurate means of detecting this disease.

**Seed-Potato Treatment.**—It is usually considered advisable to treat all potato seed stock before planting in order to control rhizoctonia and scab infection in the new crop and prevent infesting the soil with these diseases. Various materials and methods are in use for this purpose. It should be clearly understood that seed treatment will kill only the disease germs carried on the seed itself. When potatoes are planted in infested land, infection from the soil cannot be prevented by any treatment of the seed. For this reason, crop rotation should be practiced and seed treatment should be looked upon as a means of protecting the soil from contamination as well as preventing disease in the current crop. Before treatment, seed tubers should be graded to remove all bruised or decayed ones and, if very dirty, washed in clear water. They should be treated before cutting. Several different treatments are in use, no one of which can be called best under all circumstances.

1. Formaldehyde solution. Add 1 pint of commercial formalin (37 to 40 per cent formaldehdye) to 30 gallons of water. Soak the tubers in sacks for 1½ to 2 hours in this solution. No special temperature is necessary, and either wooden or metal containers may be used. The solution is not highly poisonous. This treatment is effective for scab but not for rhizoctonia and is now almost obsolete in favor of one of the following.

2. Hot formaldehyde. According to this method, 1 pint of formalin to 15 gallons of water is used. Keep the solution at a temperature of 124° to 126° Fahrenheit and dip the tubers for 3 minutes. Time and temperature control must be very accurate. Commercial machines for treating potatoes by this method are on the market. Both rhizoctonia and scab are controlled.

3. Corrosive sublimate. Place 1 ounce of corrosive sublimate (mercury bichloride) in 1 gallon of warm water in a wooden or concrete container; after this is dissolved, add enough cold water to make 8 gallons. Soak the seed potatoes loose in this for 1½ hours. *This chemical is a deadly poison when taken internally.* Both rhizoctonia and scab are controlled by this treatment. The solution gradually weakens and should be reinforced after 4 lots of potatoes have been dipped by adding ½ ounce of corrosive sublimate and bringing the solution up to its original volume of 8 gallons. After dipping 8 lots of seed, the solution should be discarded and a fresh one prepared.

4. Hot corrosive sublimate. Use the same solution as in no. 3 and soak the seed for 2 minutes at 126° Fahrenheit. This is a very powerful solution and the directions must be followed explicitly.

5. Acidulated corrosive sublimate. Soak the seed potatoes for 5 minutes in a solution composed of 6 ounces of corrosive sublimate, 1 quart of commercial hydrochloric (muriatic) acid (31 per cent acid) and 25 gallons of water. This requires no special temperature control and is very effective against scab and rhizoctonia. All these mercury solutions are very corrosive to metal containers, poisonous to animals, and prone to become gradually weakened with use.

6. Proprietary organic mercury compounds. Several different compounds of this nature (p. 104) are on the market for treatment of seed potatoes. Manufacturer's directions should be followed.

## PUMPKIN

See "Cucurbits" (p. 45)

## RADISH

See "Crucifers" (p. 36)

## RHUBARB

**Crown Rot.**—Rhubarb plants sometimes die from a rotting of the crowns and main roots caused by a fungus, *Phytophthora cactorum,* or by a species of *Pythium.* The disease is favored by poor drainage, overirrigation, or uneven land, which causes water to stand in low places. To prevent the disease, avoid these conditions.

**Downy Mildew.**—Rather dense, light-colored masses of fungus growth occasionally appear on the undersides of the leaves, in patches margined by the veins. The fungus is *Peronospora rumicis*. No treatment has been found necessary.

**Leaf Spot.**—In leaves attacked by this disease, caused by a species of *Ramularia* and possibly other fungi, the blades and backs of the veins show oval or irregular dead spots. Leaf spot is not serious on rhubarb.

**Oak-Root-Fungus Disease, Armillaria Root Rot.**—*Armillaria mellea*, a common fungus parasite on the roots of many kinds of trees and shrubs,

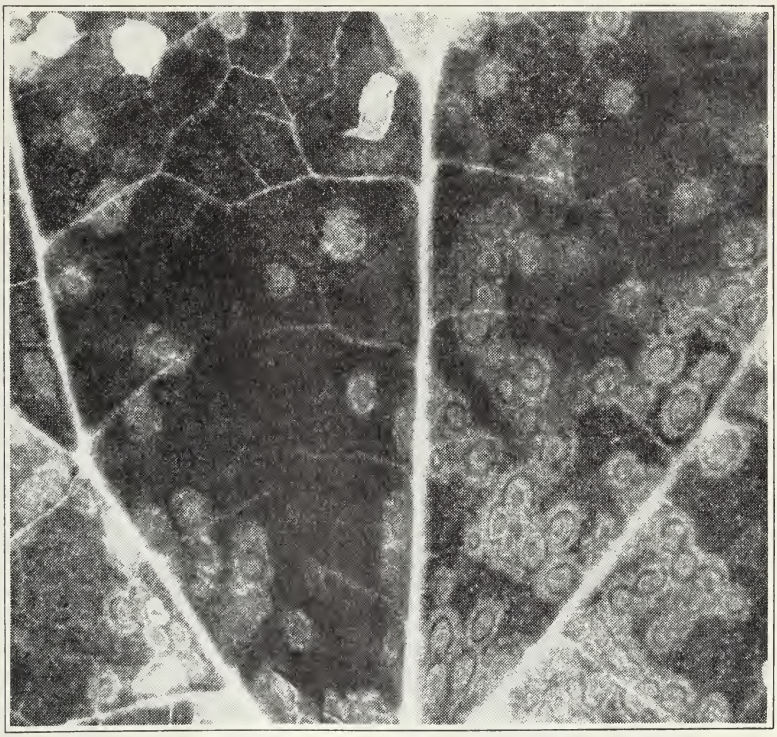

Fig. 32.—Ring-spot virus disease of rhubarb.

sometimes attacks rhubarb, but is not often serious on it. Affected plants die and the tissue at the crown is permeated with the white, felty fungus growth. Clumps of tan-colored toadstools often come up at the base of trees attacked by this parasite. Rhubarb plants which show this disease should be dug out and burned with special care to get all the roots.

**Rust.**—A true rust, *Puccinia phragmitis*, with dusty, red, spore pustules of the fungus is rarely seen on rhubarb leaves in California; it is not serious.

**Virus Diseases.**—One or more virus diseases of rhubarb have been observed in California, characterized by clear, chlorotic areas, mottling, and irregular growth of the leaves. One disease of this sort has the character of a "ring spot" with concentric rings of light and darker tissue (fig. 32). In another, the veins are transparent while the tissue between shows its normal color. None of these is serious or prevalent.

## SALSIFY

**White Rust.**—This disease is characterized by white, blisterlike pustules of spores, of the fungus *Albugo tragopogonis,* covering the leaves and sometimes the stems. Badly affected plants are stunted and deformed. No method of control is known.

## SPINACH[21]

**Curly Top.**—In curly-top plants, the young leaves become crinkled, rolled, stunted, and deformed, and the plants turn yellow and die. This disease (see p. 91), caused by a virus, is the same as curly top of sugar beets (p. 15) and is spread by the beet leafhopper, *Eutettix tenellus.*

Nothing can be done for curly top after it appears. It is not as common on spinach as on sugar beets, and growers have learned by experience where and when the crop can be planted without serious danger. Most spinach for canning is grown in winter, when curly top is not likely to develop.

**Damping-off, Seedling Blight.**—If damping-off is present, the seedlings die at a very early stage or fail entirely to develop from seed on account of the attacks of soil fungi, including a species of *Pythium* and others. This results in a poor stand of plants in the field and in reduced yields.

Adequate control of damping-off of spinach can usually be secured by treating the seed with red copper oxide (p. 102) or with zinc oxide (p. 105) at the rate of 2 pounds per 100 pounds of seed. To facilitate the flow of seed through a drill, approximately ½ pound of graphite (special grade for seed treating) should be added to the above amount of dust before mixing with the seed. Several commercial concerns are prepared to treat the seed for growers, or the grower may treat his own by rotating it in a drum mounted on an axle or in any other device that will provide uniform coating with the dust.

*Caution:* Avoid inhaling any of these dusts. Treated seed should not be fed to farm animals.

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[21] For information on the culture of spinach see: Scott, G. W. Spinach production in California. California Agr. Ext. Cir. 92:1–26. 18 figs. 1935.

**Downy Mildew.**—The leaves of affected plants are somewhat puckered or distorted and show pale-yellow spots with patches of violet-gray fungus growth or spores on the underside. The plants are sometimes badly injured or ruined by this disease, which is caused by *Peronospora effusa.*

The development of resistant varieties seems to hold out the best promise of a feasible method of controlling downy mildew. No such varieties are available at present.

**Fusarium Blight.**—Yellowing and dying of the young plants with slight curling and distortion of the leaves characterize this disease. The fungus, *Fusarium spinaciae,* causes blackening and death of the roots and some internal discoloration. Mature plants may wilt and die. The disease is not common. Badly infested soil should not be replanted with spinach.

**Leaf Spot.**—In this disease, the leaves show dead spots which sometimes blight them and severely injure the crop. This fungus disease, caused by *Heterosporium variable,* is most severe on winter-grown crops subjected to cold, wet conditions.

**Mosaic, Blight.**—The young, inner leaves of affected plants become mottled, crinkled, and yellow, and finally die. The whole plant, if affected while young, remains stunted and yellow and is a total loss. The disease, caused by a virus, is spread by aphids. It is most severe on fall-planted spinach and is usually not abundant on the spring canning crops. No method of controlling this disease is available at present.

**Yellows.**—In this disease, the foliage is of various shades of yellow, or often shows green on the veins and yellow between. The plants are usually more or less stunted. This condition is nonparasitic; it often denotes a lack of some chemical element, such as iron or manganese, in the plants, and usually develops on soil that is high in lime, alkali salts, or some other unfavorable ingredient. Similar symptoms are caused in the Sacramento Valley by high water table during wet years. Spinach should not be planted on land where this condition commonly develops.

## SQUASH

See "Cucurbits" (p. 45)

## SWEET POTATO[22]

**Black Rot.**—Affected potatoes when dug show large, circular, almost black spots on the surface (fig. 33). Under these spots is a rather dry, very black, fungus decay of the flesh, caused by *Cerastomella fimbriata.*

[22] For further information on sweet-potato culture, with descriptions and illustrations of diseases see: Porter, D. R. Growing and handling sweet potatoes in California. California Agr. Ext. Cir. 55:1–35. 15 figs. Revised 1935.

This may develop and increase in storage. Young plants also show this disease as a black discoloration at the lower end of the stem.

All sweet potatoes which show any symptoms of black rot should be

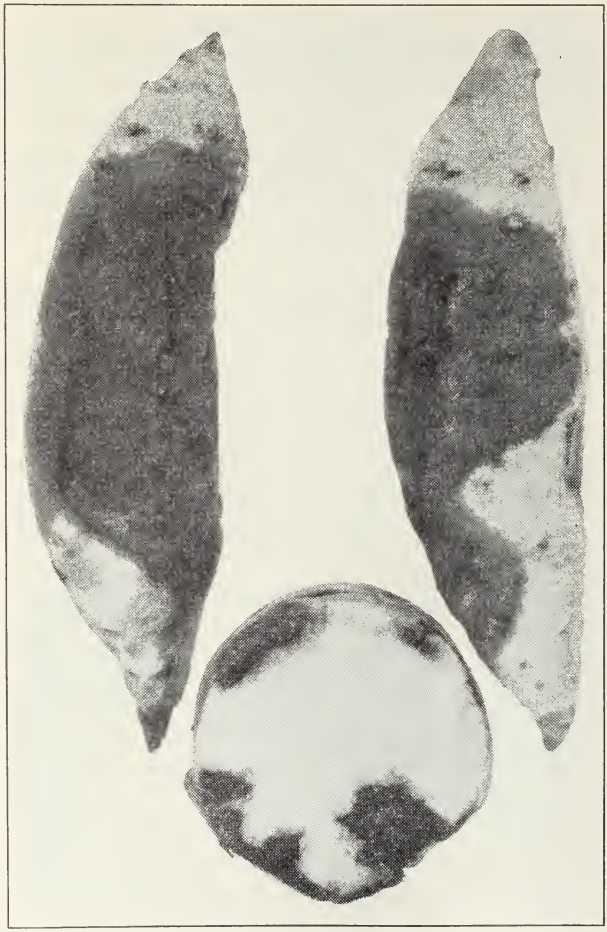

Fig. 33.—Black rot of sweet potato.

discarded in digging, sorting, shipping, or planting. To prevent this disease, seed potatoes should be treated as described later for stem rot.

**Root-Knot Nematode.**—This nematode, *Heterodera marioni,* causes numerous little swellings or galls to develop on the roots and stunts the growth of the plants. This pest, the common garden nematode, is often very abundant and troublesome on many different crops in the light, sandy soil on which sweet potatoes are usually grown. The Yellow Jersey variety is much less affected by nematode than the Nancy Hall.

Crop rotation is the only method by which nematode infestation in the soil can be reduced, but this is usually rather difficult in raising sweet potatoes, since melons, tomatoes, peaches, almonds, grapes, figs, and many other crops are so susceptible to the pest. By vigorous methods, however, much can be accomplished. See page 94 for details.

**Scurf.**—Irregular patches of a brown russeting appear on the skin of affected potatoes, sometimes covering most of the surface with a uniform discoloration. *Monilochaetes infuscans,* the fungus responsible for this trouble, causes no actual decay or injury to the flesh, but the appearance and value of the crop is affected. Careful selection of seed which is free from scurf will largely control this disease. Dipping the seed as recommended for stem rot is also helpful.

**Soft Rot.**—The potatoes in storage or transit are often attacked by a soft, mushy, dripping, fast-spreading rot, which entirely destroys them. The fungus, *Rhizopus nigricans,* develops on the outside as a very vigorous, bushy mold, which is at first white and then becomes covered with black spore heads. This rot attacks mostly potatoes which have been bruised in digging or handling, injured by low or high temperatures, insufficiently cured, or stored with poor ventilation. Sound, well-cured potatoes, held at proper temperatures and with good ventilation, are not likely to be affected.

**Stem Rot, Wilt.**—In the field some plants are attacked by a fungus, *Fusarium bulbigenum* var. *batatas* or *F. oxysporum* f. 2, and wither and die before ever starting to grow. Others develop more or less, then die, and the leaves turn black. Many plants have the main stem partially decayed, some of the shoots alive and some dead. If the stem is split lengthwise, dark-colored streaks will be seen in the inner woody tissue. These streaks run down into the potatoes (fig. 34) and form, in cross section, a dark-brown ring in the flesh near the stem end. The stem-rot fungus does not usually rot the potatoes but may be the cause of dark streaks in the flesh when they are cooked. If affected roots are planted in the hotbed, some never grow, while in others the fungus grows up into the young sprouts and the disease is thus perpetuated. Diseased vines are inclined to set a large number of small potatoes about the right size for seed, so that, if careful selection is not practiced, a high percentage of affected seed potatoes are likely to be planted.

The production of clean planting stock in the seedbed is the best method of control for this disease. Seed selection is the first step. The best way to obtain clean seed is to examine the main stem of each plant when the potatoes are harvested, and save seed only from those which do not show the dark streaks or discoloration. After the "hands" of potatoes

have been plowed and pulled out, a very careful man should examine each one by splitting the stem; he should throw all the plants which show any signs of stem rot into a separate pile. This is a very particular job which cannot be trusted to ordinary help. The extra expense is not very

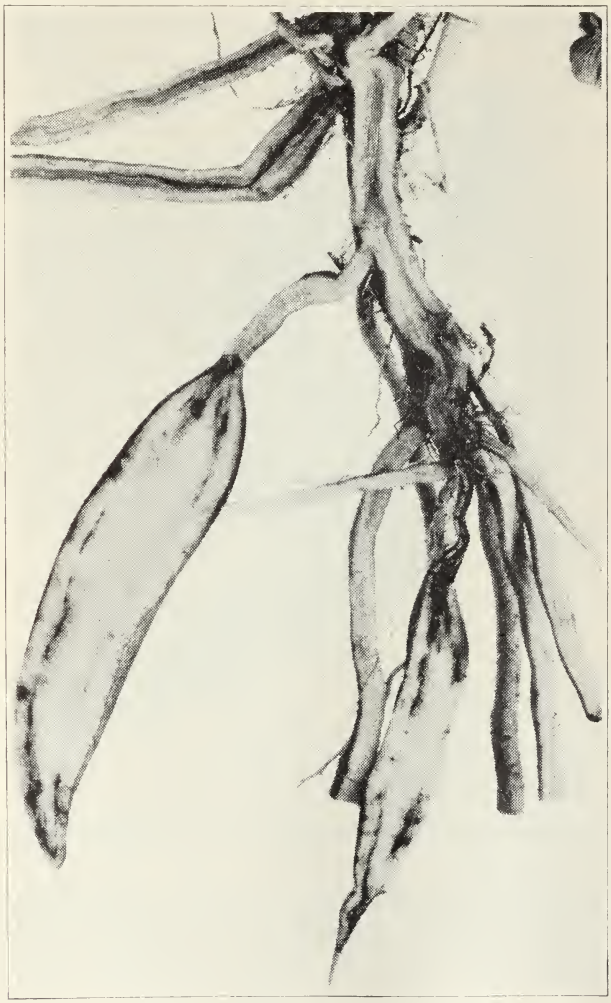

Fig. 34.—Stem rot of sweet potato.

great. The seed potatoes should then be taken from the clean plants, all those which show blemishes of any kind being discarded. This should be done before the stems have been injured by frost. If the seed is not selected in this way, many diseased potatoes will be used for planting and stem rot will keep on increasing.

Crop rotation helps to keep down stem rot, because the soil, both in the hotbed and in the field, gets infested if sweet potatoes are grown in it year after year. The soil or location of the hotbed must be changed often and crops rotated in the field to avoid this disease. If the seed is selected carefully, the same seedbed and field can be used for sweet potatoes longer than if unselected seed is used. No trash, soil, manure, or other

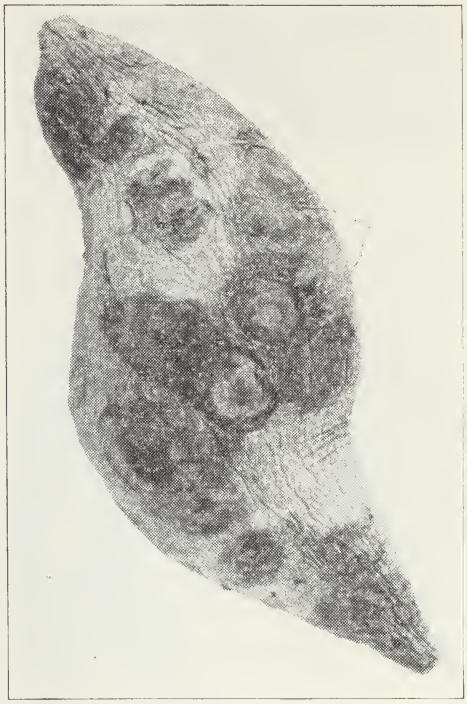

Fig. 35.—Surface rot of sweet potato.

material which might contain refuse of diseased plants should be used in the hotbed.

Seed treatment by dipping the seed potatoes in a disinfecting solution does some good but is not so important as seed selection. If the stem-rot fungus is already inside the potatoes, dipping will not do any good.

All diseased or suspicious seed potatoes should be sorted out and thrown away before planting. The selected seed should be soaked for 10 minutes in a solution of 1 ounce of corrosive sublimate (p. 103) (also called "bichloride of mercury") dissolved in 8 gallons of water, in a wooden container. After treating 500 pounds of seed, ¼ ounce of the chemical and enough water to bring it up to the original amount should be added to keep up the proper strength. The solution should be thrown

away entirely and made up fresh after dipping about a ton of seed potatoes.

Another control method which has given good results in other places is to plant 2 or 3 plants in each hill. If this is done, at least one plant is usually left alive so that a good crop of potatoes is obtained.

There are some resistant varieties of sweet potatoes which bear a good crop, even in infested soil. Of the varieties which are commonly grown in California, the Nancy Hall is not much affected by stem rot, while the Yellow Jersey is one of the worst. This, unfortunately, is the reverse of the relation of these varieties to nematode and black rot.

**Surface Rot.**—This fungus disease, caused by *Fusarium oxysporum,* attacks sweet potatoes in storage, and produces good-sized, roundish, somewhat sunken spots (fig. 35), below which a shallow dry rot develops. Later the potato shrinks between the spots and finally becomes dry, mummified, and completely ruined. The spots start at digging time from infections at the bases of the fine rootlets. This is one of the most important storage diseases in California.

Rough handling, poor curing, freezing, and poor ventilation are all conditions favorable to surface rot, so that if they are avoided there should be less loss from this cause.

## SWISS CHARD

See "Beet" (p. 15)

## TOMATO[23]

**Bacterial Canker.**—A bacterial organism, *Phytomonas michiganensis,* blights the leaves and on the stems produces yellowish streaks which crack open and thus form cankers. The interior of diseased stems is brown and mealy, especially at the nodes, and the pith is easily separated from the woody portion. Fruits infected when young are stunted and distorted. Infection is carried through the seed, and in California the disease is spread mainly in the seedbed. Handling the plants, as in cutting off the tops and transplanting, helps to distribute it.

Seed should be taken from fields which are free from this disease. As an extra precaution, the pulp of the entire crushed tomatoes, with no added water, should be fermented at or below 68° Fahrenheit for 3 to 6 days, during which it should be stirred twice a day. The seed should be dried, and at any time before planting, soaked in a solution of corrosive sublimate 1–3,000 (1 ounce to 23 gallons, see p. 103) for ex-

[23] For further information on tomato culture, with descriptions and illustrations of diseases, see: Porter, D. R., and J. H. MacGillivray. The production of tomatoes in California. California Agr. Ext. Cir. 104:1–61. 39 figs. 1937.

actly 5 minutes. It should then be washed in running water for 15 minutes and dried. Old tomato soil should not be used for plant beds. If plants are purchased, care should be taken to make sure that they are from beds free of bacterial canker.

**Bacterial Speck.**—In bacterial speck, very small, dark-brown or black spots develop on the leaves and fruit. When close together on the leaves, the spots coalesce into large, irregular blotches and the surrounding tissues become yellow. Young plants in plant beds sometimes

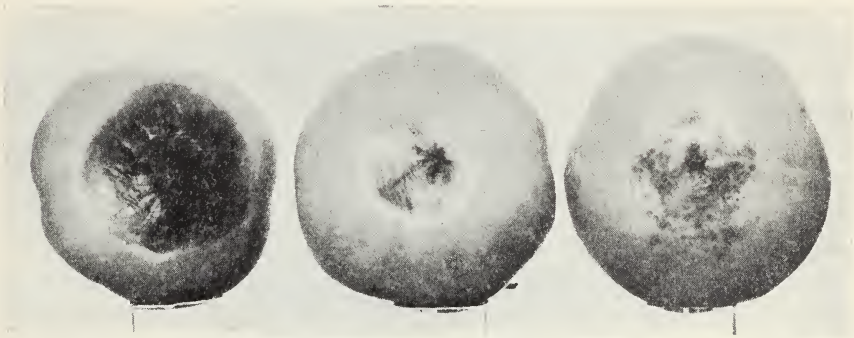

Fig. 36.—Blossom-end rot on tomato fruits. (From Bul. 239.)

become severely affected. The disease is due to *Phytomonas punctulans* and appears to be seed-borne.

**Blight.**—This term is often used by growers to describe any disease which kills the vines. Spotted wilt in the Santa Clara Valley, western yellow blight in the San Joaquin Valley, late (phytophthora) blight in the southern coast counties, and verticillium wilt wherever it occurs are all commonly called "blight." The expression "blight-proof" tomato plants sometimes used by seedsmen does not mean very much unless some specific disease is designated.

**Blossom-End Rot.**—Small, discolored spots sometimes appear on the green fruit at the blossom end and these coalesce into a large, flattened, brown, dead area. (fig. 36). Molds and bacteria invade this tissue but do not seem to be the primary cause of the trouble, which is apparently nonparasitic and usually appears in fields which have been irregularly or poorly irrigated. In irrigated fields, plants should not be allowed to suffer for water at any time. Land should be properly leveled to avoid high spots.

**Curly Top, Western Yellow Blight.**—The diseased plants are stunted and bear little fruit. The stems have a stiff, erect habit, the leaves show a purple color on the veins, the petioles curve downward, and the leaf-

lets curl inward and become crisp, yellow, and thickened (fig. 37). This is the same disease as curly top of sugar beets: it is caused by the same virus and is also spread by the beet leafhopper, *Eutettix tenellus*. It is most prevalent in the southern interior valleys of the state and some years wipes out entire crops of tomatoes.

Tomatoes should not be planted where the hazard of this disease is

Fig. 37.—Tomato curly top. (From Ext. Cir. 66.)

too great. No good resistant varieties are available at present. The Red Currant tomato is resistant to this and several other diseases but is not a good variety commercially; it is being used as a basis of breeding.

**Damping-off.**—The young plants in the seedbed often collapse and die, the stems rotting off just at the ground level. The trouble first starts in spots here and there in the bed, and, if conditions are favorable, may spread rapidly through the soil and kill large areas of plants. Weblike fungus threads of any of several fungi may be seen on the soil and affected seedlings. See page 92 for methods of control.

**Early Blight.**—A fungus, *Alternaria solani,* produces small, dark-colored spots on leaves and stems, especially on young seedlings in plant beds. Along the coast, the disease occasionally appears in the field when prolonged wet weather occurs in the fall. Small, roundish spots are also produced on the green fruit. Infected seedlings should not be planted in the field. Seedbeds should not be located in places where this disease gives much trouble.

**Fusarium Wilt.**—In this disease the leaves turn yellow, usually first on one side of the plant, which dies prematurely. A light-brown discoloration develops in the woody tissue of the stem. The causal fungus, *Fusarium bulbigenum* var. *lycopersici,* which enters the plant through the roots and attacks no other host plant, sometimes infests soil so that tomatoes can no longer be grown in it. The organism is favored by soil temperatures of 80° Fahrenheit or higher. In general, fusarium wilt of tomatoes is not so serious in California as in many eastern states but occurs to some extent in the San Joaquin Valley and other districts. Verticillium wilt is much more common.

A number of wilt-resistant varieties have been developed, among them Marglobe, Norton, and Pritchard. These may not be resistant, however, to other diseases which attack the plants, and are not immune even to fusarium wilt under conditions favorable to a severe outbreak. The fungus may attack young seedlings in the plant bed if it is introduced by means of infested soil or old plant remains. The small Red Currant variety is resistant to this and several other tomato diseases and is being used as a basis for breeding a resistant commercial variety.

**Late Blight.**—On the leaves, petioles and stems of affected plants there develop rapidly enlarging, moist, brown or black blotches, which cause a sudden blighting and killing of the tops. On the fruit, small, water-soaked blotches appear, spread rapidly over the surface, and cause complete rotting or spoilage. This disease is seen mainly in the late fall crop of tomatoes in the coast districts of the southern counties after early rains, when entire plantings are sometimes wiped out within a few days. Young plants in seedbeds are occasionally affected. The disease is caused by a fungus, *Phytophthora infestans,* which may be seen in moist weather as a delicate, whitish mold on the affected parts of leaves, stems, and fruit. It is very similar to the late-blight fungus of the potato.

Late blight may be prevented by spraying the vines thoroughly just before the disease appears with 4–4–50 bordeaux mixture (p. 100). Dusting with 15–85 copper-lime dust (p. 102) serves the same purpose in a more convenient manner but may not be quite so effective. The time of the first spraying, or the decision whether or not to spray at all, must

depend a good deal on previous experience in any given locality. If heavy fall rains or continuous foggy weather occur and such weather has been followed by tomato late blight in former years, then spraying should be done at once. Sometimes spraying after the first signs of the disease have appeared is effective. If wet weather continues, treatment must be repeated to protect the new growth and fruit. All visible spray residue should be wiped from the tomatoes before shipment.

To prevent development of fruit rot in transit in tomatoes from blighted fields, it has been recommended to dip them in a solution of commercial Formalin, 1 part to 300 parts of water (p. 103). They should then be allowed to stand for 4 or 5 days before being sorted and packed for shipment. It is not known that this treatment has been tried in California, so it would be well to test it on a small scale before dipping a large quantity of tomatoes.

**Leaf Mold.**—In greenhouse tomatoes, the leaves sometimes show large, yellow patches, with a brown, velvety fungus growth, *Cladosporium fulvum,* on the under surface. Under conditions which favor this disease, the fruit also sometimes becomes moldy.

Adequate ventilation and avoidance of overwatering are usually sufficient to hold this disease in check. Rank-growing vines which are allowed to become matted and overcrowded are more apt to develop leaf mold. Spraying with copper fungicides, sulfur dusting, or vaporizing sulfur are sometimes tried with more or less success, but good ventilation is the most important thing.

**Mosaic Diseases.**—Two types of mosaic, both caused by viruses, are found on tomato. In common mosaic, the plants are somewhat stunted and the leaves show color mottling and puckering and the fruit a faint calico pattern. The disease is spread by aphids and may also be transmitted from plant to plant by handling. It infects other plants such as tobacco, petunia, nightshade, and delphinium. Common mosaic often originates in smoking or chewing tobacco used by men handling the plants.

Fernleaf, filiform, or "shoestring" frequently affects a few scattered plants. In this form, the plant is greatly dwarfed and the leaflets are narrowed so that often not much more than the midribs are left. These plants bear no salable fruit. This disease is caused by the same virus as cucumber mosaic. It is transmitted by aphids but not readily by handling.

No specific method of controlling these diseases is known. Plant beds should be located away from ornamentals and gardens.

**Pleospora Rot.**—This disease has caused considerable loss in November and December shipments of tomatoes from certain coastal areas. A

firm, dark-brown rot develops in transit, beginning from fungus infections in cracks near the stem end of the fruit. The fungus that causes it is *Pleospora lycopersici*. Progress of the rot is checked at 45° Fahrenheit and is most rapid between 65° and 70°.

**Psyllid Yellows.**—Psyllid yellows is not common on tomatoes in California but has been seen in Imperial Valley. The symptoms of this disease somewhat resemble those of curly top. There is a puckering of the very young leaflets followed by dwarfing, upward folding along the midrib, and curling and twisting of the petiole. There may be also a purpling of the margins and veins of the leaflets. This condition is produced by the feeding of a small insect, the tomato psyllid, *Paratrioza cockerelli,* apparently by the injection of some toxic substance into the plant. It is not a virus disease, and the plants recover if the insects are removed.

**Rhizopus Canker.**—Some of the shoots on an affected plant turn yellow and die. The fungus, which is the common black or bread mold, *Rhizopus nigricans,* causes a soft rot of some of the older fruits and grows up through the fruit stem into the main shoot. The disease, which is not common enough to need control, is sometimes mistaken for fusarium wilt.

**Root-Knot Nematode.**—The plants attacked by this nematode, *Heterodera marioni,* become yellow and stunted and the roots are covered with roundish, fleshy swellings or galls (fig. 38). This pest, the common garden nematode, is very common on tomatoes as well as a great variety of other plants. Tomatoes should not be planted on nematode-infested ground. For further suggestions on control see page 94.

**Spotted Wilt.**—This disease causes tremendous losses in coastal districts. The growing tips of affected plants are blighted as by a light frost, with brown, dead spots on the young leaves and stems. The plants are stunted, the older leaves somewhat yellowed, and the fruit shows very characteristic symptoms, being marked with concentric rings of red and yellow (fig. 39). Plants affected when very young either die or make little growth and bear no crop. The virus which causes this disease attacks many other plants (p. 97) and is spread by thrips.

No effective control for spotted wilt has been found. In order to limit infection of tomato plant beds, they should be located as far as possible from home gardens, flower beds, or alfalfa, all of which harbor infective thrips. Weeds should be kept out of plant beds and off the surrounding land. Plants should not be purchased from beds in which this disease is present.

In the greenhouse crop of tomatoes, spotted wilt may be controlled

by fumigating with nicotine once a week or oftener to kill thrips and by removing all sources of infection such as weeds, ornamentals, and diseased tomato plants. Varieties of tomatoes resistant to spotted wilt have been developed from hybrids with the Red Currant variety. None

Fig. 38.—Roots of tomato plant affected by root-knot nematode. (From Cir. 280.)

of these have as yet been commercially perfected but progress is being made.

**Verticillium Wilt, Verticilliosis.**[21]—Leaves of affected plants turn yellow, then brown, and finally die and fall off, leaving the stalks bare,

[21] For further information see: Rudolph, B. A. Verticillium hadromycosis. Hilgardia vol. 5, no. 9, p. 197–361. 1931.

the fungus working in the stem from below upward. The woody portion is discolored with brown, longitudinal streaks. The main roots often show large, conspicuous, irregular, black cankers on the surface. In the central-coast districts, this disease causes great losses in canning toma-

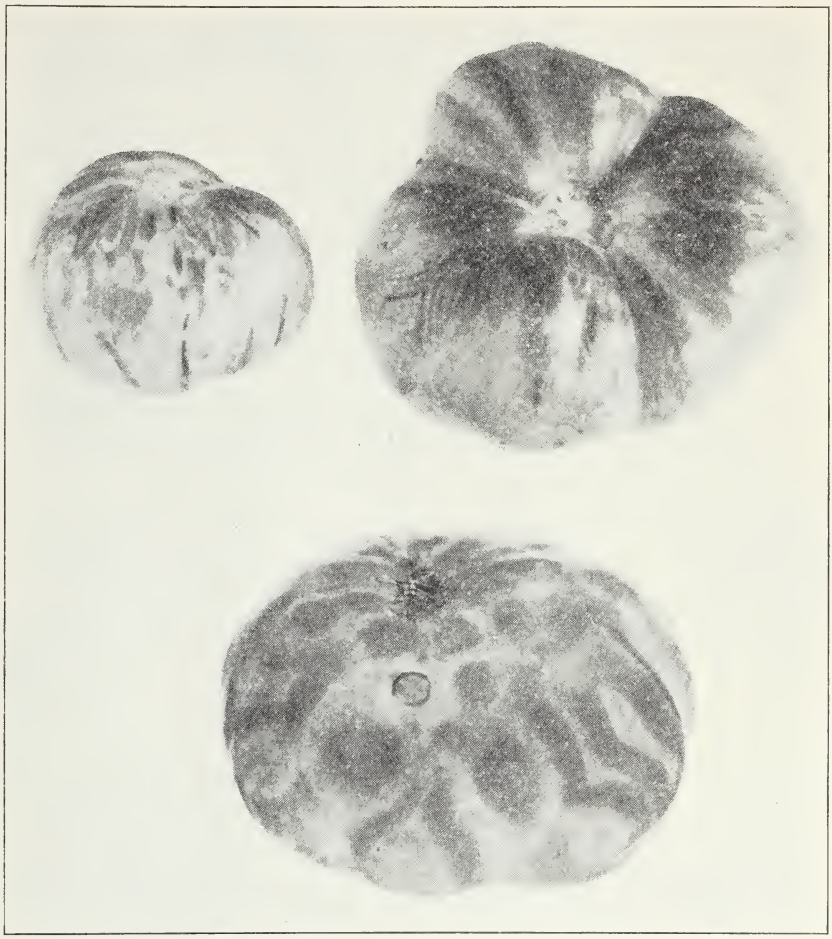

Fig. 39.—Spotted wilt of tomato. (From Ext. Cir. 104.)

toes by stunting and killing of plants and in reduced size, quality, and yield of tomatoes. Market, shipping, and canning varieties are susceptible. Many other hosts are attacked by the same fungus, *Verticillium albo-atrum,* which causes blackheart of apricots, blue stem of raspberries, and important diseases of strawberry, potato, and cotton.

The chief hope of combating this disease in tomatoes lies in resistant varieties. The problem is complicated by the fact that another serious

disease, spotted wilt, is abundant in the same districts and often on the same plants. It is therefore desirable to get a good canning tomato with resistance to both diseases. Tomato-breeding work for disease resistance is being done at the University Farm, Davis; the Citrus Experiment Station, Riverside, and at the University of California Deciduous Fruit Field Station, San Jose. Further information about tomato varieties resistant to verticillium wilt may be obtained at the latter institution.

Excessive irrigation should be avoided because large amounts of water in the soil favor the fungus. In land which has become badly infested with verticillium-susceptible crops should not follow each other. Cereal or grass crops like hay, grain, and corn are immune. Many weeds are susceptible to the fungus and help to keep it alive in the soil.

**Western Yellow Blight.**—See "Curly Top" (p. 82).

### TURNIP

See "Crucifers" (p. 36)

### WATERMELON

See "Cucurbits" (p. 45)

## DISEASES AFFECTING MANY CROPS

### ALKALI, BORON, SALT[25]

Affected plants usually look yellow and sickly, and the leaves show burning at the margins and between the main veins. Stems may show peculiar swellings or deformities. Such injury to plants caused by harmful chemical substances in the soil or irrigation water often occurs in California. Some of the most frequent cases are due to the so-called "white alkali" (sodium sulfate) and "black alkali" (sodium bicarbonate). Common salt (sodium chloride) may also be the cause of injury to plants. In recent years it has been discovered that in some localities boron is present in soils and waters in injurious amounts and this has accounted for some hitherto mysterious plant troubles.

In the case of symptoms like these, which cannot be explained in any other manner, samples of soil and irrigation water for analysis should be sent to the Division of Plant Nutrition, University of California, Berkeley. It would be well first to write a letter describing the case and asking for instructions about taking samples. Faulty soils can be cor-

[25] For more complete information on this subject see:
Kelley, W. P. The reclamation of alkali soils. California Agr. Exp. Sta. Bul. 617:1–40. 1937.
Eaton, Frank M. Boron in soils and irrigation water and its effect on plants. U. S. Dept. Agr. Tech. Bul. 448:1–132. 1935.

rected to a certain extent by chemical treatment, washing with fairly pure water, and drainage. Harmful irrigation water cannot be improved by any known method.

### COTTONY MOLD

The fungus *Sclerotinia sclerotiorum* is referred to rather frequently in this circular as the cause of diseases of various plants. In such cases it causes a rotting of stems, roots, leaves, fruit, or other fleshy parts,

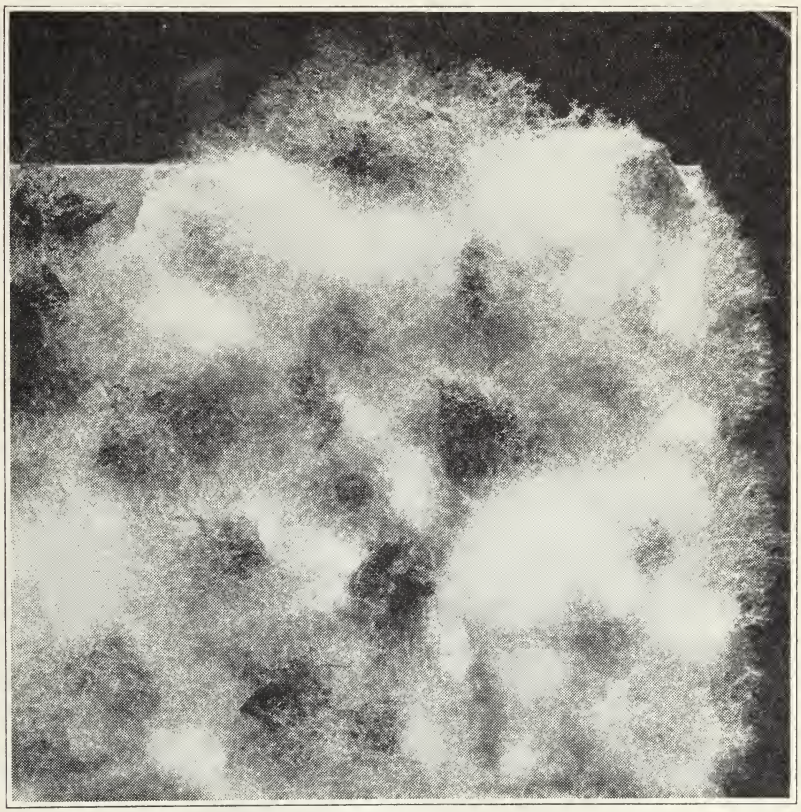

Fig. 40.—Cottony-mold fungus. (From Ext. Cir. 118.)

and develops an abundant growth of pure-white, cottony, fluffy mold upon the affected tissue (fig. 40). This is a soil fungus which ordinarily grows upon dead vegetable matter, but when moisture is abundant, it may attack living plants, fruit, or vegetables. The fungus forms no spores of any kind upon the white mold, but when there is plenty of moisture, this growth may spread very rapidly. Embedded in it and upon the affected plant parts are seen roundish, black, solid bodies of various sizes up to about ½ inch long and ¼ inch in width or even

larger. These bodies are called "sclerotia." During the rainy season, the sclerotia, which have become embedded in the soil, send out little trumpet-shaped, fleshy, toadstoollike bodies with hollow, disk-shaped tops about 1/8 to 1/4 inch in diameter on the surface of the ground (fig. 41). These are called "apothecia," and the spores of the fungus are developed in them.

Plants which have a thick mass of vegetation near the ground, or the stems or roots of plants, may become infected with cottony rot by direct contact with the cottony-mold growth; blossoms and fruits and other parts growing entirely aboveground, which are sometimes attacked, can

Fig. 41.—Sclerotia (the black bodies) of the cottony-mold fungus developing apothecia (the trumpet-shaped, toadstoollike protuberances) in which spores of the fungus are produced at the surface of the ground. (Natural size.) (From Ext. Cir. 118.)

only become infected by spores developed from sclerotia in the soil and blown about by the wind. The fungus may become very abundant and kill almost any kind of plant in certain spots or areas of soil where there is a good deal of moisture and dense vegetation, but it does not always persist long enough to attack other plants growing later in the same places. Sometimes in greenhouses the soil becomes permanently infested with the cottony-rot fungus and must either be changed or disinfected before susceptible plants can be grown again. Treatment with steam or with formaldehyde (see "Damping Off," p. 92) is effective.

## CURLY TOP

This disease, which is best known in connection with the sugar beet (p. 15) and tomato (p. 82), sometimes attacks a variety of other plants under especially favorable circumstances. Beans, cantaloupes, celery, cucumbers, geraniums (*Pelargonium*), mangels, nasturtiums, pansies, peppers, squash, and zinnias are examples of this. This is a virus disease which is spread from plant to plant by a small insect, the beet leafhopper, *Eutettix tenellus*. (See Extension Circulars 87 and 95).

These insects overwinter on native plants in the foothills in the more arid portions of the state, whence they migrate in spring to beet fields and other vegetation in the valleys and introduce the disease. In the vicinity of a badly affected beet field, when the beets are ploughed out, swarms of infective leafhoppers spread to all neighboring vegetation, and various kinds of plants may show disease symptoms. These are usually of the nature of stunting, mottling, and deforming of the leaves.

## DAMPING-OFF

Young seedlings often rot at or below the surface of the ground, fall over, wilt, and die. The disease starts at spots here and there in the seedbed and spreads through the soil from plant to plant. Typical damping-off is usually seen only in seedlings growing under glass, cloth, or lath covers, where conditions of high soil moisture, high humidity, and high temperature are apt to occur. Such conditions are favorable to the growth of soil fungi like *Pythium, Rhizoctonia,* and *Fusarium.* The term "damping-off" may also be applied to the death of young seedlings in the field of crops like beans, beets, corn, cotton, peas, and spinach.

**Treatment before Planting.**—The prevention of damping-off in the seedbed[26] consists in preparing the bed so as to keep out these fungi, handling the soil to prevent their development, and treatment to check their spread if they should get started. Seedbeds should be made up of fresh soil and materials which have never before been used for the same purpose. If the bed is on the surface of the ground, it should be well drained and properly leveled to avoid any low spots where the water might stand. The soil should be made of fairly light texture by the use of sand, and the top ½ to 1 inch (or less with very fine seeds) may be of pure sand. For growing seedlings in flats, a mixture of one-third soil, one-third peat moss, and one-third sand is recommended.

In places where there has been much trouble with damping-off, the soil may be treated before planting to kill fungi, as well as nematodes, and possibly insects and weed seeds. All this can be accomplished by treatment with steam.[27] This requires special equipment. Soil disinfection by means of electricity has received considerable attention in recent years and may be of interest to some growers. Details of these methods and references to literature may be obtained by addressing the Division of Plant Pathology, College of Agriculture, Berkeley.

[26] For a good account of methods see: Newhall, A. G., Chas. Chupp, and C. E. F. Guterman. Soil treatments for the control of diseases in the greenhouse and the seedbed. New York (Cornell) Ext. Bul. 217:1–56. 23 figs. Revised 1938.

[27] See: Seener, Arthur H. Application of steam in the sterilization of soils. U. S. Dept. Agr. Tech. Bul. 443:1–19. 5 figs. 1934.

Many different chemical materials have been used to disinfect the soil before planting the seed. Formaldehyde solution is one of the best of these. This kills fungi but does not destroy weed seeds, insects, or nematodes. Use 1 gallon of commercial formalin to 49 gallons of water, applied at the rate of ½ gallon to each square foot of surface. After the solution has been sprinkled over the soil, it should be covered with paper, burlap, cloth, or boards to hold in the fumes. The cover should be removed in a day or two and the soil stirred with a rake as soon as it is dry enough, in order to dissipate the formaldehyde. After this, a period of 8 to 14 days must elapse before it is safe to put in the seed. Soil for flats or pots may be treated in a tight box.

Treatment with acetic acid has given good results in some cases. The details of the treatment are the same as those for formaldehyde, a solution of 1 gallon of glacial acetic acid (almost 100 per cent pure) to 99 gallons of water being used, or a similar preparation of any other strength to make a final solution of 0.8 per cent of the acid. One-half gallon of this should be used to each square foot of soil.

The formaldehyde-dust method consists in mixing 15 pounds of commercial formalin with 85 pounds of some dry, powdered, inert carrier like kaolin, "chalk rock" (infusorial earth), or clay. Lime should not be used. This mixture must be kept in an airtight container or it will rapidly lose its strength. The dust may be thoroughly mixed with soil that is to be used in pots or flats at the rate of 6 ounces of formaldehyde dust to 1 cubic foot of soil. Most kinds of seeds may safely be sown in this soil at once provided it is thoroughly watered. For transplants or cuttings, fully 3 days should elapse. In sandy cutting-bench soil, 3 ounces of dust per cubic foot is sufficient.

Another method is to increase the acidity of the soil while preparing the seedbed by scattering aluminum sulfate over the surface at the rate of 1 ounce per square foot and raking it in to the top inch.

To prevent the development of damping-off and other seedling diseases, treatment of seed before planting is sometimes practiced with advantage. In most cases the seed is shaken up with a dry, finely powdered chemical so as to cover the surface with the fungicidal substance. Red copper oxide is used for this purpose, also zinc oxide and some of the proprietary mercury dusts (p. 104) are similarly employed (manufacturer's directions should be followed).[28]

**Treatment After Planting.**—In seedbeds, immediately after the seed is planted, the surface of the soil may be sprinkled with formalin 1 part

[28] For further information see: Haskell, R. J., and H. D. Barker. Cottonseed treatment. U. S. Dept. Agr. Leaflet 198:1–8. 3 figs. 1940.

to 200 parts of water (1 pint to 25 gallons), 1½ pints of this solution being used to each square foot of soil.

Another method which has been well recommended is to mix ¾ ounce of red copper oxide in 5 gallons of water. As soon as the seed is planted, the bed should be watered thoroughly with this mixture; it should be kept constantly stirred because copper settles quickly. As the seedlings come up through the surface of the ground, they should be watered again with the same mixture and once again when they are about an inch high.

The development of damping-off in seedbeds is largely governed by watering and ventilation. Watering should be done, as far as possible, in the morning rather than at night; in heavy applications at longer intervals rather than by frequent, light sprinkling; and as little as possible during dull or cloudy weather. Ventilation should be given to the greatest possible extent.

**Control of Infested Seedbeeds or Flats.**—If damping-off starts in the seedbed or flats, it may be checked by keeping the soil as dry as possible, by extra ventilation, and to some extent, by chemical treatment. The plants and soil may be sprinkled with the copper oxide mixture described above, or with 1 pound of copper carbonate stirred into 25 gallons of water, or with 2–2–50 bordeaux mixture (p. 100). Some of the proprietary mercury compounds mentioned above are recommended for this purpose and should be used according to directions on the package. Corrosive sublimate (mercury bichloride) and calomel (mercury chloride) may also be tried. Dry, powdered zinc oxide (p. 105) may be dusted lightly over the surface.

It may be repeated here that prevention of damping-off is mainly a matter of proper preparation and (if it seems desirable) treatment of the soil or seed before planting, together with subsequent care and skill in watering and ventilation, rather than of treatment with chemicals after the trouble starts.

## NEMATODES, EELWORMS

Nematodes which attack plants are small worms scarcely visible to the eye which enter or attach themselves to different parts like roots, stems, buds, bulbs, or leaves, and continue their existence there in the living tissue. The presence of these parasites either kills the part affected or causes the development of galls, swellings, and other abnormal growths and eventually weakens or even kills the host plant. These effects are similar to those often produced by fungi and bacteria and, since the causative organism is invisible to the eye, may properly be classed as diseases. Nematodes reproduce by means of eggs which become abundant in diseased plant parts and in infested soil. The eggs average about $\frac{1}{250}$

inch in length and hatch into young worms of a length of about 1/32 inch (fig. 42). These again attack plants when favorable conditions and hosts are available.

The root-knot, or common garden, nematode, *Heterodera marioni*,[29] causes swellings or galls on the roots of a great many different kinds of plants, including most annual crops, fruit trees, ornamentals, and many weeds. The worms are imbedded in these galls, the largest form being the

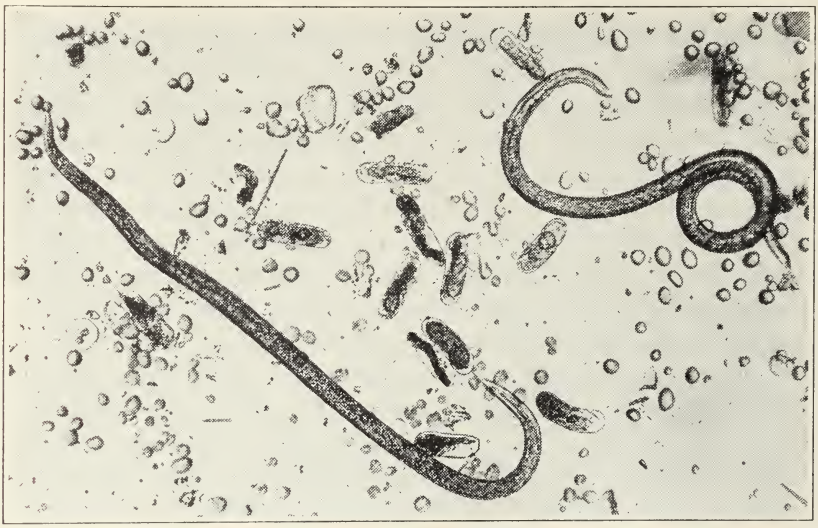

Fig. 42.—The narcissus stem nematode, with young worms and eggs. (Enlarged nearly 150 times.) (From Ext. Cir. 118.)

adult female, which has a white pearl-shaped body the size of a small pinhead.

The sugar-beet and citrus-attacking species are very similar to the garden nematode; leaf, bulb, and stem-attacking nematodes of a number of species occur commonly, especially on alfalfa, begonia, gooseberry, narcissus, strawberry, and other hosts.

Although a great deal of work has been done in many parts of the world in trying to find some way of controlling root-knot nematodes, no practical method has been found except to starve out the worms by growing some unsusceptible crop or keeping the land clear of all vegetation for one or more years. Drying the soil tends to kill out the worms. Of the crops commonly grown in California, the various grains, including sorghum, milo, and Kafir, as well as wheat, barley, oats, and rye, are highly resistant and may be grown as winter crops and followed by summer-

[29] For further information see: Tyler, Jocelyn. The root-knot nematode. California Agr. Exp. Sta. Cir. 330:1–34. 1933.

fallow for one or more seasons. The dryer the soil and the more frequently it is worked during the summer, the quicker the worms will be exterminated. Other crops which may be grown are certain varieties of cowpea (consult the Division of Agronomy, College of Agriculture, Davis, regarding names and seed), velvet bean, sweet clover (*Medicago*), and peanuts. Resistant varieties of several crops are mentioned under the respective headings. *All weeds must be kept down* whenever the eradication of nematodes is being attempted.

Many different chemicals have been tried for treating the soil to destroy nematodes. Newhall[30] lists about fifty different materials which have been experimented with for this purpose. None of them has proved to be of practical value, either on account of poor efficiency, injury to crops, or prohibitive cost. Miss Tyler (see footnote 29, p. 95) discusses this phase of the subject in detail and states that the most promising of these substances are carbondisulfide and chloropicrin. In greenhouse soils these or some other chemical may have some possible value but effective and practical methods of application have not yet been developed.

The leaf and bud nematode, *Aphelenchoides fragariae,* lives in the fleshy foliage tissue of plants like begonia, dahlia, and gloxinia (no important truck crops are attacked), and produces large dead areas in the leaves. The only way of controlling this pest is to discard or disinfect with steam all soil, pots, benches, and other material with which affected plants have been associated. Such diseased plants should be destroyed by burning.

The bulb or stem nematode, *Ditylenchus dipsaci,* also lives in the tissues of affected plants of many different species, like strawberries, alfalfa, garlic, narcissus, and phlox. In this case, however, many of the host-plant species have distinct strains or races of the parasite, so that the worms from narcissus, for instance, will not attack the strawberry, even though they are of the same species.

In greenhouses, nematodes of all types must be handled by destroying affected plants and steam-sterilizing infested soil, pots, beds, benches, and other equipment or replacing with fresh material.

With all crops or plants which are known to be subject to nematode attacks, great care should be taken to guard against introducing these pests into new places. They are usually spread on nursery stock, growing plants, or bulbs, tubers, or other plant parts. All such material should be carefully inspected for nematodes and, if symptoms are found, should be rejected. Nurserymen and florists should be particularly careful in

[30] Newhall, A. G. Control of root-knot nematode in greenhouses. Ohio Agr. Exp. Sta. Bul. 451:1–60. 12 figs. 1930.

this respect, since nematode infestation is likely to cause them serious losses in rejected stock.

## SOIL DEFICIENCIES

It is a well-known fact that plants require for their normal development the presence of certain chemical elements, as well as water, in the soil. Until rather recently, these essential elements were supposed to be nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur. It is now known that at least four others—namely, boron, manganese, copper, and zinc—must be added to this list, and there may still be others. One usually thinks of three elements—nitrogen, potash, and phosphorus—as being most likely to benefit plants when added to the soil. Of these, nitrogen is the one most commonly lacking in California. Ordinary effects of nitrogen deficiency, where fertilization of plants with this element results in increased growth or vigor are not usually considered as diseases. Cases are not unknown of plant failure from lack of one of the other two elements. Certain obscure troubles of plants seem to be due to deficiencies of some of the less common elements, or at least they are corrected by supplying them. Chlorosis, due to lack of available iron, is an example. Symptoms caused by excess of certain substances (see "Alkali, Boron, Salt," p. 89), may not be unlike those due to deficiencies.

In cases where plants fail to grow well from no apparent cause, one of the first things that suggests itself is to supply some fertilizer or chemical food material to the soil. This may be in the form of manure or a complete fertilizer, or one may attempt to prove the lack of a single element by experimenting on a small scale with single substances like ammonium sulfate, sodium nitrate, potassium sulfate, copper sulfate, iron sulfate, zinc sulfate, superphosphate, or sulfur. Various methods are given in the cases referred to above. There is a very common belief that deficiencies of substances necessary for plant growth can be detected by chemical analysis of the soil. This unfortunately is seldom true.[31]

## SPOTTED WILT

Spotted wilt, a disease described in this circular under several hosts, represents one of the most serious plant diseases in California. The symptoms vary a great deal on different plants, but the cause of the trouble is the same, since it is readily transmitted from one to another. Over a hundred species of plants have been found to be infected by the spotted-wilt virus, including such crops as celery, tomato, lettuce, pepper, and horse bean; such ornamentals as calla lily, aster, nasturtium, tuber-

[31] See: Hoagland, D. R. Fertilizer problems and analysis of soils in California. California Agr. Exp. Sta. Cir. 317:1–18. 1930. Revised 1939.

ous begonia, gloxinia, cineraria, calceolaria, delphinium, dahlia, petunia, zinnia; and among weeds, nettle, Jimson weed, lactuca, and mallow.

The disease is transmitted by the flower thrips, *Frankliniella californica,* and the onion thrips, *Thrips tabaci.* The larvae of the thrips pick up the virus by feeding on diseased plants and then spread it to healthy ones in the same manner. Symptoms appear in the plant about 2 or 3 weeks after infection occurs. The virus may also be transmitted by rubbing leaves of a healthy plant with juice from a diseased plant, but this type of infection seldom occurs under field conditions.

The disease is most serious in the coastal regions, perhaps because there is no freezing weather to reduce the reservoir of infection in winter crops, ornamentals, and weeds; perhaps because the flower thrips are extremely abundant in those districts. The trouble has been found serious in the interior valleys only where it was introduced on plants grown near the coast, or where there are nearby market gardens where truck crops are grown the year around.

Certain localities apparently function as endemic centers or foci of infection from which there may be considerable spread of the spotted-wilt virus in the spring and summer. These localities are characterized by mild winters, no summer rainfall, and the presence of living host plants throughout the year. Apparently the thrips are active in these centers at all times, but the virus is least abundant just after the winter rains, possibly because of a reduction in the thrips population. Occurrence of the disease in regions remote from foci of infection is often traceable to introduction of the virus with imported transplants. It is not spread through the seed from affected plants. Seedlings from such seed do not develop spotted wilt unless they are inoculated by infective thrips.

In localities where the virus is prevalent, there is less infection in celery, celeriac, peas, endive, and chicory than in tomatoes, peppers, and lettuce. No infection has been observed in onions, rhubarb, beets and sugar beets, chard, globe artichoke, carrots, parsley, beans (*Phaseolus*), crucifers (except ornamentals), or cucurbits. Potatoes, though susceptible, also appear to escape infection. Besides certain ornamentals and winter crops, certain common winter weeds such as mallow and chickweed may harbor the virus. There is no indication that the virus exists in the native vegetation of uncultivated lands, as does the curly-top virus.

Frequently spotted wilt occurs in the plant beds, and crops set from such beds are sure to be heavily infected. Since the plant beds are usually located near the house and hence near ornamentals and kitchen gardens, infective thrips may readily find their way into the beds.

No effective control for spotted wilt is known. The difficulty of con-

trolling thrips is well known. Spraying with nicotine in the field or plant bed has not been effective. Certain precautions are recommended, however. Spotted wilt is frequently carried over from year to year and from one host to another on affected plants, like nasturtiums, which remain alive in a sickly, stunted condition. All disease carriers of this sort should be destroyed. Plant beds should be located as far as possible from kitchen gardens, flower beds, and alfalfa. Alfalfa harbors the flower thrips abundantly during the winter. All weeds should be kept out of the plant beds and the paths and land surrounding them. If old plant beds are to be used again, they should be kept clean-cultivated all summer. Plant beds should be closely watched for spotted wilt, and infected plants should be placed in a cloth sack and removed to a considerable distance from the beds. It is better, if possible, not to use any plants from beds in which infection is occurring, and certainly no plants should be purchased from such beds.

Field roguing of diseased plants may be worth while, at least as long as such plants can be replaced. Before pulling diseased plants, these should be sprayed with nicotine to kill the thrips. Since plants infected early are worthless, no loss is occasioned by roguing early in the season.

Good resistance to field infection is shown by tomato varieties recently developed from crosses between commercial varieties and the Red Currant type.

In a greenhouse crop, spotted wilt may be controlled by fumigation with nicotine once a week or oftener to kill thrips, and by removing all sources of infection such as weeds, ornamentals, and diseased plants.

### VERTICILLIUM WILT, VERTICILLIOSIS[32]

Verticillium wilt is a soil-borne fungus disease of considerable importance throughout California, particularly in the coastal counties. It is caused by *Verticillium albo-atrum*. More than 150 host plants, including stone fruits, bush fruits, truck crops, field crops, ornamentals, and weeds, are known. The disease is contracted through the root system. The woody tissue of the stem is invaded, and the fungus ascends to all parts of the plant. This brings about a wilt in the tops which is identical in most respects with severe drought injury and is often mistaken for it, but, if the wood cylinder be cut into, it will usually be seen to be streaked or stained dark brown. This discoloration has led to the use of the term "blackheart," particularly by apricot growers, as a common name for the disease.

[32] For more complete information see: Rudolph, B. A. Verticillium hadromycosis. Hilgardia vol. 5, no. 9, p. 197–361. 1931.

Trees sometimes recover from verticilliosis after individual limbs have been killed. Smaller plants and annuals usually die as a result of this disease.

No satisfactory control is known. Spraying is useless, since the parasite attacks exclusively through the root system. Soil disinfectants and amendments have not met the problem satisfactorily. Excessive irrigation should be avoided even though the plants seem to need more water, because the presence of too much moisture in the soil often favors the fungus. When feasible, dead and dying plants should be removed immediately with as much of the root systems as possible. It is not always necessary to remove affected orchard trees, unless they are actually dead, or even to prune out defoliated limbs, because such trees often recover completely the year after the attack. Weeds are susceptible and harbor the fungus. Rotation with susceptible crops should be avoided. In severely infested soil where field crops are grown, immune plants like hay, grain, corn, or other grass crops may be planted for several years to starve out the fungus.

## FUNGICIDES[33]

### COPPER

**Bordeaux Mixture.**—The following formula, known as the 5–5–50 mixture, is one of the most commonly used:

| | |
|---|---|
| Copper sulfate (bluestone) | 5 pounds |
| Quicklime | 5 pounds |
| Water | 50 gallons |

Various other concentrations of bordeaux mixture are recommended for certain purposes, like 8–4–50, 2–2–50, and so forth. The first figure always indicates pounds of copper sulfate, the second, pounds of quicklime, and the third, gallons of water.

Dissolve the copper sulfate and slake the lime in separate containers. Copper sulfate dissolves slowly in cold water but more rapidly in hot water and when in a finely crushed or powdered form. If the material is in coarse crystals, it should be placed in a coarse sack suspended in the top of the water, in a wooden container. Fresh, high-grade quicklime should be used, or the so-called "processed lime," which is pulverized quicklime.

Fresh hydrated lime may be used if no good quicklime is available, but not that which has become air-slaked. If hydrated lime is used, the quantity should be increased by about one-third over that of quicklime.

[33] For more complete information see: Robinson, R. H. Sprays, their preparation and use. Oregon Agr. Exp. Sta. Bul. 336:1–30. 1935.

If large quantities of bordeaux mixture are to be made, it is well to prepare concentrated stock solutions of copper sulfate and lime. A convenient strength of each is 1 pound to 1 gallon of water.

The two ingredients should never be combined in a concentrated form but should be diluted with as much of the water as possible before mixing together. The following method will give good results. Fill the spray tank half full of cold water and start the agitator. Pour in the proper amount of the copper sulfate solution, start the water running, add the right amount of lime solution through a 20-mesh screen, and fill up with water. If finely pulverized copper sulfate is used, it will dissolve almost instantly in the water and can be poured gradually on to the screen and washed through into the tank without preliminary soaking in another vessel. In preparing smaller quantities of bordeaux mixture, each ingredient may be diluted with half the total quantity of water before mixing.

**Commercial Bordeaux Mixture.**—Several commercial brands of bordeaux mixture in a powdered or paste form are on the market. These are more convenient to use than the homemade preparation and usually give satisfactory results, although they are admittedly inferior in sticking and lasting quality to a properly prepared, freshly made mixture. The cost is also greater.

**"Two-Package" Bordeaux Mixture.**—In this commercial preparation, finely powdered copper sulfate and hydrated lime are put up in proper proportions in separate packages. If the lime is fresh and if both substances are well diluted with water before mixing, this may produce a satisfactory material, but not equal to a freshly and properly prepared homemade mixture. Directions on the packages should be followed.

**Oil Bordeaux.**—Oil emulsion is sometimes added to bordeaux mixture to improve its spreading, sticking, and penetrating properties. An amount of commercial spray emulsion sufficient to make 1 per cent of actual oil in the final spray is commonly used; this is probably insufficient to increase the adhesiveness of bordeaux mixture materially. It is, however, enough to improve spreading of the spray on plant parts which are difficult to wet. Two per cent or more of actual oil is needed to improve the sticking qualities of bordeaux mixture to any appreciable extent.

**Bordeaux Paste.**—Bordeaux paste, which is frequently recommended as a wound dressing and antiseptic, is made as follows: dissolve 4 pounds of copper sulfate in 3 gallons of water, slake 6 pounds of quicklime with 3 gallons of water, and mix the two together. Or, mix commercial powdered bordeaux mixture with water to a consistency of a paste.

**Copper-Lime Dust.**—For the control of certain fungus diseases, the practice of dusting plants with a dry powdered material containing copper finds considerable use. This is prepared by thoroughly mixing together finely pulverized copper sulfate (bluestone) and hydrated lime. Since copper sulfate is a crystalline, gritty, and moist material, it can be pulverized much more effectively by first heating it to drive off part of the water. This causes the crystals to disintegrate and form the so-called "monohydrate." The respective percentages of the two ingredients are given in expressing the composition of the dust. A 20–80 dust for instance, the usual formula, contains 20 pounds of monohydrate copper sulfate and 80 pounds of hydrated lime. The materials must be fine enough so that 95 per cent of each ingredient will pass through a 200-mesh screen. Better results with copper-lime dust will be obtained if it is applied when plants are wet.

**Copper Carbonate.**—This is a finely pulverized, light-green powder which is used extensively in seed treatment, especially for cereals. It is also used in some cases as a preventive of damping-off by sprinkling the powder lightly over the surface of the soil and affected plants.

**Ammoniacal Copper Carbonate.**—When a clear solution which leaves no sediment, is required, ammoniacal copper carbonate is occasionally used as a spray instead of bordeaux mixture. It is much less effective as a fungicide. To prepare the spray, mix 7 ounces of copper carbonate into a thin paste with 1 gallon of water. Add slowly to this 3 pints of strong ammonia and stir thoroughly. A clear blue solution is produced. Dilute to make 50 gallons of spray.

**Copper Oxide.**—Finely pulverized, red oxide of copper (cuprous oxide) has in recent years come into extensive use as a dry powder for seed treatment (see p. 75) and is also showing promise as a spray material, suspended in water. Commercial brands are available. To be of value, the red oxide must not have deteriorated to the black (cupric) oxide. Superiority is claimed for a yellow, more finely divided form which is now on the market. Powdered graphite is sometimes added to seed being treated with copper oxide to make it run more evenly through a seed drill.

**Copper Acetate.**—A solution of copper acetate in water has been recommended as a fungicide when a clear solution is desired. Three ounces of the chemical in 50 gallons of water is the strength suggested. This is rarely used and is probably not very effective.

**Flordo Spray.**—The Florida Agricultural Experiment Station suggests the following formula, especially for treating plants where a more disfiguring spray is objectionable. This should be tested in a small way before it is used on a large scale or upon valuable plants.

| | |
|---|---|
| Soap (granular or chip) | 10 pounds |
| Copper sulfate | 2½ pounds |
| Ammonia (26–28 per cent) | 1 quart |
| Water | 100 gallons |

Dissolve the copper sulfate in 5 gallons of water, add the ammonia to this, stir the soap into another portion of water, and mix all together with the remainder of the water.

**Other Copper Sprays.**—Many other copper fungicides have been developed for the purpose of improving upon or supplanting bordeaux mixture, and a number of these are on the market at present. Some of them have the advantage, for certain purposes, of forming clear solutions which do not disfigure plants as much as bordeaux mixture. Some are also claimed to be less liable to cause burning than bordeaux mixture. It is impossible in a publication of this sort to evaluate fairly these preparations, most of which are new and comparatively untried. It may be said, however, that in the treatment of diseases of vegetables, fruits, flowers, and ornamentals, there is need of a good, nonstaining fungicide.

## FORMALDEHYDE

Formaldehyde, which is a gas at ordinary temperatures, is available in the form of a commercial preparation called "Formalin." This is a solution of formaldehyde in water which is commonly referred to as a 40 per cent solution and should never contain less than 37 per cent for use in the various dilutions recommended for disinfecting purposes. Formaldehyde is used for disinfecting seed, tubers, and bulbs and also for treating soil for destroying parasitic fungi.

## MERCURY

**Corrosive Sublimate, Mercury Bichloride.**—This very poisonous substance is commonly used in plant-disease control as an antiseptic and disinfectant. It is usually dissolved in water and the concentration is expressed in parts by weight as, for instance 1–1,000. This means 1 gram of corrosive sublimate in 1,000 cubic centimeters (1 liter) of water, or 1 ounce in 1,000 ounces (7¾ gallons). The chemical reacts very strongly with alkaline and metallic substances and so should be used only in wooden, porcelain, or glass containers. Alkaline or "hard" water is unsuitable for preparing this solution; distilled water should be used whenever possible. Corrosive sublimate is also neutralized by dirt and organic matter. Tablets are obtainable of the proper size to make a 1–1,000 solution when 1 tablet is added to a pint of water.

**Other Mercury Salts.**—Other salts of mercury like mercuric cyanide

and calomel (mercurous chloride) are occasionally recommended as disinfectants in plant-disease control work.

**Proprietary Mercury Compounds (Semesan and Ceresan).**—A number of organic mercury preparations are on the market which have much value for seed and bulb treatment, soil disinfection, and control of damping-off. These are referred to in a number of places in this circular and are to be used according to directions given by manufacturers. Among the best-known of these materials are those called Ceresan (ethyl mercuric chloride), New Improved Ceresan (ethyl mercuric phosphate), Semesan, several types, (chlorophenol mercury and other materials), and Merko.

## SULFUR

**Dusting Sulfur.**—The essential feature of a dusting sulfur for control of powdery mildews and other diseases is extreme fineness. A good brand should be fine enough so that most of the particles pass through a screen of 325 meshes to the inch. Some types of sulfur are much finer than this. There are many brands of dusting sulfur on the market, each claiming peculiar qualities and advantages, but there has been no clear demonstration of any essential factor except the size of the particles.

Sulfur causes burning to some plants, especially at high temperatures. Other plants show a toxic effect when treated with sulfur in any form, dry or wet.

**Wettable Sulfur.**—This is pulverized sulfur to which some substance has been added to make it mix readily with water. Good commercial brands of this material are on the market. Homemade wettable sulfur may be prepared by the following formula:

| | |
|---|---|
| Calcium caseinate | 4 ounces |
| Water | 1 quart |
| Sulfur (dusting) | 2½ pounds |
| Water to make | 50 gallons |

Make a smooth paste of the calcium caseinate and 1 quart of water, mix with the sulfur, and add the rest of the water. Wettable sulfur may also be made by substituting ⅜ ounce of glue dissolved in 3 quarts of water for the calcium caseinate paste in this formula.

**Lime-Sulfur Solution.**—Lime-sulfur solution, which is both a fungicide and an insecticide, is a concentrated solution made by cooking together quicklime and sulfur. It was originally a homemade spray made by boiling the ingredients in a kettle, but at present practically all the lime-sulfur in use is bought in the form of commercial brands. The concentration of satisfactory brands is expressed as being usually about 32° or 33° Baumé. Commercial lime-sulfur solution needs only to be

diluted with cold water to the proper strength. The various concentrations are expressed either in gallons ("1–100" meaning 1 gallon of a commercial lime-sulfur solution of 32° to 33° Baumé to 100 gallons of water), or in percentages by volume.

Lime-sulfur solution is very caustic and is used as a winter spray on dormant trees, or on foliage in summer with great dilution and much caution. From 1 to 3 per cent solution (1 to 3 gallons of lime-sulfur solution in 100 gallons of water) is usually the greatest concentration which can be used on foliage.

### ZINC

**Zinc Oxide.**—This is a white powder which is used to some extent for seed treatment and control of damping-off. Commercial brands are available for this purpose.

### SPREADERS AND STICKERS

The spreading and sticking qualities of spray materials may be improved by the addition of certain substances. This is particularly important in spraying plants with smooth, shiny leaves which have a strong tendency to shed water. A number of spreaders are on the market, many of them having a base of casein made from milk. Some of the spray-oil emulsions are also used as spreaders. All these commercial spreaders should be used according to manufacturer's directions.

**Rosin Soap.**—With lime-sulfur solution, rosin soap gives exceptional sticking qualities on smooth foliage and also seems to improve the effectiveness of the spray. The rosin soap is made by melting together with heat the following ingredients, measured by weight:

| | |
|---|---|
| Rosin (E grade) | 25 parts |
| Potash lye (KOH) | 5 parts |
| Alcohol | 1 part |
| Water | 69 parts |

In mixing the spray, the rosin soap should be added to the water before the lime-sulfur and should be used in equal volume. Thus, for a 2 per cent rosin-lime-sulfur, mix 2 gallons of rosin soap with 96 gallons of water and then add 2 gallons of lime-sufur.

### COMBINATION SPRAYS

It is sometimes convenient and economical to mix two or more sprays together and apply them at one operation. It may happen, for instance, that a fungus disease and an insect both attack a plant at the same time. There may be no one spray material which is capable of destroying both these pests but it is often possible to combine a fungicide with an in-

secticide and save the cost of one spraying operation. The only objection to such procedure lies in the fact that some sprays cannot be mixed together without producing an undesirable effect or reaction. The result may be a lessening of the efficiency of one or both of the sprays or it may be the formation of some substance which is injurious to the plant. Sprays which react with each other in this way are said to be incompatible.

In Extension Circular 87, a table is given showing which of the common fungicides and insecticides are incompatible. Of the combinations to be guarded against, the following may be mentioned here: Lime-sulfur should not be mixed with standard lead arsenate but may safely be combined with the basic type. Mixtures of sulfur or lime-sulfur with oil sprays should be used with caution, especially in hot weather. Applications of bordeaux mixture or other copper-containing materials should not be followed by fumigation with hydrocyanic acid gas within a year.

New or untested combinations, materials, or methods of preparation should not be used in spraying plants without competent advice or preliminary tests upon a small scale. Even then injury sometimes occurs under certain weather conditions like high temperature or high or low humidity, or only upon certain varieties or species of plants, when ordinarily no trouble is experienced.

### AIRPLANE SPRAYING AND DUSTING

In order to cover large areas in a short time or to be able to dust or spray when the ground is too muddy for wheeled vehicles, airplanes are sometimes used. For spraying by this method it has been thought necessary to dissolve or suspend the fungicide in oil since a fine spray of water would evaporate before reaching the surface of the plants. Recent experiments have indicated, however, that it may be possible to use water for this purpose, which would make a material saving in cost. Various copper compounds are being tried for this method. For dusting crops grown in large fields with sulfur or other dry materials, the airplane is finding considerable use in California and elsewhere. Further information on this subject may be obtained by writing the Division of Plant Pathology, College of Agriculture, Berkeley.

## ACKNOWLEDGMENTS

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[34] The Plant Disease Reporter. (Mimeo.) Issued by the United States Department of Agriculture, Bureau of Plant Industry, Division of Mycology and Disease Survey.

# INDEX

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