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DISEASES OF FRUITS AND NUTS

RALPH E. SMITH

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CONTENTS

DISEASES OF FRUITS AND NUTS

RALPH E. SMITH[1]

INTRODUCTION

Discussed in this circular are diseases of fruits (both tree and small fruits) and nuts. Similar circulars on diseases of truck crops, 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 in his particular place.

Plant diseases may be divided into two types, parasitic and nonparasitic. In the former group are included fungus, bacterial, insect, and nematode attacks. Fungi are microscopic organisms that cause diseases

[1] Professor of Plant Pathology and Plant Pathologist in the Experiment Station.

[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 119, *Diseases of Truck Crops;* and Extension Circular 121, *Diseases of Field Crops.*

Note: The name of the fire-blight organism, given on pages 19, 101, and 120

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. 74, p. 137), mildews (fig. 8, p. 23), smuts, scabs (fig. 10, p. 25), and rusts (fig. 45, p. 94) 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. 76, p. 142) 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, and often cause 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, College of Agriculture, 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 disease. 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 sent 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 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. Some books on insects or plant diseases are of general interest in California.[3]

[3] 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., Inc., New York, N. Y. 1933.

Heald, F. D. Introduction to plant pathology, xi + 579 p. 200 figs. McGraw-Hill Book Co., Inc., 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

ALMOND[4]

Bacterial Canker, Bacterial Gummosis.—This disease is characterized by a clear or amber-colored gum that runs out of the bark on the trunk or branches from dead spots or cankers. This condition sometimes kills the branch or whole tree. The true bacterial canker, or gummosis, caused by *Phytomonas cerasi,* and discussed under "Apricot," "Cherry," and "Plum, Prune," does not commonly attack almond. Sometimes, however, it gets into a limb through a wound or twig stub and instead of killing large areas of bark as in the cherry or plum, a rough, chronic, gummy canker is formed. In other cases, this organism produces a condition called "sour sap," in which the inner bark becomes brown, fermented, and sappy without gumming, and the branch or tree dies. Gumming of various types is sometimes produced by other causes like brown rot, wood decay, and insects.

Cutting out diseased bark or cankers or removing affected branches entirely and treating the wounds with corrosive sublimate 1–1,000 (p. 159) or the solution recommended for pear blight (p. 159), followed by bordeaux paste (p. 157) may be practiced.

Blackheart, Verticilliosis.—Affected branches or young trees wilt and die with black streaks in the wood. The disease, caused by a fungus, *Verticillium albo-atrum,* is not so common in almonds as in apricots (p. 30). Many other plants are affected. See general discussion on page 151.

Dead trees or limbs should be removed. Trees in which only part of the branches are affected may recover.

Brown Rot.—In this disease of the almond, the blossoms wither and die; they do not fall off like ordinary dead flowers but stick to the twigs all through the summer. Brown rot also kills many of the twigs by running in from the dead blossoms, and sometimes it affects fairly large shoots and branches. These may either be entirely killed or a rough canker may be formed on one side. Gum usually breaks out on the bark, especially where the dead and live parts come together. The fungus, *Sclerotinia fructicola* or *S. laxa,* can sometimes be seen in wet weather, when little gray, dusty tufts of fungus spores or mold develop on the dead flowers and twigs. The disease is worst when there is a good deal of rain or fog during the blooming period. The Drake variety suffers from brown rot much more than other kinds of almonds. The same fungi cause brown rot of apricots, peaches, cherries, and plums.

[4] For further information, with descriptions and illustrations of diseases, see: Wood, Milo N. Almond culture in California. California Agr. Ext. Cir. 103:1–96. 47 figs. 1937.

To control the disease, cut out all brown-rot cankers and dead twigs before blooming time and spray the trees thoroughly with 5–5–50 bordeaux mixture (p. 156) when the pink color of the petals first begins to show in the earliest blossoms. If the weather is wet during blooming, another spraying just before full bloom will give better control. For the sake of economy, spraying of almonds for control of brown rot may be concentrated on trees of the Drake variety.

Cercospora Leaf Spot.—Leaves affected by this disease, caused by *Cercospora circumscissa,* show dead spots which are considerably larger than those produced by the ordinary shot-hole fungus, *Coryneum Beijerinckii.* This trouble is not common in California and requires no special treatment.

Crown Gall.—In this disease, which affects a great many different kinds of trees and plants, large, roundish, rough galls or swellings develop on the roots and at the crown just at the surface of the ground. Galls may also appear on the trunk or stem above the ground. The bacterial organism which causes crown gall, *Phytomonas tumefaciens,* lives in the soil and may become very abundant in old orchard or nursery land or wherever affected plants have grown. Trees are sometimes weakened, stunted, or even killed by crown gall, especially if they are already affected when planted. The almond is very susceptible, and no doubt a large percentage of all the almond trees in the state would be found to be affected if the roots could be examined. A great many almond trees contract the disease in the nursery. Even though all those which show visible root galls are thrown out at the time of planting in the orchard, it sometimes happens that at the end of one or two years some of the trees look sickly and stunted, and if the roots are examined they are found to be badly affected with crown gall.

Little can be done toward the control of this disease in almonds except by planting clean trees on clean land. In buying nursery trees, try to get them from lots which have shown no crown gall. Examine all planting stock very carefully and never plant a tree which shows any sign of galls on the roots. If young trees look stunted at the end of the first season in the orchard, examine the roots for crown gall and, if they are much affected, pull out the trees and replant, using fresh soil around them as far as possible.

Growers sometimes cut out galls on the roots of orchard trees, but this is not usually very satisfactory on almonds because the galls are so numerous and new ones develop so rapidly. If this is attempted, the dirt should be removed from around the crown of the tree, deep enough to work under the main branching of the roots. All the gall tissue must then be cut out very carefully with a chisel or gouge and the exposed

tissue thoroughly swabbed with 1–1,000 solution of corrosive sublimate (p. 159), or the solution recommended for pear blight (p. 159). This should be allowed to dry, after which the wound may be painted over with bordeaux paste (p. 157). If the hole around the base of the tree can be left open for several weeks or longer, the chance of reinfection will be less and it will be possible to see whether or not the diseased tissue has been entirely removed. The spring, after most of the rains are over, is a good time to do this work.

In the case of some kinds of trees, there is a possibility of propagating on roots which are more or less resistant to crown gall; this would be the ideal method of control, but nothing of this sort is available for the almond.

Crown Rot, Phytophthora Canker.—Affected trees either fail to start growth in the spring or, after producing a full crop of leaves, die during the first hot days of early summer. A dead, sunken area will be found to have girdled the crown of the tree at the ground level (figs. 2 and 3). This disease is often seen on nursery trees, which have cankers or areas of dead bark just above the crown, sometimes completely girdling them. It is more apt to develop on trees which have been given excessive irrigation or those which have been heeled in for a long time in wet soil. The same disease, which is caused by a species of *Phytophthora*, also attacks peach or pear nursery trees. Brown rot of citrus fruit and citrus gum disease are caused by the same or a similar fungus. Much of the so-called "sour sap" of almond orchard trees is of this nature.

To prevent this trouble in nursery trees, the conditions mentioned above of overwet soil should be avoided. Nursery trees which are not girdled or badly crippled may recover and outgrow this trouble if planted out in the orchard. If the tree is not killed in the first attack, the fungus usually dies out. The recovery of orchard trees is favored by removing the dirt from around the crowns. For further treatment see "Sour Sap" (p. 11).

Fruit Gumming.—There appear to be different forms of this disease. Sometimes masses of clear gum ooze out of the green nuts on the tree and harden on the surface (fig. 1); this gum originates at the surface of the nut just beneath the hull. In other cases, the kernel turns into a mass of sticky gum which may push through the shell and hull to the surface. This happens frequently some years in certain places. It is sometimes thought that frost injury in spring may be the cause of fruit gumming, but there is no proof of this. Attacks of brown rot in the blossoms sometimes seem to be followed by gumming. The trouble somewhat resembles fruit gumming and split pit in peaches (p. 95). No method of control is known.

Green Rot.—In green rot of the almond, young fruits and shoots are killed and wither soon after the petals have fallen. Infection takes place through the "jackets" while they are still on the young fruit. The disease is likely to attack almonds only when there is a great deal of rain or fog after blooming. It is the same as green rot in apricots (p. 35) and is caused by the well-known cottony-mold fungus (p. 136), *Sclerotinia sclerotiorum.*

Green rot does not often affect almonds seriously enough to warrant special control methods. Some growers make a practice of jarring the

Fig. 1.—Gumming of almonds.

branches to shake off the jackets as soon as they can be loosened. Spraying for brown rot and shot-hole may help. Bordeaux mixture 3–3–50 (p. 156) during full bloom has been suggested, also oil bordeaux (p. 157) when the bulk of the petals have fallen.

Little-Leaf.—The foliage of trees affected by little-leaf develops in tufts or rosettes of narrow, yellow leaves, and the tree has a characteristically weak, sickly appearance. This disease, which affects many different kinds of trees, is discussed at more length on page 141. The almond is one of the fruit trees least susceptible to little-leaf, and the disease is not a serious factor in any of the main almond districts in California.

Spraying the trees in the dormant season with zinc sulfate, 25 to 50 pounds to 100 gallons of water, gives good control of little-leaf in almonds.

Nonbearing.—When almonds regularly fail to produce crops, it is usually due to lack of a proper combination of varieties for cross-pollination. The county farm advisor or experienced local growers should be consulted in this matter. Frost injury must also be guarded against. For further information see Extension Circular 103 (mentioned in footnote 4, p. 6).

Oak-Root-Fungus Disease, Armillaria Root Rot.—When this dis-

ease is present in an orchard, trees in certain areas die, and the trouble usually keeps on extending in a slowly enlarging area and kills more trees each year.

For description and discussion of control methods, see page 144. No kind of root resistant to this disease is known upon which almond trees can be grown. Treatment of the soil with carbon disulfide is the only method to be recommended for reclaiming infested soil for almonds. Without such treatment, walnuts, pears, figs, pecans, persimmons, or annual crops may be planted.

Powdery Mildew.—A white mildew, *Sphaerotheca pannosa,* occasionally appears on the leaves and young fruits. This fungus is much less common on almonds than on peaches, but has been observed. Control is not needed.

Root-Knot Nematode.—Small, roundish swellings or galls develop on the fibrous roots of plants attacked by this nematode, *Heterodera marioni.* In these are imbedded the small, almost microscopic worms, the largest of which look to the eye like tiny pearls (p. 142). A great variety of plants are susceptible. The almond root is moderately affected, although this universal pest is not usually considered among the major troubles of the almond tree.

Affected nursery trees should be avoided. In infested soil, especially if it is light and sandy, the roots of almond trees are likely to become chronically affected with nematode. The resistant roots mentioned for peach on page 93 may also be used for almonds. For latest information on rootstocks and varieties of almonds, consult the Division of Pomology, College of Agriculture, Davis.

Rust.—The rust disease of almonds causes powdery, dark-brown spore pustules on the leaves in summer and autumn; the trees may be defoliated by the fungus if the disease is severe. The same fungus, *Tranzschelia pruni-spinosae,* affects the prune, peach (p. 94), and apricot. Control is not often needed.

Shot-Hole Disease.[5]—This disease gets its name from the fact that small spots are killed on the young leaves and, as the leaves grow, these drop out, leaving round holes. Many leaves fall and young fruits are often spotted and drop off or develop in a deformed condition. Small spots are also produced on the twigs. Fruit buds may be killed, with more or less gumming at the base. This is the most important almond disease in California and causes much damage in seasons when there is a good deal of rain during and after blooming. The same fungus, *Coryneum Beijerinckii,* causes apricot shot hole and peach blight.

[5] For further information on this subject, see: Wilson, E. E. Shot-hole disease of stone-fruit trees. California Agr. Exp. Sta. Bul. 608:1–40. 13 figs. 1937.

To control, spray with bordeaux mixture 5–5–50 (p. 156), or stronger if preferred, just before the blossom buds begin to swell, generally during late January. In some years no further treatment may be necessary to control shot-hole disease. On account of the need of spraying during the blooming period for brown rot and green rot, however, and the danger of much rainy weather at that time, it usually happens that another application of bordeaux mixture to almonds when the first flower buds are showing color is advantageous, and even a third spraying toward the end of the bloom is not wasted (table 1). In rainy seasons, these

TABLE 1

SPRAY PROGRAM FOR ALMOND DISEASES

Time	Spray and strength*	Disease	Remarks
Nov. 15–Dec. 10	Bordeaux 5–5–50	Shot-hole	This should control the disease on twigs, but is less important on almonds than on peaches and apricots
Just before buds swell	Bordeaux 5–5–50	Shot-hole Brown rot	This is the most important spray for shot-hole and may be of some benefit in preventing brown rot
Blossom buds showing color	Bordeaux 5–5–50	Brown rot Shot-hole	Advisable for control of brown rot
Full bloom	Bordeaux 3–3–50	Brown rot Green rot Shot-hole	Suggested to try especially for green rot
Petals fallen	Bordeaux 5–5–50	Brown rot Green rot Shot-hole	In wet seasons

* For directions see page 156.

applications cannot always be made exactly when planned so that extra spraying may be needed to get results. Thorough work every year will keep down the amount of disease in those seasons when continuous rain during the blooming period favors shot-hole disease and brown rot and interferes with spraying. The spraying program should be supplemented with a thorough removal of all diseased parts from the trees.

Sour Sap.—Affected trees or branches die or fail to start in spring, often in large numbers. The inner bark and wood become discolored and have a sour or fermented odor. Trouble of this sort is common in California in almond, apricot, cherry, peach, plum, prune, and apple trees, and some years many young orchards are almost ruined by it (fig. 2). This happens most commonly in low, wet parts of the orchard and on heavy soil, but sometimes sour sap is worst at higher points and on shallow or gravelly soil. The disease is most common in wet years.

The cause of this condition is not always the same; it is sometimes due to bacterial gummosis (p. 6), sometimes to *Phytophthora* canker at the base of the tree (p. 8 and fig. 3); occasionally it is confused with blackheart (p. 6) or other diseases; and again it may be a direct climatic or soil-moisture effect, like injury to the roots by standing water. Most of the diseases mentioned are greatly influenced by seasonal conditions, so that sour sap is only serious in certain seasons when favorable weather occurs.

Usually by the time an outbreak develops, the damage has already

Fig. 2.—Sour sap of young almond trees, commonly caused by crown rot.
(See p. 8.)

taken place and it is too late to do very much about it. Experience often shows that almonds or other kinds of trees cannot safely be planted in certain places on account of this trouble. In other cases, however, good-sized orchard trees which have previously been healthy fail to start in spring and develop sour sap. This is usually after wet winters. In such cases as soon as the trouble is discovered, the soil should be dug away from the bases of all trees, whether the top shows any trouble or not. If dead areas of bark or cankers are found at the ground level (fig. 3), these should be carefully cut out on trees which are not more than half girdled, the wounds swabbed with corrosive sublimate 1–1,000 (p. 159) or the disinfectant recommended for pear blight (p. 159), and then, after drying for several days, covered with bordeaux paste (p. 157). The basins around the trees should be left open all summer or as long as possible. If the ground level is such that the dirt is inclined to come up above the

point where the trees were budded, this should be kept uncovered; or, if some filling cannot be avoided, coarse sand may be used instead of heavy soil. Trees which fail to start into fairly good growth or heal over the wound at the base may just as well be pulled out, for they will linger along and finally fall prey to sunburn and borers. Those that are in-

Fig. 3.—Crown rot in young almond tree.

jured but show hopeful signs of recovery may be whitewashed for protection.

Wood Decay.—One of the commonest almond-tree troubles is the rotting of the wood in the trunk and branches; limbs partly or entirely die or break off and the tree gets into a brokendown, half-dead condition. Sporophores (bracket fungi, toadstools) of the various fungi which cause the rot usually develop on the surface and produce spores which infect other wounds, cuts, or injuries. The almond is very susceptible to this trouble, which reduces the size and productive capacity of the tree and shortens its life. Wood decay is a sign of weakness usually brought on by sunburn, drought, bad pruning, top-grafting, defoliation by foliage diseases or red spider, attacks of borers, or other injuries.

The profitable life of almond trees may be much lengthened by avoiding at all times the conditions which favor wood decay. To do this, efforts should be made to give the trees proper irrigation and pruning; young trees should be protected from sunburn by whitewashing the trunks both in summer and winter, and severe attacks of red spider and shothole fungus should be controlled by spraying. In pruning, clean, close cuts should be made so that no stubs are left. Large cuts should be avoided as much as possible and, together with other wounds, should be given a protective covering. Grafting cuts should be well waxed and special care taken to protect top-grafted trees from sunburn by whitewashing the trunks. Borers should be controlled. (See Extension Circular 87.)

For further discussion see page 152.

APPLE[6]

Bitter Pit.—Apples on the market often show brown, dead, sunken spots on the surface and dead streaks in the flesh, mostly near the calyx end. This is the trouble called "bitter pit," which is sometimes seen in apples when they are still on the tree, although much more commonly, fruit which looks sound when picked develops the trouble in storage. Large quantities of apples are ruined in this way every year. Although bitter pit has been extensively studied in many different countries, its exact cause has never been discovered. It seems to be due to some weakness of the apple which causes the flesh to break down prematurely in spots after maturity and is probably nonparasitic. It is worse in some seasons, districts, and varieties than in others. Early-picked apples are more apt to develop bitter pit than those which are left longer on the trees. Heavy pruning and irrigation or rain late in the summer has a tendency to produce this trouble. Bitter pit is usually worse on fruit from young trees, on large fruit, and in years of light crops.

Apples which are likely to develop bitter pit should be left on the trees as long as possible and not be gathered prematurely if this disease is to be avoided. Storage at low temperatures (30° to 32° Fahrenheit) retards bitter pit, but when brought back to normal temperatures such fruit may develop the trouble worse than apples which have not been in cold storage. In the case of the Gravenstein apple, where early picking is necessary in order to reach a profitable market and cold storage is not practiced, no practical method of avoiding bitter pit is known.

Bitter Rot.—This disease causes immense losses in the East and

[6] For further information, with descriptions and illustrations of diseases, see: Allen, F. W. Apple growing in California. California Agr. Exp. Sta. Bul. 425:1–95. 19 figs. Revised 1937.

Middle West but is not known in California, presumably on account of the rainless summers. The fruit on the tree becomes infected with a brown, dry rot which may finally involve the whole apple. Many of these fruits hang on the tree all winter in a dry, mummified condition. Small, black dots which are the spore pustules of the fungus *Glomerella cingulata* develop abundantly on the surface of the rotted tissue. The branches are also attacked, with the formation of cankers which carry the fungus over from year to year.

Black Rot.—In the Middle West and East this is a very serious apple disease, causing rotting of the fruit, blight and cankers of the twigs and limbs, and a spotting of the leaves. In California black rot has occasionally been seen in the central and northern coast districts, but it is rare and of no importance. Here it is usually found in the form of small oval cankers or dead areas an inch or more in length on the younger shoots. On the surface of these cankers, little spore pustules of the fungus *Physalospora obtusa* break out. No control is needed in California.

Blister Canker.—This is a bark canker disease which in the Middle West and East has been the cause of killing thousands of apple trees. Only one or two cases have been observed in California, these being apple seedlings already infected with blister canker which were brought from an eastern state and planted in California. Some of the trees budded on these seedlings developed the disease while in the nursery, but it did not spread any further. The bark of infected trees dies, beginning at wounds or pruning cuts, and cankers form that sometimes kill large areas of bark and the wood beyond and sometimes even entire limbs. Small, round, blisterlike protuberances appear all over the affected bark. The cause is a fungus, *Nummularia discreta.*

Brown Rot.—Fruit in storage occasionally shows a dark-colored rot caused by the fungus *Sclerotinia fructicola.* It is not important.

Canker.—Most of the apple-tree canker diseases of other parts of the country have been observed in California but only in rare, isolated cases. Reference is made under the corresponding headings to black rot, blister canker, northwestern anthracnose, and perennial canker, all of which have been definitely identified in the coast or Sierra Foothill districts during the past thirty years. A canker caused by the fungus *Phomopsis mali* has also been seen. None of these, however, or any other similar canker disease of apple is established in this state or is of economic importance. Lack of rain in summer appears to be responsible.

Chlorosis.—Chlorotic leaves are bright-yellow, especially in the younger parts of the tree, and the growth more or less stunted. The type of chlorosis which is caused by excess lime in the soil may be corrected by applications of iron. See page 135 for more detailed discussion.

Core Mold, Blue-Mold Rot.—Sometimes apples in storage show a mass of mold in the core cavity, and this may extend out into and rot the surrounding flesh. Cases have also been seen where apples dropped prematurely from the trees and showed a moldy core condition. This may be due to some weakness or injury to the fruit and also is very common in apples in storage, especially if they are overripe. The mold involved may be *Penicillium expansum*, a species of *Alternaria*, or some other fungus.

Affected lots of fruit should be kept at as low a temperature as possible until they can be disposed of.

Cork, Drought Spot, Corky Core.—This disease is characterized by brown, spongy, or corky masses in the flesh of the fruit anywhere from the core to just beneath the surface, where pits or broad depressions are often formed. These symptoms usually appear when the fruit is on the tree, distinctly earlier than those of bitter pit, often when the apples are scarcely half mature in size. A dieback of branches may accompany such fruit symptoms. The trouble is nonparasitic.

Experiments, mostly in other states and countries, have shown that this trouble can usually be prevented by addition of borax to the soil. The amount required varies considerably. If no local experience is known, experimental treatments should be made on a few trees with 1 to 5 pounds for each tree during the dormant season.

Crown Gall.—Crown gall (see under "Almond," p. 7) on the roots of apple trees is not a serious disease in California; in fact, it is seldom seen in orchard trees. Nursery trees sometimes develop soft tumors and overgrowths, either on the crowns and roots or at the graft union as a result of infection with the crown-gall organism, *Phytomonas tumefaciens*. The hairy-root form of the disease, with an excessive development of small fibrous roots, may or may not accompany this. Hairy root develops abundantly on apple roots under certain conditions and has been claimed by nurserymen to be a normal and harmless occurrence. This is true, for instance, of bench-grafted, piece-root Northern Spy stocks. Hairy root has in recent years been attributed to a bacterial organism (*Phytomonas rhizogenes*) distinct from that which causes crown gall.

Apple trees which show any distinct galls or abnormal swellings or roughening at the crown or on the roots should be rejected in planting. Galls that appear on the crowns of trees in the orchard may be cut off with a chisel and the wounds disinfected with corrosive sublimate solution 1–1,000 (p. 159) and covered with bordeaux paste (p. 157). Apple trees propagated by budding are less likely to be affected by crown gall than those which have been grafted.

Delayed Foliation.—See page 140.

Dematophora Root Rot.—Trees attacked by the dematophora-root-rot fungus, *Rosellinia necatrix,* die from a rotting of the roots. The effect is like that of the oak root fungus, *Armillaria mellea* (p. 144), in that there are certain places in the orchard where all the trees are killed and those areas keep enlarging by the dying of more trees around the margins every year. The disease can be distinguished from that caused by *Armillaria* by the fact that the fungus growth in the bark and between the wood and bark is more delicate and less dense and there are none of the black, shoe-string-like strands, or rhizomorphs. Furthermore, no toadstools are produced by this fungus. On the surface of affected roots, a fungus growth, or mycelium, develops, which is at first white but in the older parts becomes black and is cobwebby in appearance. During wet weather, a delicate, pure-white mold growth may be seen on the surface of the bark and in the soil around the base of the tree. The disease has been found on apple trees in a number of places in California and also on walnut, privet, and other hosts. Since its effects are so much like those of *Armillaria,* it is probable that in many cases the dematophora disease has not been recognized. This is a dangerous disease and should be looked for in all cases of dying of trees or shrubs from root rots.

Badly affected or dead trees should be removed with as much of the roots as possible. Adjacent trees should be examined and, if they are only slightly diseased, surgical work as described for oak-root fungus (p. 147) may be done to eliminate affected roots and bark. In doing this, the soil should be removed from around the crowns of all trees which might be affected and, after treatment, these basins may be left open for a time and the bases of the trees and the surrounding soil sprayed with 5–5–50 bordeaux mixture (p. 156) if any indication of the disease or the fungus is seen.

Dieback.—In certain places and seasons, some of the trees, or parts of them, fail to start properly in the spring, the buds remain dormant or partially opened, branches die back, and finally strong shoots push out from below and may grow vigorously for the remainder of the season (fig. 4). The cause is unknown. In some cases these symptoms blend into those of little-leaf (p. 21), but no benefit is obtained on typical dieback trees by the application of zinc as used to cure little-leaf. The disease also seems to have something in common with sour sap of apples. Both may be related to subsoil moisture conditions, but the specific cause is obscure. There are some indications that boron deficiency may be involved. (See "Soil Deficiencies," p. 150.)

Apples should not be grown on orchard sites where dieback and sour sap occur persistently. Drainage of wet areas is advisable.

Exanthema.—This disease causes a characteristically dwarfed,

bushy growth. The new shoots push out vigorously in spring for a short distance, then the terminal buds die, lateral shoots develop, and the same thing happens to them (fig. 5). Corky outbreaks or swellings also develop on the branches. Exanthema affects several kinds of trees.

Treatment with copper, either through the soil, trunk injection, or

Fig. 4.—Apple dieback.

by spraying the foliage, has completely cured this disease in a number of instances. Pulverized copper sulfate (bluestone) may be scattered over the soil around the tree and spaded under just before the last rains, 1 to 5 pounds, according to size, being applied for each tree. On some soils this is less effective than spraying the foliage in early summer with 5–5–50 bordeaux mixture (p. 156). Copper may also be applied by boring holes about 3 inches apart around the circumference near the base of

the trunk and inserting 5 to 10 grains of powdered bluestone in each hole. The holes should be plugged with grafting wax or similar material. Exanthema is also discussed under "Citrus" (p. 60), "Olive" (p. 80), "Pear" (p. 101), and "Plum, Prune" (p. 112).

Fire Blight, Blight.—In apple trees affected by fire blight, or blight, the blossoms and tender growth wilt, wither rapidly, and die, the dead flowers and leaves hanging to the twigs. The disease runs down into the

Fig. 5.—Exanthema dieback of apple.

larger twigs and branches to a certain extent, killing the bark and producing a sticky ooze upon the surface, but not so much as in blight of pear trees, which is the same bacterial disease. Both are caused by *Phytomonas amylovora*. The Transcendent Crab and some varieties like Red Astrachan, Alexander, and Spitzenburg are very susceptible. Delicious, Gravenstein, Yellow Bellflower, and Yellow Newtown are more resistant.

Treat as in pear blight (p. 101). Worthless apple trees which may harbor blight in the vicinity of pear orchards should be removed.

Flat Limb.—In this condition, which is peculiar to the Gravenstein variety, the limbs have a flattened, ridged, twisted appearance on account of unequal growth at different points in the circumference. On

some sides almost no growth takes place, although the tissue is alive and sound, while at other places the wood develops vigorously and bulges out in ridges. This is seldom seen except on orchard trees top-grafted with Gravenstein scions above the crotches. The cause is unknown. The flat-limb condition persists in scions taken from affected trees and may be a virus disease.

Hairy Root.—See "Crown Gall" (p. 16).

Fig. 6.—Little-leaf of apple. Normal twig on left.

Internal Browning.—In certain varieties of apples, especially the Yellow Newtown, grown in cool, moist localities, there is a tendency for the flesh to develop a soft, brown condition in storage. This is worse on fruit which is left on the trees until late in the season. In storage, more browning develops at 32° Fahrenheit than at higher temperatures. The trouble is nonparasitic.

The conditions which prevent internal browning (early picking, storage at moderate temperatures) are exactly those which favor bitter pit, so that the methods of handling the two diseases conflict with one another. Fortunately, however, these diseases are not apt to be equally bad on the same variety of apple. With the Yellow Newtown, if the apples are left on the trees until they are mature and then stored at 36° to 37°

Fahrenheit, there is not usually much trouble with either disease. In the case of Yellow Bellflowers, properly matured apples should be stored at 34° to 35° Fahrenheit. These temperatures represent the practice of the Watsonville district.

Little-Leaf, Rosette.—The foliage on affected young shoots consists

Fig. 7.—Northwestern anthracnose of apple.

of tufts of very small, narrow, straight leaves (fig. 6). The terminal leaves on each shoot may develop a little more than the lateral ones, and form tufted rosettes. The trouble is nonparasitic.

Little-leaf may be corrected by applications of zinc sulfate (p. 141, 161). An effective method for apples is to spray the trees in the dormant season with zinc sulfate, 50 pounds to 100 gallons of water in the first year, and 25 pounds to 100 gallons in subsequent years.

Meadow Nematode.—The rootlets of "dieback" apple trees (see above) occasionally show small, brown, dead spots on the sides or the finest roots are entirely dead. Microscopic worms of a species called the "meadow nematode," *Anguillulina pratensis,* are abundant in such lesions. Whether or not they are of any importance in causing dieback has not been proved. The same worm is a parasite on fig roots (p. 71 and fig. 29, p. 72).

Measles, Pimply Bark.—The branches show areas of rough bark with numerous, small, pimply swellings or pustules. This has been most commonly seen on trees growing in poorly drained locations, but the cause is unknown.

Northwestern Anthracnose and Perennial Canker.—In both these somewhat similar fungus diseases, which are caused respectively by *Pezicula malicorticis* and *Gloeosporium perennans,* bark cankers are formed on affected branches (fig. 7). There is also some spotting and rotting of the fruit. Perennial canker is a wound infection, while the true anthracnose fungus is able to infect living bark. These diseases are abundant and important in Oregon and Washington but in California have been observed only in rare instances in the central and northern coast districts. No treatment is necessary.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Characteristics of the oak-root-fungus disease are that the trees die in certain parts of the orchard and the trouble keeps spreading in an increasing circle from year to year, and gradually takes in more trees. This disease, caused by *Armillaria mellea,* has a great many hosts and is discussed in detail on page 144. The apple is not particularly susceptible, and yet the trees are by no means immune to this fungus and in some districts there is considerable loss.

Since the oak fungus spreads rather slowly in apple roots, there is some opportunity to prevent or at least delay its progress by surgical methods. Where there is an oak-root-fungus spot in a valuable apple orchard, it may be profitable to remove the dirt from around the base of each tree on the edge of the spot and, if any are found to be slightly affected, cut out diseased roots or bark near the crown and treat the wounds with corrosive sublimate 1–1,000 (p. 159). The holes should then be left open as long as possible. In this way, the spread of the disease and the death of trees may be retarded.

Powdery Mildew.—A white mildew, *Podosphaera leucotricha,* sometimes covers the terminal shoots and leaves (fig. 8) and stunts the growth. Mature leaves and fruit of the apple are not much affected by mildew in this state. The tree is weakened and its growth interfered with. This fungus disease is especially bad in foggy districts.

For control of mildew, cut out all mildewed twigs (fig. 9) very carefully every winter at the time of pruning. Spraying with liquid lime-sulfur, 1 or 2 gallons to 100 gallons of water (p. 160), or wettable sulfur, 6 pounds to 100 gallons (p. 160) in the cluster-bud stage, followed by a second application of the latter spray after most of the petals have fallen and, if necessary, a third spray two weeks later, should give excellent control. These sprays will also help to control scab (p. 25) and may be combined with lead arsenate for insects. Dusting with dry sulfur gives good control of apple mildew in some places. In certain districts, sulfur

Fig. 8.—Powdery mildew of apple on leaves. Normal twig on right.

has an injurious effect upon apple trees and it is unsafe to use more than ½ gallon of lime-sulfur to 100 gallons of water.

Root-Knot Nematode.—Small beadlike galls develop on the roots of trees attacked by the root-knot nematode, *Heterodera marioni*. The apple is not often seriously affected but sometimes, especially in sandy soil, this pest is found on the roots of apple trees. See page 142.

Root Rot.—When trees die or look sickly and the roots are found to be more or less decayed, the name "root rot" is often applied. Trouble of this sort is produced in apple trees by various causes, sometimes by definite parasites like the oak-root fungus, and again by improper conditions such as poor drainage and heavy soil.

Trees which die of root rot should be pulled out and destroyed. If the trouble seems to spread from tree to tree it may be handled as advised under "Oak-Root-Fungus Disease, Armillaria Root Rot" (p. 22), by

digging the dirt away from the crowns of the marginal trees, cutting out diseased roots and bark, and disinfecting the wounds.

Rust.—No disease of this sort is commonly known in California, but in various parts of the country several different rust fungi attack the

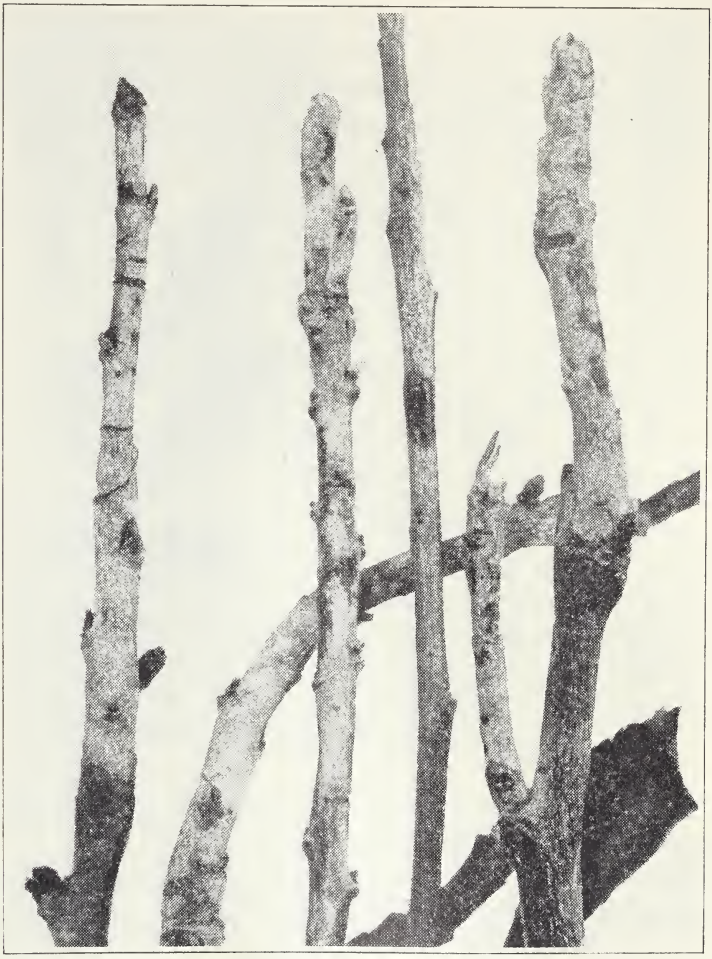

Fig. 9.—Powdery mildew of apple on stems of twigs.

apple, injure the leaves, and cause deformity of the fruit. These rusts have the peculiarity of also affecting another entirely different kind of plant, on which they produce a different form of rust. This is similar to the connection between wheat rust and the barberry bush or white pine blister rust and the wild currant. In the case of the apple rusts, the second (alternate) hosts are species of cedar and juniper on which are formed woody, or sometimes gelatinous, galls, or "cedar apples."

Sappy Bark.—On occasional trees, the bark of some limbs becomes swollen and puffy in winter, dries out later, and becomes loose and papery. The disease recurs in succeeding winters and causes death of limbs and general breakdown of trees. Wood decay in the limbs, the effect of *Polystictus versicolor,* the common oyster-shell fungus, is the cause. The fungus seems to secrete a toxic substance which affects the bark.

Sappy bark can be avoided by preventing wood decay, which means

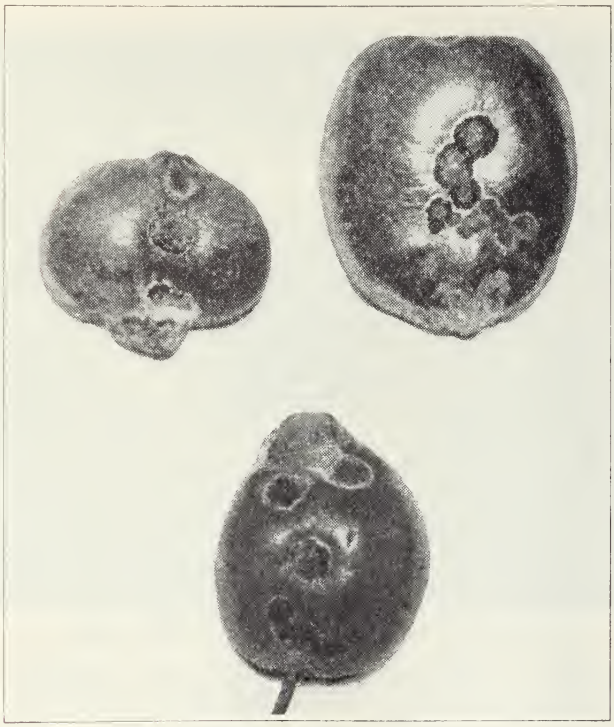

Fig. 10.—Apple scab on young fruit.

keeping the wood-decay fungi from getting into the tree. The only way to do this is to avoid injury to the limbs by sunburn, wounds, unhealed pruning and grafting cuts, and similar conditions. See "Wood Decay" (p. 152).

Scab.[7]—Apple scab, as a rule, is less serious in California than in many other parts of the country and is less troublesome here than pear scab. It is one of the troubles which causes spotting and blemishing of the fruit rather than injury to the tree. In the spring, small, velvety,

[7] For further information about apple scab, see: Roberts, J. W. Apple scab. U. S. Dept. Agr. Farmers' Bul. 1478:1–12. 7 figs. 1935.

dark, moldy patches of the fungus *Venturia inaequalis* appear on the young apples (fig. 10) and leaves. As the apples get older, if there is much scab fungus on them, they develop rough, corky, deformed spots which ruin their appearance and make them more likely to rot. Small scab spots sometimes develop on fruit which is full grown, even in storage (fig. 11).

To prevent apple scab, spray the trees with liquid lime-sulfur 2–100 (p. 160) or wettable sulfur, 6 pounds to 100 gallons (p. 160), or both mixed together, in the cluster-bud stage (just before the blossom buds

Fig. 11.—Late scab of apple on mature fruit.

separate) and again after most of the petals have fallen (table 2). This will also control mildew and may be combined with lead arsenate for insects. To lessen the possibility of injury, the growers in certain districts use only 1 gallon of lime-sulfur or even ½ gallon to 100 gallons of water, adding 5 to 7 pounds of sulfur. Wettable sulfur alone without any lime-sulfur is still safer. Bordeaux mixture 3–3–50 (p. 156) is sometimes used but may russet the fruit (fig. 12).

Scald.—This is a nonparasitic storage trouble in which the apples become soft and discolored, with no mold on the surface. Scald is prevented by good ventilation and air circulation in the storage room and wrapping the fruit in special oiled-paper wrappers that are made for this purpose.

Sour Sap.—In certain seasons, many young trees, or some of their

branches, fail to start properly and the buds remain unopened or poorly developed. The tissues of the branches and trunk at first appear normal, but eventually the inner bark often becomes discolored and fermented and the branch or tree dies. Parts which are not too badly affected may recover and start growth later in the season. Sprouting from below usually occurs if the tree is not entirely dead. This disease may be related to dieback (p. 17) and boron deficiency.

No way is known at present of controlling this trouble. Keeping the trunks of young orchard trees covered with whitewash summer and winter may help to prevent it or at least to assist in the recovery of par-

TABLE 2
SPRAY PROGRAM FOR APPLE DISEASES

Time	Spray and strength*	Disease	Remarks
Cluster-bud stage.....	Lime-sulfur 2-100 or wettable sulfur 6-100	Scab Mildew	If injury is feared reduce lime-sulfur to 1 or ½ gallon; both lime-sulfur and sulfur may be used in the spray in places favorable to scab and mildew
Petals off, calyx open...	Lime-sulfur 2-100 Wettable sulfur 6-100	Scab Mildew	May be combined with sprays for codling moth and aphids
10-14 days later, apples set	Wettable sulfur 6-100	Mildew	May be combined with spray for codling moth
10-14 days later, apples sizing	Wettable sulfur 6-100	Mildew	May not be needed in all localities

* For directions see page 160.

tially affected trees. Where the disease is associated with poor drainage, this condition should obviously be corrected before apple trees are replanted in the same spot. The popular practice of "slitting the bark" (making longitudinal slashes from the ground up with a knife) is of doubtful value.

Spray Burn.—Spray-burned fruit is roughened and deformed, with patches of corky or scabby tissue on the surface (fig. 12). This is caused by spraying the apples, when young, with injurious fungicides. In some places and under certain weather conditions materials like lime-sulfur and bordeaux mixture are more likely to cause damage than in others. In the formula or concentration used, one must be guided by experience in any given locality.

Water Core.—Hard, watery, glassy areas sometimes develop in the flesh of the apple, extending out from the core toward the surface. This is due to the presence of water or sap instead of the normal air in the intercellular spaces of the pulp. Water core, which is probably non-

parasitic, affects some varieties of apple much more than others and varies in abundance in different seasons and places. No definite method of preventing this trouble is known.

Wood Decay.—Branches or whole trees occasionally break down or die from a rotting of the heartwood. Bracket fungi often appear on the

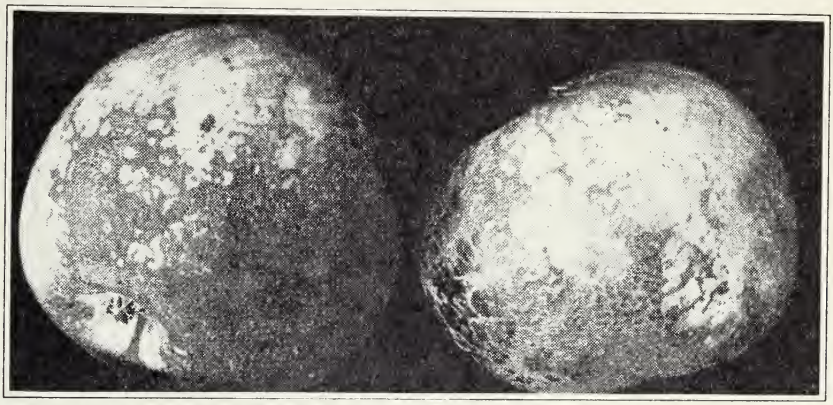

Fig. 12.—Spray burn on apples.

surface. See page 152 for fuller discussion. See also ' Sappy Bark," page 25. The apple, being naturally a hardy, long-lived tree, well repays careful attention to preventing this trouble.

APRICOT[8]

Bacterial Canker, Bacterial Gummosis.—It is common to see globules or masses of transparent or amber-colored gum upon the surface of the trunk, branches, twigs, or even fruit of many kinds of trees, especially those of citrus and stone fruits. This is not a symptom of any one specific disease. In the stone-fruit trees, however, especially the apricot, cherry, and plum, there is in California a very widespread, definite, bacterial infection of the trunks and branches, due to *Phytomonas cerasi,* which kills or injures the trees in a manner very similar to the effect of blight on pear trees. Formerly this disease often went under the name "sour sap." In the apricot tree, cankers, blister pockets, or streaks of dead, brown tissue develop in the bark of the trunks or branches, usually in winter and early spring. Many young trees and branches are killed in this manner. Gum usually runs out from the cankers; it is at first a sticky liquid, but hardens into a stiff, amberlike substance (see fig. 24, p. 50, under "Cherry"). Killing of buds (fig. 13), blossoms, or fruit spurs with more or less gumming may also take place in a manner somewhat similar to the

[8] For further information, with descriptions and illustrations of diseases, see: Hendrickson, A. H. Apricot growing in California. California Agr. Ext. Cir. 51:1–60. 14 figs. Revised 1937.

effect of brown rot or shot-hole fungus. In seasons of late spring rain, bacterial gummosis of apricots may attack the new growth and produce many small, dead spots on the leaves and a shiny, black, scabby condition on the tender young shoots. The occurrence of the disease is extremely variable. In some years, there are extensive epidemics and thousands of

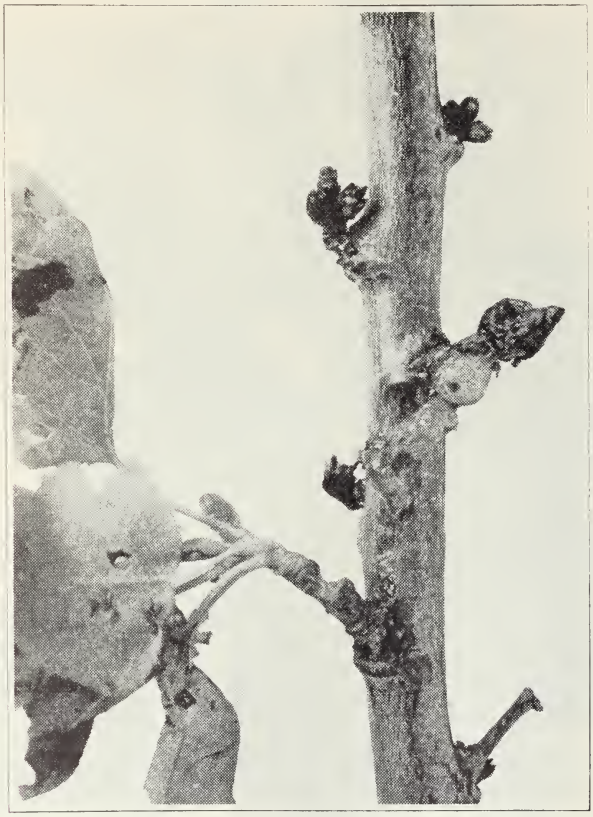

Fig. 13.—Bacterial gummosis of apricot.

trees are killed, especially in the foothill districts. During other seasons, the disease can scarcely be found.

If the cankers are not too numerous or too large, they may be cut out, with care to remove all the diseased tissue and disinfect the tools and cuts with the mercuric disinfectant used in pear-blight work (p. 159). Dead or nearly dead limbs should be cut off and dead or badly crippled trees removed. Wounds should be covered with bordeaux paste (p. 157). Whitewashing the trunks of young trees in the fall may prevent some of the infection which develops abundantly during the winter in certain years. The recommendation given for plum trees (p. 109) of keeping the

bodies of the trees covered with a spray of bordeaux mixture at all times might be advisable with young apricot trees in places where bacterial gummosis is very troublesome.

Blackheart, Wilt, Verticilliosis.—In this disease of young apricot

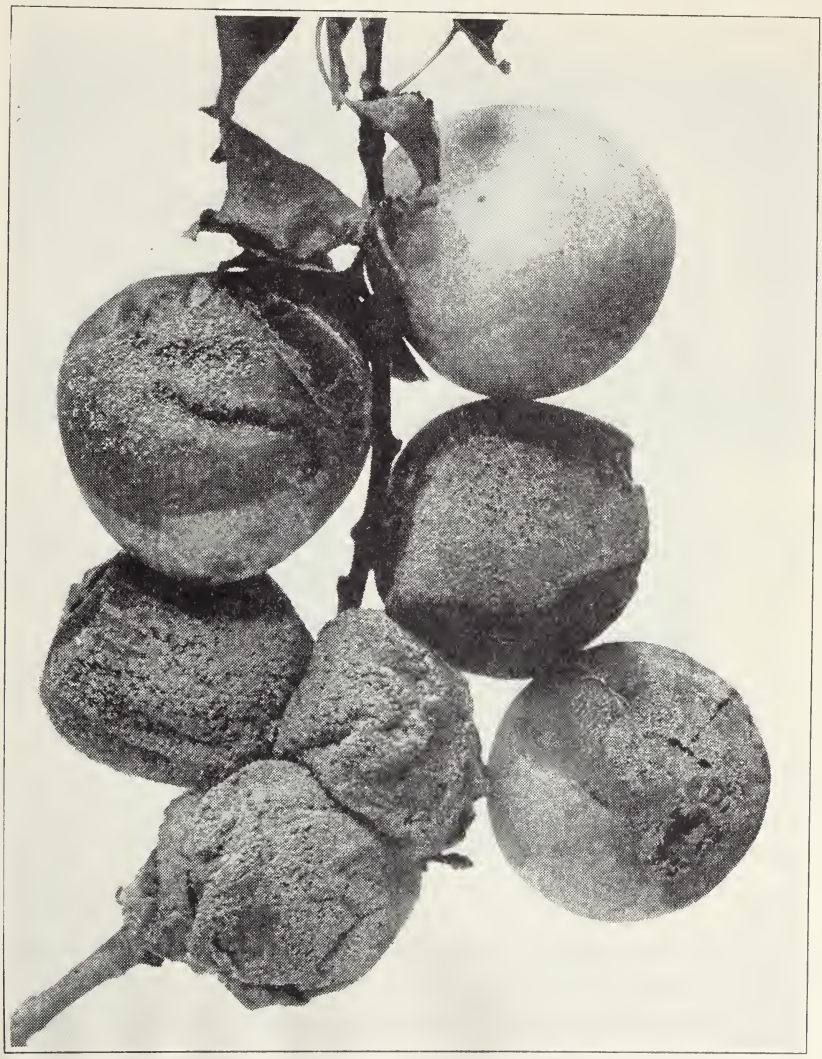

Fig. 14.—Brown rot of apricot fruit.

trees, some of the shoots and branches die suddenly in summer, the leaves remaining attached, and the wood is darkened far back into the tree. The disease is caused by a soil fungus, *Verticillium albo-atrum,* which also causes wilt in tomatoes, bluestem in raspberries, and similar diseases of many other plants. See general discussion on page 151.

To prevent blackheart, avoid excessive irrigation, severe cutting back, or otherwise promoting too succulent growth in young apricot trees. Trees usually outgrow the trouble and entirely recover after the dead shoots have been removed. On account of this disease, it is a poor practice to interplant young apricots with tomatoes.

Fig. 15.—Blossom-blight phase of apricot brown rot.

Blossom-End Rot, Internal Rot, Alternaria Rot.—Blossom-end rot is characterized by a firm, black rot, beginning at the blossom end and progressing internally around the pit, which becomes surrounded with a black mold and spores of a species of *Alternaria*. Some injury probably precedes this. There is no apparent way in which this trouble can be controlled, but it is not of very common occurrence.

Brown Rot, Monilia Blossom Blight.—This disease is named from the soft rotting of the ripe fruit of apricots, cherries, plums, and peaches, which it causes in humid summer climates. In California the fruit-rot form is less common but is sometimes seen in places where conditions are favorable (fig. 14). The ordinary form of the disease here is a blossom and

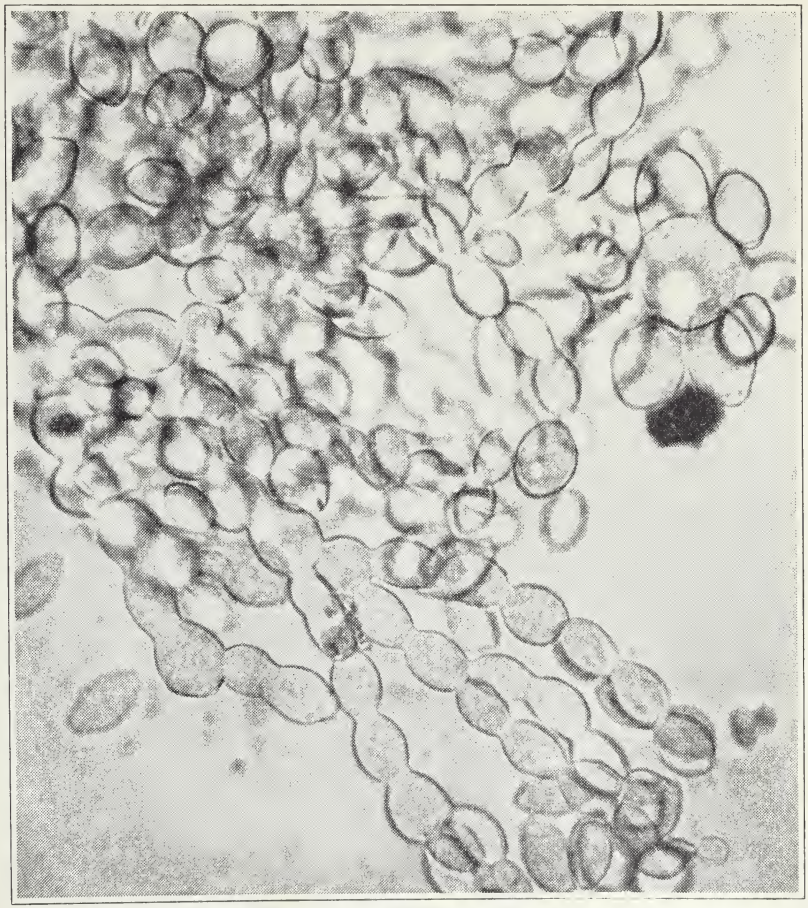

Fig. 16.—Spores of brown-rot fungus from one of the tufts shown in figure 17. The chains break up into single spores. Magnified about 500 times.

twig blight (fig. 15), with considerable gumming, which attacks mainly apricots, peaches, and the Drake variety of almond (p. 6). Rotted fruits hang on the tree over winter in a dried-up "mummy" condition. Many twigs and spurs may be killed and cankers or scars produced on the branches. On such mummies, dead spurs, and cankers, the fungus spores (fig. 16) of *Sclerotinia fructicola* or *S. laxa* break out early in spring in the form of little, gray, dusty tufts (fig. 17). This happens

and the disease develops much more abundantly in years when there is frequent rain just before and during blooming. The fungus also has another spore form, developed in the soil, similar to that described under "Green Rot" (p. 35) and under "Cottony Mold" (p. 136). Until rather recently, brown rot was largely limited in California to the districts near San Francisco Bay, but it is now common in the interior valley and foothill districts. In addition to most of the stone fruits, the Japa-

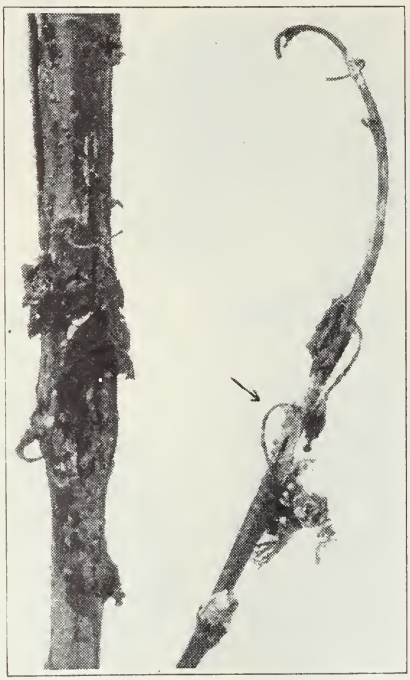

Fig. 17.—Dead twig and canker produced by brown-rot fungus. Note spore tufts on twig at right.

nese quince, some varieties of pears, and a number of ornamental species of *Prunus* are subject to this disease in the blossoms, twigs, or fruit, and may form sources of infection for apricots.

After the leaves are off, or at any time during fall or early winter, remove and burn or bury all mummies and dead twigs. Where the disease is serious, spray with bordeaux mixture 8–8–50 (p. 156) in the red-bud stage (just before the white petals show); and if very bad, spray again before full bloom. If more protection seems necessary, repeat the spray just after petals fall, with a 5–5–50 strength. For the fruit rot, bordeaux 3–3–50 may be used up to the time when it will show on the ripe fruit. The full spray program for brown rot, green rot, and shot-

hole disease is given in table 3. Lime-sulfur or (to prevent fruit rot) plain sulfur, is efficient in control of brown rot but has frequently caused "sulfur sickness" in apricot trees, and is not safe to use. Sulfur sickness of apricots appears as yellowing of foliage, stunting of fruit, and failure of trees to bloom normally the following year. Control of brown rot in apricots is mainly a matter of complete removal of mummies and blighted twigs of the preceding year and thorough spraying at just the

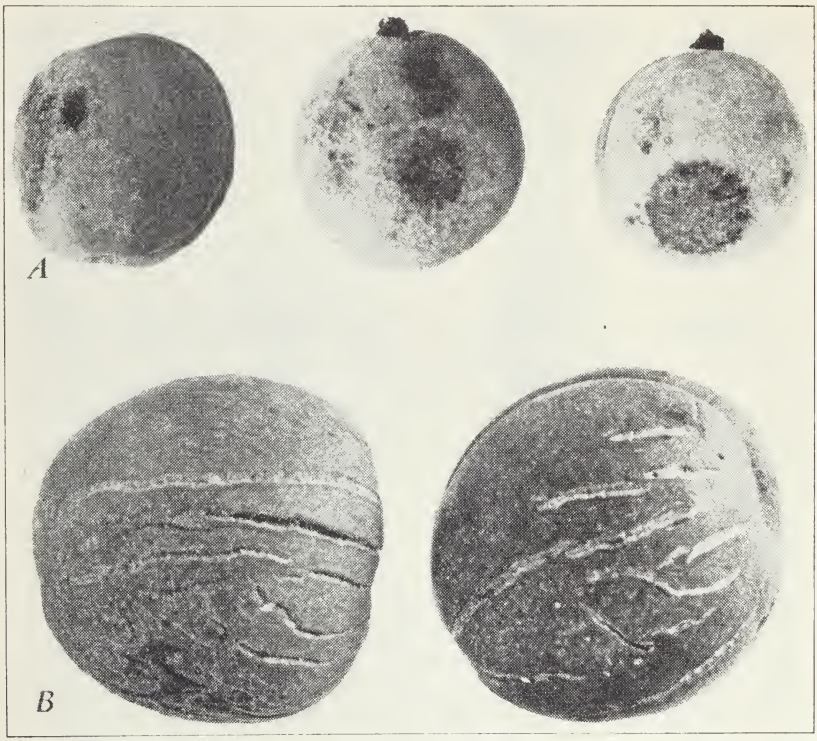

Fig. 18.—*A*, Powdery-mildew effect on green apricots. *B*, Apricots showing effect of frost or weather injury when fruit was young.

right time in spring, especially when the fruit buds are almost showing white color. Too early and too late spraying are equally useless. In rainy seasons, blossom and twig blight, especially on susceptible varieties like the Blenheim, can only be prevented by two or more thorough sprayings before the blossoms are fully open, beginning when the buds are swelling. If control methods are properly carried out every year, there will be less trouble in wet years when it is difficult to spray at the right time.

Crown Gall, Root Knot.—See discussion under "Almond" (p. 7). The apricot root is very susceptible to this bacterial disease, caused by

Phytomonas tumefaciens. The Japanese apricot, *Prunus mume,* is highly resistant.

Delayed Foliation.—See page 140.

Frost-Blisters and Cracks, Weathering.—The upper side of the ripe

Fig. 19.—Apricots in the jacket stage. Continuous wet weather at this time favors green-rot infection.

fruit is disfigured with a scabby, rough condition with longitudinal cracks (fig. 18,*B*). No control is known.

Green Rot.—The development of green rot depends upon wet weather when apricots are in the jacket stage (fig. 19). This name refers to a disease in which the young apricots soon after setting are attacked by a rot that starts in spots where the old calyx or "jacket" is sticking

to the fruit (fig. 20). The disease is not common every year but occasionally causes serious losses in seasons when there is continuous wet weather during and after the blooming time of apricots. The Tilton variety is rather susceptible because the jackets hang on longer than in other varieties.

Fig. 20.—Green rot of apricots on the tips of young fruits. A "jacket" is still adhering on the center fruit; the rot usually starts under the jacket.

The fungus which causes green rot is the so-called "cottony mold" fungus, *Sclerotinia sclerotiorum,* a snow-white mold which develops upon mustard, vetch, alfalfa, weeds, or any thick-growing surface vegetation and produces its spores only on the soil (p. 137), whence they are distributed by wind. These spores are produced more or less continuously from December to May and are probably abundant every year.

This fungus, unlike the one which causes brown rot, produces no spores upon the apricot tree.

Epidemics of green rot are not usually frequent enough to encourage preventive methods for that disease alone. Thorough spraying for brown rot, especially an application of 5–5–50 bordeaux mixture after the petals fall (table 3), may be of some benefit. Some recommend the addition of oil to the spray (p. 157), while others suggest spraying in full bloom with 3–3–50 bordeaux mixture. Shaking or jarring the trees after blooming to remove the jackets from the young fruit may help.

Little-Leaf.—See page 141. Spraying with zinc sulfate solution in the dormant season, as recommended for apple (p. 21), should give satisfactory control. This treatment if applied before November 15 will also help to control shot-hole disease.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The apricot root is very susceptible to *Armillaria mellea* and should not be planted on infested soil. Some of the most resistant myrobalans form the best roots for apricots under such conditions, but no strain is known at present which by any means can be considered immune. See page 144.

Powdery Mildew.—The most serious effects of this disease are seen some years in early summer, when the small, green apricots show good-sized, reddish-colored, disfiguring spots, sometimes covering most of the surface (fig. 18, *A*). The fruit is somewhat flattened on the affected side. These spots are at first of a light-green color and covered with a fine coating of mildew fungus threads and a very few spores (conidia). Perithecia (another spore form produced by powdery mildews) have not been found on the fruit. The spots afterward become darker-colored so as to disfigure the mature fruit and spoil it for first-grade canning or shipping purposes, although they are very superficial. As much as 50 per cent of the fruit has been affected in certain orchards, but it is not a very common disease and occurs only in certain seasons and places and not in all varieties. Similar spots appear on the leaves at the same time but no spores have been observed upon them at this time of year. In late summer, apricot trees in the coast and San Francisco Bay regions often develop an abundant growth of powdery mildew on the leaves, with conidia and abundant perithecia of the *Podosphaera* type—possibly *P. oxyacantha,* which attacks apple, cherry, and other hosts. If this is the same fungus as that which disfigures the fruit in spring, its behavior and aspects are very different at the two seasons of the year. The fungus causing the spring form has sometimes been identified as that which causes peach mildew, *Sphaerotheca pannosa.*

For the control of this disease, the usual sulfur treatment for mildews is not safe since sulfur sometimes has a bad effect on apricots (see

"Brown Rot, Monilia Blossom Blight," p. 32). Copper sprays as a rule have little effect upon powdery mildews, so that the regular spray schedule for shot-hole and brown rot (table 3) unfortunately does not ordinarily control this disease as well. Spraying in spring with certain brands of summer oils is claimed to have shown a benefit in some cases without any injury, but more experience is required before this can be recommended.

Root-Knot Nematode.—Trees attacked by this nematode, *Heterodera marioni,* if badly affected, are stunted and show numerous small swellings or galls on the roots. The apricot root is somewhat resistant to this omnivorous pest and may be selected for fruit trees on nematode-infested soil. It is not entirely satisfactory for any fruit other than its own species, but is occasionally used for peach, plum, and possibly other stone fruits.

Rust.—The term "rust" is applied to this disease because of the red, dusty spore pustules of the fungus, *Tranzschelia pruni-spinosae,* that appear on the leaves and fruit. Small, hard points in the skin of the fruit may result. In wet seasons, there has been in a few cases severe dropping of young leaves in early summer and much damage to fruit after heavy spring infection. This early infection comes from fall-infected leaves, which under mild weather conditions remained on the tree through the winter. This is the same rust as that which attacks the peach and other stone fruits.

To prevent the danger of early spring infections, avoid summer pruning, which induces young fall growth with overwintering leaves. In addition to this, the trees may be sprayed with bordeaux mixture 5–5–50 (p. 156) in the fall (October 15 to November 1) if the disease is serious enough to justify it. The lime-sulfur spray recommended for this purpose on peaches is not safe to use on apricots.

Scab.—This disease is characterized by sooty fungus patches, about ½ inch in diameter and often running together, that form on the fruit and result in drying and cracking. It is caused by *Cladosporium carpophilum.*

Sprays for brown rot (p. 32 and table 3) will probably control this, but if not effective, additional sprays of bordeaux mixture after full bloom should be tried. The disease is not at all common in California.

Shot-Hole Disease.[9]—In this common fungus disease of the apricot, which is caused by the fungus *Coryneum Beijerinckii,* the buds are blackened and killed during winter; spots killed in the young leaves fall out, which gives the disease its name. Small red spots with light

[9] For further information on this disease, see: Wilson, E. E. Shot-hole disease of stone-fruit trees. California Agr. Exp. Sta. Bul. 608:1–40. 13 figs. 1937.

centers are formed on the fruit, and in bad cases the apricots are completely covered and roughened with small, scabby spots. The latter form of the disease occurs in the interior valley more than in the coast and Bay districts.

To control, spray with bordeaux mixture 5–5–50 (p. 156) between November 15 and December 1, and repeat with the same or a heavier strength in the spring as the buds start swelling (red-bud stage). The later spraying will also help to prevent brown rot. In districts where

TABLE 3

Spray Program for Apricot Diseases

Time	Spray and strength*	Disease	Remarks
Nov. 15–Dec. 1	Bordeaux 5–5–50	Shot-hole	Important for control of shot-hole in interior valleys
Red-bud stage before petals show white	Bordeaux 8–8–50	Brown rot Shot-hole	The most important spray for brown rot; helps to control shot-hole
A few blossoms open	Bordeaux 8–8–50	Brown rot Shot-hole	Necessary for good control of brown rot when disease is bad; helpful for shot-hole
Petals fallen	Bordeaux 5–5–50	Brown rot Green rot† Shot-hole	Not usually needed unless much rain during blooming period
Jackets shedding	Bordeaux 5–5–50	Shot-hole Green rot Brown rot	Useful in some places where shot-hole on fruit is often bad
Fruit half grown	Bordeaux 3–3–50	Brown rot	To prevent fruit rot; must not be applied late enough to show on ripe fruit

* For directions see page 156.

† The use of oil-bordeaux (p. 157) in this and the next spraying, or an application of 3–3–50 bordeaux mixture during full bloom has been suggested for control of green rot.

spring rains are frequent and spotting of the fruit follows, further spraying with bordeaux 5–5–50 may be done before the petals fall and just as the "jackets" (calyxes) are shed from the young fruits (table 3). See "Shot-Hole Disease" under "Almond" (p. 10), and "Blight, Shot-Hole Disease," under "Peach" (p. 84).

Silver Leaf.—Affected leaves show a silvery, lead-colored appearance or glisten. The disease has been attributed in some cases to a wood-decay fungus, *Stereum purpureum,* which has been found in California on some but not all apricot trees which show silver leaf.

Sour Sap.—Young trees or branches fail to start properly in spring or wither and die after starting (fig. 2, p. 12). The inner bark is discolored and sour-smelling, or may be dead and gumming in definite areas or pockets without souring. Sometimes the roots are the first part af-

fected; again, all or part of the top is killed; while in still other cases, the seat of the trouble is found at the base of the trunk just aboveground. In the latter cases, sprouts may come up from the roots. In certain seasons, extensive epidemics of this trouble occur in young apricot trees. The cause of the disease is not the same in all cases. Much of the so-called "sour sap" is really due to bacterial canker (p. 28). But other parasites may be responsible, for instance, fungi of the *Phytophthora,* or water-mold, type, like those which attack almond (p. 8), citrus (p. 61), and many other plants. The blackheart fungus, *Verticillium albo-atrum* (p. 30), is also responsible for more or less sour sap. When the trouble is located in the root, it is usually caused by too much moisture. Weather conditions during the winter appear to have a decided influence in bringing about this condition. It is only in occasional years that large numbers of young trees which were apparently normal in the fall are found to be dead or dying in the spring.

The above discussion indicates that no specific method of control or prevention can be applied to ward off the sporadic epidemics of sour sap in young fruit trees. Keeping the trunks of young trees well covered with whitewash in winter is of general value. In soils and climates well adapted to apricots, replanting is perfectly safe in orchards where trees have died in this manner. Faulty conditions such as poor drainage, too deep planting, or improper soil should be corrected or avoided.

Thrips Effect, Tip Blight.—The growth at the tips of the young developing twigs is sometimes blasted or deformed, and the terminal shoot may be killed or caused to branch. This is caused by numerous thrips—*Frankliniella tritici* or other species—which congregate at this point but are too small to be readily seen with the naked eye. For control of thrips, see Extension Circular 87.

Tumor.—In affected trees, conspicuous, dark, rough, large, roundish enlargements or galls, sometimes several inches in diameter, appear on main limbs, especially of old Moorpark apricot trees. This fungus disease, caused by *Monochaetia Rosenwaldia,* is very slow-working and for a long time is not noticeably injurious. Finally growth of limbs or whole trees is checked. Diamond canker on prune trees somewhat resembles this disease but does not appear to be the same.

Cut out tumors as soon as they are detected and treat wounds with corrosive sublimate (p. 159), pear-blight solution (p. 159), and bordeaux paste (p. 157).

Wood Decay.—See page 152. This trouble, which is due to any of various fungi, is severe on the apricot, and efforts to protect the trees will be repaid by their longer life. The effects of wood decay in the apricot are the same as those in other fruit trees—a rotting of the heartwood

and breaking down of branches. Large globules of hard gum sometimes form on the bark as a result of wood decay within.

AVOCADO[10]

Apoplexy, Asphyxiation.—The first indication of this trouble is the sudden collapse and withering of the leaves and stems on some of the branches. The trunk and larger branches usually remain alive, and after a time new growth is put out and the tree is restored rapidly. The disease has not been fully studied, but it is now believed to be due to complete saturation of the surface layers of the soil with water, which causes injury to roots and indirectly to tops.

To prevent this trouble, try to avoid excessive wetting of the surface soil by management of irrigation, and by suitable drainage ditches to carry away excessive rainfall. Avocados should not be planted in poorly drained ground.

Blast, Citrus Blast.—The citrus blast bacterium, *Phytomonas syringae* (p. 56), sometimes attacks the avocado and causes black spots and cracks on the surface of the fruit. The disease may easily be confused with other spots and fruit blemishes.

Canker and Gum Diseases.—Large, striking, and serious cankers or sores sometimes appear on the trunks of avocado trees. Some of these are due to the same fungi that cause gummosis and root rot of citrus trees (*Phytophthora,* p. 61). In the avocado, the gum soon changes to a whitish, granular mass.

Cankers of a chronic, destructive nature should be cut out, and the wound disinfected and treated with bordeaux paste (p. 157).

End Spots.—Avocados ordinarily do not soften while attached to the tree, but often after maturity, if not harvested, they finally undergo some form of decline. Mature fruits often become withered, spotted, and cracked at the lower end. If picked promptly and permitted to soften, these end-spotted fruits may be used with only slight waste. If left on the trees, drying and cracking continue and sometimes decay enters and the fruit is entirely spoiled. Certain varieties, such as Blake, Ganter, and Ward, have a short period of maturity before end spots appear. Others, like Fuerte, may remain on the tree in good condition for a long time. Unequal maturity in the two ends of the fruit seems to be a factor.

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

Hodgson, Robert W. The California avocado industry. California Agr. Ext. Cir. 43:1–94. 26 figs. Revised 1934.

Horne, W. T. Avocado diseases in California. California Agr. Exp. Sta. Bul. 585: 1–72. 34 figs. 1934.

As preventive measures, it is suggested that the trees should not be allowed to suffer from lack of water and the fruit should be harvested promptly when mature.

Fruit Blemishes.—Mature fruits are sometimes marked by large, corky scabs covering much of the surface. Deep cracks allow fungus spores to enter and cause decay. At least part of these scars originate when the fruit is very small, even when less than ½ inch long. Contact of the tender young fruit with a leaf edge or petiole may cause a surface injury which soon turns dark and later cracks and forms a hard surface blemish. Biting insects, snails, and thrips cause surface blemishes, and some defects are not yet understood. The scab disease of Florida, which causes small corky spots to appear on very young fruit, has not been observed in California.

Fruit Spoilage.—Fruit of the avocado is used after the flesh has become soft, and in this condition is very perishable. It does not soften on the tree; but after picking, when kept at a temperature above 45° Fahrenheit, softening begins after several days. This is true even though fruit is gathered before full maturity. When oversoft, the flesh becomes somewhat darkened, especially in the fibers, and flavor declines. The firm fruit on the tree, except where cracked or injured, is not very subject to decay in California, but the soft fruit, especially in injuries, is very subject to invasion by many molds and bacteria.

The most destructive decay of ripe fruit in California is caused by the common black, or bread mold, *Rhizopus nigricans*. The rot spreads rapidly and causes the flesh to become very soft, watery, and offensive in odor. A coarse, cottony mold may appear in injuries or on the surface. It is at first white, but soon becomes covered with black points.

Dothiorella rot,[11] due to the fungus *Botryosphaeria ribis,* is a soft, rapidly spreading, surface rot which begins as small vague spots when the fruit first starts to soften. Affected fruit may be covered with decay spots almost as soon as usable, so that the period for sale and use in the soft condition is much shortened. The fungus causing the decay propagates in dead twigs and in tipburned leaves. It is abundant only in the moist coastal areas.

Anthracnose rot caused by the fungus *Colletotrichum gloeosporioides*, attacks ripening fruit in storage, producing decayed spots with minute pink spore pustules.

Many molds cause decay of soft avocados but grow slowly so that the affected spot may be trimmed off and the fruit used. The blue and green

[11] For further information, see: Horne, W. T., and D. F. Palmer. The control of dothiorella rot of avocado fruits. California Agr. Exp. Sta. Bul. 594:1–16. 3 figs. 1935.

molds of citrus fruits are not of importance on the avocado, but related forms, such as the apple core mold, *Penicillium expansum* (p. 16), cause slow types of decay. Putrefactive bacteria enter in late stages of oversoftness or spoilage and cause offensive rot.

Treatments of harvested fruit to prevent rot have not been successful. Spraying the trees repeatedly with bordeaux mixture to keep the fruit covered controls dothiorella rot but is considered too costly. Control of tipburn, removal of dead twigs, early picking, and prompt utilization of fruit are considered the most promising measures for this disease. Low temperatures retard the ripening process and also the growth of most of the molds which cause decay, but Fuertes and most other varieties should not be kept colder than 45° Fahrenheit. The calyx or stem scar is the most vulnerable point for entrance of decay organisms; it may be disinfected and waxed.

Sun-blotch.—Affected green stems show yellowish depressed streaks, leaves are sometimes variegated and misshaped, and the fruits are deformed by depressed broad streaks or spots. Older stems are abnormal, with dead areas; they age prematurely and hang down. Severely affected trees are worthless, but many are only slightly affected and appear to recover. This disease is poorly named, for it is not caused by sunburn. It is a virus disease transmitted to healthy scions by diseased stocks or to healthy stocks by diseased scions. It is not propagated by seed.

Select mother trees from which scions are to be taken by carefully observing the twigs and fruits, and by observing the growth of scions from the individual trees under trial. Trees which show any sun-blotch symptoms or which give sun-blotched propagations should not be used.

Tipburn.—This trouble gets its name from the fact that the mature leaves dry back from the tips and edges, the trouble increasing as the time for leaf shedding in the spring approaches. The new leaves are for a time normal. The disease is due to an accumulation of salt (common salt) in the leaves, and is brought about by an excess of this substance in the soil or irrigation water. Drought, wind, and lack of organic matter and nitrogen in the soil contribute to the trouble. Avocados will tolerate somewhat less salt than citrus fruits. Fungi like *Botryosphaeria* and *Colletotrichum,* which cause decay in the softening fruit, propagate in tipburned areas, particularly in the coastal districts.

To prevent this trouble, make sure that the drainage is adequate, use water of low salt content for irrigation, and water freely to wash down accumulated salt and keep soil moisture fairly high.

Unfruitfulness.—Many large seedling avocado trees do not blossom. Other trees blossom but set no fruit; still others set fruit, but it falls before maturity. Avocado flowers are perfect, but have an unusual

blossoming behavior (see Extension Circular 43, mentioned in footnote 10, p. 41); pollination may be defective.

Girdling large limbs or whole trees may help to increase fruitfulness. Nonbearing seedling trees are usually budded or grafted to good fruiting varieties.

Water Injury.—Certain tree failures are evidently due to excess water in the soil. Hardpan or other defects in soil structure may be responsible. Avocado trees are sensitive to excess soil moisture and have poor recuperative power after such injury.

BLACKBERRY AND RASPBERRY[12]

Anthracnose.—Symptoms of this disease are white spots with purple borders on the leaves, and larger, similar spots, which often run together into cankered areas, on the canes. The spores of the fungus *Elsinoe veneta* are abundant in such places. It is worst on black raspberries.

For this and the following cane and leaf diseases, it is advisable to cut out and destroy dead or badly diseased canes whenever they are seen and to clean up with special care during the winter pruning, in February or March, just before the leaf buds open. Spraying at this time with lime-sulfur solution (p. 160), 8–100, will be beneficial and also control the blackberry mite which causes the redberry disease. This treatment may also do some good in cleaning up scale insects. If redberry is not a problem, spraying may be done with 5–5–50 bordeaux mixture (p. 156) just before the leaf buds open. A second spraying may be made after the leaves are out, using bordeaux mixture. At both times, the base of the canes and the surrounding soil should be sprayed as well as the tops.

Blue Stem, Verticilliosis.—The leaves of affected bushes become sickly and drop and the canes develop a characteristic bluish color. Black raspberries and the Ranere (Ranaree) red variety are particularly susceptible, but other raspberries and blackberries (including the Young blackberry, or Youngberry) sometimes show this trouble. The disease is caused by *Verticillium albo-atrum*—the same soil fungus that causes blackheart of apricots and wilt of tomatoes, potatoes, and many other plants.

To prevent the disease, select plants from healthy fields and avoid planting raspberries after tomatoes or potatoes. When the disease appears, pull affected plants immediately, and also one plant on either side in the row to keep it from spreading.

Cane Blight.—In this disease, dead areas of brown color appear on the canes, which are often girdled and killed. The young berries some-

[12] For further information, see: Butterfield, H. M. Bush berry culture in California. California Agr. Ext. Cir. 80:1–53. 21 figs. Revised 1937.

times dry up prematurely. This disease is most common on black raspberries and may be definitely distinguished from anthracnose and leaf spot by the character of the spores of the fungus, *Leptosphaera coniothyrium,* but this can be done only with the aid of a microscope. Treatment is the same as given for anthracnose.

Chlorosis.—Affected plants are weak and the leaves take on a bright-yellow color. This condition is very conspicuous on red raspberries in certain districts where the soil contains large amounts of lime, and seems to be a nutritional disturbance.

Fig. 21.—Crown gall on roots of Phenomenal blackberry.

Berries should not be planted in soils where this condition exists. Strawberries are also susceptible, as well as pear trees and other fruits. If the trouble on raspberries is not too severe, some benefit may be obtained by spraying the foliage occasionally with a solution, 1 pound to 12 gallons, of ferrous sulfate.

Crown Gall.—Large, fleshy tumors develop on the infected roots and weaken the plant. On raspberries and blackberries, these galls are sometimes of extraordinary size (fig. 21). This is the same disease as crown gall of fruit trees, and is caused by the same organism, *Phytomonas tumefaciens.* Plants once affected cannot be cured, so that it is very important to avoid planting infested stock.

Fruit Mold.—The ripe berries are sometimes covered with a dense, dusty, gray mold, *Botrytis cinerea,* which ruins them for market. This

usually happens in places or at times when there is a good deal of fog or moisture in the air.

If this trouble is serious, keep the tops thinned out as much as possible by pruning. Do not pick berries when wet. Pick closely to avoid overripening, and remove all moldy fruits.

Leaf and Cane Spot.—Small, dead spots with brown or reddish margins on leaves and canes are characteristic of this disease. On the Young blackberry, this fungus, *Mycosphaerella rubi*, appears to be the cause of a cane blight (fig. 22) with very little leaf spotting. Leaf spot, an-

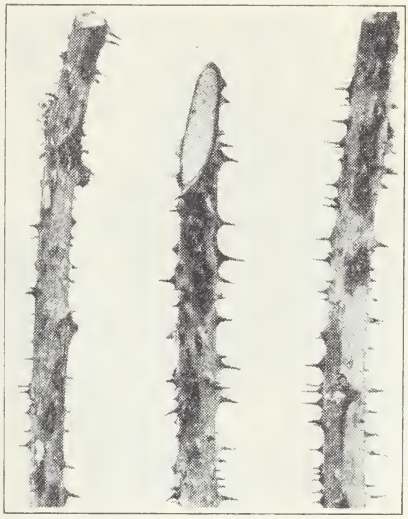

Fig. 22.—Spots on blackberry stems caused by leaf-spot fungus.

thracnose, and cane blight can be readily distinguished with the aid of a microscope by the spores of the fungi which cause each disease, but the symptoms on the plants are often difficult to distinguish. Practically, however, this is not important, since the treatment is the same as recommended for anthracnose (p. 44).

Leaf Rust.—In infected plants, small, light-yellow spore pustules of the fungus *Phragmidium rubi-idaei* appear on young leaves, and black spores form in the same pustules later in the season. On the variety Ranere (Ranaree), the attack is usually confined to the older leaves and is not destructive except in coast districts. On Cuthbert, the rust may be very severe; it may attack all leaves and occasionally forms pustules on the canes. There is no practical remedy for leaf rust except the winter cleanup and the spraying recommended for anthracnose (p. 44).

Mosaic, Leaf Curl, Yellows.—Several virus diseases of this type

occur in other states but none have been positively recognized in California. They have typical characteristics of virus diseases: yellow, mot-

Fig. 23.—*A*, Raspberry "nubbins"; *B*, "redberry" of Himalaya blackberry, caused by a blister mite.

tled, deformed, or curled leaves and stunted growth. Most diseases of this kind are spread by aphids from plant to plant. Care should be taken

not to introduce these diseases on nursery stock or to propagate from any suspicious-looking plants.

Nubbins.—This term is applied to a condition in which the berries are imperfectly developed, consisting of only a few segments (fig. 23,*A*). This has been attributed to thrips working in the blossom, and to imperfect pollination, but there has been no proof of either of these explanations. The trouble is serious at times on the Ranere (Ranaree) variety of raspberry.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The killing of plants by the well-known fungus *Armillaria mellea* sometimes occurs in berry plantations. The fungus affects the plants by destroying the roots in the usual manner. Bush fruits, although susceptible, are not often seriously affected by this disease since they are too shallow-rooted to pick up the fungus in the soil very frequently.

Removal of affected plants and all diseased roots around them is advisable for control (see p. 144).

Orange Rust.—In this disease, certain individual plants are first affected and ruined. New shoots come up pale, dwarfed, and with the leaves curved inward and pointed upward. Bright orange-colored spores of the fungus *Gymnoconia Peckiana* completely cover the surface of such leaves and these spores spread the disease to new plants.

Dig out and burn affected plants at the first appearance of the disease. Spray healthy plants in the vicinity with bordeaux mixture (p. 156) to prevent new infections. Affected plants can never be cured because the fungus grows internally down through the stems to the roots and comes up again in the new shoots.

Powdery Mildew.—A white mildew fungus, *Sphaerotheca humuli,* often attacks the foliage and fruit of raspberries and sometimes blackberries, especially in humid localities. Considerable injury is caused in some cases.

Sulfur, the usual remedy for powdery mildews, cannot be applied to raspberry foliage on account of the severe injury which it causes. Thorough cleaning up and spraying with lime-sulfur in winter, as recommended for anthracnose (p. 44), will be of benefit.

Redberry.—In certain varieties like the Himalaya and Mammoth blackberries, the berries are sometimes partially red, hard, and deformed when they should be fully mature (fig. 23,*B*). This trouble is caused by a very small mite, *Eriophyes essigi,* which winters in the buds and attacks the young fruit in the blossom stage. It is mentioned here because the effect is that of a disease. See Extension Circular 87 for further details.

Spraying with lime-sulfur as the buds are swelling (see "Anthrac-

nose," p. 44, and also Extension Circular 87) is very effective in preventing this trouble.

Rosette, Dwarf.—This virus disease, which typically attacks the Logan blackberry (loganberry), causes a stunting and dwarfing of the plant and ruins its commercial value. This condition, which appears to be different from any of the recognized virus diseases of the raspberry, was formerly common in Sonoma County when Logan blackberries were extensively grown there, but now is rarely seen. Affected stock should be avoided in new plantings.

Rust.—See "Leaf Rust" (p. 46) and "Orange Rust" (p. 48).

Spur Blight.—Early in the season, the tissue surrounding the bud at the base of the leaves in affected plants turns brown and the bud stops development and becomes shriveled. Discolored areas spread so that the entire lower part of the cane may become dark purplish-brown. The spores of the fungus *Mycosphaerella rubina* appear on such places the following spring. Affected canes bear fruit only near their tips.

To control, clean up and spray in winter as for other diseases above. If further treatment seems necessary, spray with bordeaux mixture 3–2–50 (p. 156), the first application being made when young canes are 8 to 12 inches high and the second two weeks later. A sticker (p. 161) may be added to this spray with advantage.

Yellows.—This name is sometimes used for raspberry virus diseases (see "Mosaic, Leaf Curl, Yellows," p. 46), but is usually applied in California to the chlorosis of raspberries which occurs on limy soil (p. 45).

CHERRY[13]

Bacterial Canker, Bacterial Gummosis.—The principal symptom of this disease is masses of amber-colored gum that are exuded from rough cankers or depressed areas in the bark on the trunk and main limbs (fig. 24). Trunk or limbs may be girdled and killed by the disease or be so crippled that wood decay sets in and ruins the tree. The disease, caused by *Phytomonas cerasi,* also affects most other kinds of stone fruits like apricot, peach, plum, and almond.

Young cankers may be cut out and the wounds treated with corrosive sublimate 1–1,000 (p. 159) or bordeaux paste (p. 157). Cutting out older cankers or those on badly affected trees is not usually satisfactory. In certain districts, cherry orchards which suffered badly from bacterial canker have been seeded down to alfalfa (with the trees on the check ridges) with apparent benefit. The varieties Chapman, Republican

[13] For further information about cherry culture and diseases, see: Philp, Guy L. Cherry culture in California. California Agr. Ext. Cir. 46:1–42. 20 figs. 1930.

(Black Republican, Black Oregon), and Black Tartarian are less susceptible than Lambert, Royal Ann (Napoleon), and Bing.

Brown Rot.—The characteristic effect of this disease on cherry is a rotting of the ripe fruit, with powdery, ashy-gray, moldy tufts of fungus spores on the surface (fig. 25). In wet seasons, this happens to

Fig. 24.—Bacterial canker of cherry.

cherries on the tree and, at times, much more with fruit in transit and on the market. Blossom, bud, and twig blighting from this fungus disease, which is caused by *Sclerotinia fructicola* or *S. laxa,* are not so common on cherries as on the apricot and almond, which are also attacked by it (see "Brown Rot," under "Apricot," p. 32) ; but in moist localities near the coast this effect is not unknown on cherry.

Where brown rot is troublesome on cherries, the trees should be sprayed as recommended for apricots, a thorough application of bor-

deaux mixture 8–8–50 (p. 156) being given just as the first blossoms start opening. When this is done, there should be good control of bud and blossom infection and considerable reduction in rotting of ripe fruit on the tree or in transit. For further control of the latter trouble, dusting the trees with dry sulfur or spraying with wettable sulfur (6 pounds to 100 gallons of water) (p. 160) about 2 weeks before harvest time is recommended.

Buckskin.—Affected fruit has a pointed form, remains small, green, and undeveloped, and shrivels before ripening. This abnormal fruit hangs on the tree for a long time. The leaves show a red color along the

Fig. 25.—Brown rot of cherry.

base of the midrib during September and October (fig. 26). Only one or two limbs of the tree may be affected at first, but the condition, which is probably a virus disease, soon spreads to the entire tree and to other trees in the orchard. The Royal Ann (Napoleon) variety is usually the one worst affected with buckskin.

Buds for propagating should not be taken from affected orchards because the disease is spread by budding or grafting from affected trees. There also appears to be another, unknown method of spread from tree to tree. Trees on mahaleb root are resistant to this disease and should therefore be used for planting in infested districts. Best results have been obtained when the buds or scions have been set in the scaffold limbs of mahaleb seedlings established in the orchard. Any tree which shows the first sign of this disease should at once be removed, since it will soon become worthless and meantime will spread the disease to other trees. Cutting off single limbs is of no value.

Chlorosis.—This refers to a condition in which the leaves become yellow or mottled with green and yellow, the growth is usually somewhat stunted, and the branches die back from the ends. This condition may be

due to any of various causes, such as poor soil or moisture conditions or some of the virus diseases mentioned in this section, or it may be a case of "lime-induced" chlorosis.

In the latter case, treatment with iron salts applied through holes in

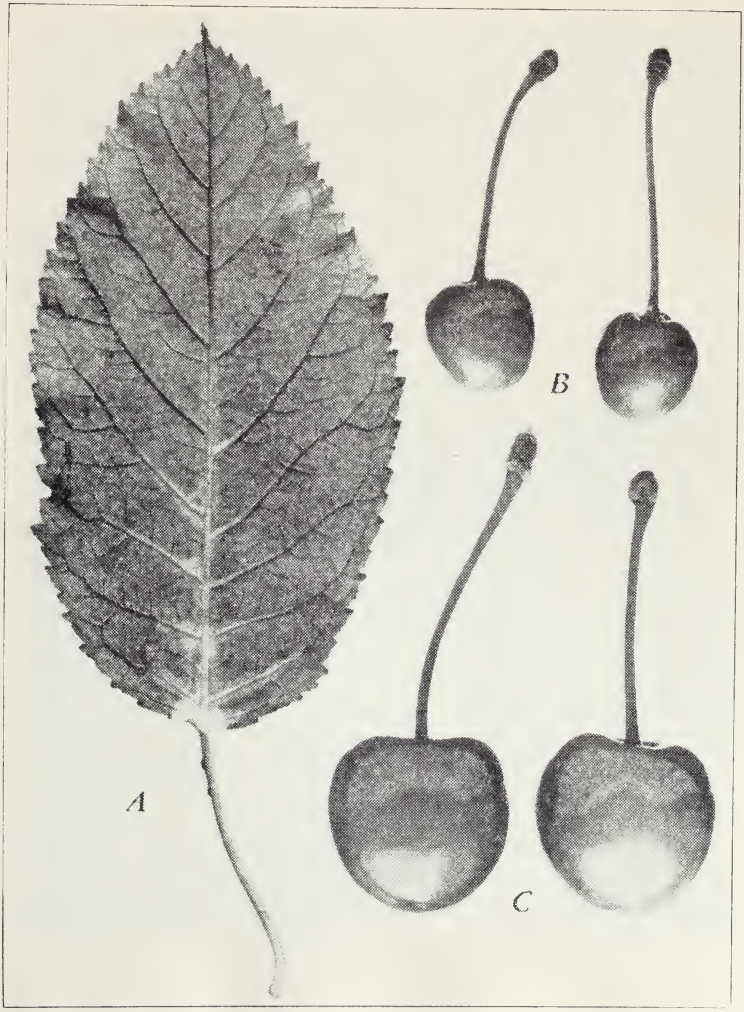

Fig. 26.—Buckskin of cherry: *A*, leaf symptoms; the light-appearing areas in the lower part of the leaf are of a red color in September and October; *B*, buckskin fruit of the Royal Ann (Napoleon) variety; *C*, normal fruit of the same age.

the trunk may be helpful (p. 135). Chlorosis due to other causes must be treated by removing or improving the injurious condition, whatever that may be. The cherry is a somewhat delicate tree, and unfavorable circumstances easily bring about such symptoms as chlorosis and dieback.

Fig. 27.—Cherry crinkle disease: above, typical affected leaves (Black Tartarian variety); below, fruit showing pointed shape and open suture; normal fruit is shown in the center.

Crinkle.—Only the Black Tartarian and Bing varieties are affected by this disease. Affected trees are large and vigorous in appearance but produce little fruit, and what is produced is small with a deep crease or suture on one side and a pointed shape (fig. 27). The leaves have a peculiar ragged, unsymmetrical form and may show mottling. Most of the blossoms abort and fail to produce fruit. Trees showing symptoms of this disease should be removed or may be grafted to any other variety except the two mentioned. The disease is carried in buds and scions, and these should never be taken from affected trees.

Crown Gall.—Large, rough knots or galls form on the roots. For further description of this bacterial disease, caused by *Phytomonas tumefaciens,* see under "Almond" (p. 7). The cherry is not so susceptible as some other fruit trees.

Delayed Foliation.—See page 140.

Dieback.—The branches sometimes die back from the ends, giving the tree a ragged, unthrifty, distressed appearance. Some years many large, fine, old trees in good soil suddenly die almost completely. In shallow soils, cherry trees seldom reach much size, but after a few years begin to die back and make only a stunted growth. After dieback has started, the trees begin to show the effects of sunburn, borers, wood-decay fungi, gummosis, and other secondary troubles and rarely recover. The cherry, while naturally a thrifty, long-lived tree, is very susceptible to certain influences, of which soil moisture is probably the most important. Dry seasons or irregular soil moisture, especially in the subsoil, are probably responsible for most of this trouble, but there are other causes.

Fall and winter irrigation in dry seasons will do much to prevent dieback. Top-working on morello root seems to produce hardier trees in some cases, but such trees are somewhat dwarfed and bear heavy crops of fruit which tends to be slightly undersized.

Leaf Curl.—The principal symptom of this disease, caused by *Taphrina cerasi,* is a crinkling and distortion of the leaves, something as in peach leaf curl (p. 89), which is caused by a similar fungus. This disease is rare in California. Spraying with bordeaux mixture (p. 156) or lime-sulfur (p. 160) as for peach leaf curl controls this disease.

Leaf Spot.—This disease is sometimes fairly abundant in coast districts. Affected leaves show small, dead spots covering most of the surface and fusing at the lower edge (fig. 28). The underside shows a whitish covering of spores of the fungus *Coccomyces hiemalis.* To control, spray with bordeaux mixture 5–5–50 (p. 156) or lime-sulfur 1–100 (p. 160) soon after fruit is set.

Oak-Root-Fungus Disease, Armillaria Root Rot.—In an orchard

where this disease is present, trees die in gradually increasing areas and show the characteristic fungus, *Armillaria mellea* (p. 144), in the roots. The cherry is moderately susceptible, being more resistant than peach or almond and about equal to the apple and olive. The mazzard cherry root appears to be more resistant than the mahaleb or morello.

There is no way of growing cherries with safety in infested soil. Treat-

Fig. 28.—Cherry leaf spot.

ment with carbon disulfide (p. 149) is the only possibility except to grow some nonsusceptible tree or crop.

Sour Sap.—Young cherry trees often fail to start in spring, and the dead, brown, inner bark has a fermented odor. This is not due to any one cause. Bacterial canker is often responsible, the trunk or limbs being girdled by cankers. Phytophthora canker may also be found at the crowns of the trees, as in almond and in citrus gummosis. Excessive water or poor drainage contributes to the trouble.

Watch young cherry trees at all times for cankers, gumming, or other signs of bark infection and if any are found, cut out the cankers and treat the wounds with bordeaux paste (p. 157) before they develop further. Protect the trunks from sunburn and borers with whitewash and tree protectors. In soils where the young trees die repeatedly from trouble of this sort, cherries should not be planted.

CITRUS FRUITS[14]

(Grapefruit, Lemon, Lime, Orange, Tangerine)

Alternaria Rot, Navel-End Rot, Black Rot.—This is not often a serious disease but is most prevalent in warm, dry sections like Arizona and the San Joaquin Valley of California. In oranges it is most commonly found in the Washington Navel variety, in which it causes a dry, firm, black type of rot at the navel end, often in only one segment. Affected oranges color up prematurely and may look sound on the outside, often constituting some of the largest and finest-looking early fruit. The causal fungus is *Alternaria citri.*

In lemons a soft, internal, dark-colored rot is produced by a similar fungus, usually in old or weak fruit. Firm, dark-brown, side spots are also formed. No control has been found except, in lemons, to avoid long storage of weak or old fruit.

Anthracnose.—For anthracnose of leaves and twigs, see "Wither Tip" (p. 66). On very mature fruit, especially in storage, the fungus *Colletotrichum gloeosporioides* sometimes produces dark-brown, sunken spots extending to the pulp. These start in slight injuries and are similar to those produced by invasion of *Fusarium, Alternaria, Pleospora,* and other fungi. A surface superficial staining of oranges known as "tear-staining" is also produced by the same fungus.

Armillaria Root Rot.—See "Oak-Root-Fungus Disease, Armillaria Root Rot" (p. 144).

Black Pit.—This disease is indicated by dark sunken spots in the rind of fruit, usually in lemons. These pits often develop at thorn pricks or other injuries and are favored by wet weather. They do not decay. The cause is a bacterium, *Phytomonas syringae.* No control is practiced.

Blast.—Blast causes a killing of the leaves and petioles, spreading to form a shield-shaped, dead area on the twig around the base of the leaf. Leaves die and dry up in place, the twig scars turn black, dry, and heal.

[14] This section covers the most important diseases of citrus trees and fruit. Descriptions of many other diseases, as well as much more discussion about those mentioned here, will be found in: Fawcett, H. S. Citrus diseases and their control. 2d ed. xv + 656 p. 187 figs. McGraw-Hill Book Co., Inc., New York, N. Y. 1936.

Another publication that may be helpful is: Klotz, L. J., and H. S. Fawcett. Color handbook of citrus diseases. University of California Press, Berkeley, California. (In press.)

and scale off in two or three years. If badly injured, the twig may die. Oranges and grapefruit are most susceptible. Blast occurs only in very wet seasons and localities, especially after cold, driving rainstorms, and is most serious in northern California orchards. The cause is the same as that of black pit.

Where blast is prevalent, it is well to grow bushy, compact trees and avoid severe pruning. The use of windbreaks is advisable to protect the orchard from severe storms. Severe injury to nursery trees may be prevented by spraying with bordeaux mixture (p. 156) by November 1 in northern California.

Blue Mold.—This is caused by one of two fungi—*Penicillium digitatum* and *P. italicum*. The affected fruit rots and becomes covered with a powdery mold which is white at the margins and blue (*P. italicum*) or green (*P. digitatum*) in the older portion. This fungus decay almost always starts from injuries of some sort in the rind. The blue-mold type has more ability to spread from fruit to fruit by contact than the green.

The chief means of preventing blue-mold decay is to avoid all types of injury to the fruit in picking and handling. Dipping the fruit in various chemical solutions, either warm or cold, is also practiced. Some of the substances used for this purpose are : borax, boric acid, sodium carbonate (soda ash), sodium bicarbonate, sodium hypochlorite, and various proprietary compounds. A method of treating citrus fruit with a gas (nitrogen trichloride) for the prevention of decay has also been developed. All these methods carry danger of injurying the fruit and detracting from, rather than improving, its keeping quality, if they are not applied in exactly the right manner. Commercial practice in these matters is constantly changing so that only the latest information should be used as to choice of material, strength, time, temperature, and other details. Such information may be obtained from the Division of Plant Pathology, Citrus Experiment Station, Riverside, California. The same procedure is not always applicable to both lemons and oranges. It cannot be too strongly emphasized that chemical treatment of citrus fruit cannot be depended upon to take the place of careful handling to avoid injuries, for the prevention of decay.

Botrytis Rot, Gray Rot.—Botrytis rot is a rather firm, dark-colored rot, in which the surface of the affected fruit eventually becomes covered with a mass of dark-gray mold, *Botrytis cinerea*. It is seen most commonly on lemons in storage; but during extended periods of cool, wet weather, the fungus may attack lemons or oranges on the tree and weakened twigs, especially in lemon trees.

The methods of preventing this rot in stored lemons are the same as those recommended for cottony rot (p. 59).

Brown Rot.—This is a light-brown, firm type of decay with no visible surface mold except in moist air, and a characteristic, slightly rancid, penetrating odor. Lemons and oranges may be affected on the tree in wet weather, especially those near the ground. Much loss is sometimes caused to lemons in storage in the packing-house, the rot spreading rapidly by contact from fruit to fruit in the boxes. The fungi which cause this disease—*Phytophthora citrophthora, P. parasitica, P. hibernalis,* and *P. syringae*—live in the soil. Infection takes place by spores spattering up from the ground to the low-hanging fruit in rainy weather, and by spores in the water of the washing tank.

To prevent brown-rot infection of fruit in the orchard, the ground under the trees and the lower branches up to a distance of 3 feet from the soil should be sprayed thoroughly with 3–3–50 bordeaux mixture (p. 156), just before the rains begin or as soon as possible after the first hard rain. If cyanide fumigation is practiced in the orchard, it is safer to use the copper-zinc-lime spray, composed of ½ pound of copper sulfate, 6 pounds zinc sulfate, and 3 pounds of lime to 50 gallons of water. Weeds growing under the trees should be cut and left lying on the ground.

When freshly picked fruits are brought to the packing house, they should be carefully sorted to remove all which show infection. When washing lemons or oranges which may develop brown rot, the wash water may be treated with 1 pound of copper sulfate (bluestone) or 100 pounds of sodium carbonate (soda ash) to 1,000 gallons of water. Hot water (115° Fahrenheit) with or without chemicals, also prevents the development of brown rot. Here, as in dipping for control of blue mold, it is very easy to injure the fruit or fail to get the best possible results if the methods used are not scrupulously accurate. Those wishing to apply such treatment on a large scale should get more detailed information on the latest commercial practice. Lemons in storage which develop brown rot should be inspected as soon as the characteristic odor is detected. Affected fruit should be thrown out and the "contacts" (fruit which touched an affected one) segregated to watch for further development.

Brown Spot.—Dark-brown, slightly sunken, round or irregular spots sometimes appear on the rind of Washington Navel oranges 2 or 3 weeks after picking, mostly in early-picked (November) fruit in inland districts. The cause is unknown but oranges left on the trees until later in the season do not develop this defect. This disease is distinct from several other rind spots and blemishes of mature fruit; see, for example, "Valencia Rind Spot" (p. 66). It is best to delay picking in groves which are likely to show a serious amount of this trouble.

Canker.—Citrus canker has never been observed in California and

may not flourish here on account of the dry summers. In Florida and the Gulf States, several million dollars have been spent to eradicate the disease, and with success. Any suspicious case should be at once reported to the County Agricultural Commissioner. Symptoms are rough, brown, corky, bacterial eruptions or cankers on both sides of the leaves, on the fruit, and on the twigs. On leaves each canker is surrounded by a yellow band or halo. The appearance of the fruit is ruined by this disease, which is caused by *Phytomonas citri.* Grapefruit, oranges, and lemons are all susceptible.

Chlorosis.—The leaves of affected trees become yellow or yellowish green, instead of the normal, dark-green color. Many entirely different causes may produce symptoms of this sort, as, for instance; gopher injury to the roots, gummosis of the trunk, cold weather, or root injury caused by poor drainage. The condition usually termed "chlorosis," however, is that which is seen in citrus and other trees growing in soil containing excessive amounts of lime. See "Chlorosis" (p. 135).

Heavy applications to the soil of organic matter like green-manure crops, stable manure, bean or barley straw, or alfalfa hay are beneficial. Trees may be injected with iron salts as described on page 136.

Citrus Root Nematode.—This nematode, *Tylenchulus semipenetrans,* which attacks only citrus trees, does not produce root galls or enlargements as does the common root-knot nematode. The microscopic worms cluster upon the surface of the finer roots and cause a layer of dirt to stick to them. Well-cared-for trees show little effect from the presence of these worms upon the roots, although some injury can be demonstrated experimentally. Trees known to be infested should receive especially good care as to fertilization, irrigation, and culture.

Cottony Rot.—The cosmopolitan fungus *Sclerotinia sclerotiorum* (see "Cottony mold," p. 136) sometimes attacks lemons in storage and causes a rapidly spreading contact decay. Affected fruit is covered with a pure white, cottony mold in which are seen the black bodies called "sclerotia." Branches of trees in the orchard are sometimes attacked and partially killed by the same fungus, especially after frost injury. The same effect is described under "Fig" (p. 71). Spores are produced only in the soil, usually where the fungus has grown on thickly matted covercrops.

In picking lemons, care should be taken to avoid letting boxes stand long on the ground in wet weather or carrying dirt or orchard trash into the washer. The fruit should be washed in hot water as for brown rot (p. 58). Lemons in storage where this trouble is present should be frequently examined and sorted.

Crinkly Leaf.—In this disease, the leaf blade, usually of lemons, shows a crinkling or "pocketing," and accompanying this condition the

fruit is frequently coarse and rough. This is a virus disease and should not be confused with a pocketing of leaves somewhat similar to this brought about by certain mites. Crinkly leaf is transmitted by budding, and hence affected trees should be avoided as parents for propagation.

Damping-off.—The young plants in the nursery seedbed sometimes droop, fall over, and die from a rotting of the root and stem at the surface of the ground. The disease spreads from plant to plant through the soil, killing the young seedlings in irregular patches. It may be caused by any of a number of fungi, especially *Corticium vagum* and species of *Fusarium* and *Pythium*. See page 138 for further discussion and methods of control.

Dry Root Rot.—Trees are occasionally affected by a rotting of the bark and wood on the roots at or below the crown, usually below the surface of the soil. The bark may be moist at first, but the final stages are a dry rot of both the bark and the wood. Various causes, such as injuries to the roots, excessive moisture with poor aeration, and other unfavorable conditions, are thought to be factors in bringing about dry root rot. Prevention consists in avoiding as far as possible any of the contributing factors.

Exanthema, Florida Dieback.—This disease appears to be the same as that which affects the apple, olive, pear, prune, and other fruit trees. In each case there is the characteristic bushy growth produced by death of the terminal buds and continuous pushing out and dying back of lateral shoots. In citrus trees the development of elongated, corky, bark excrescences on the twigs is well marked, also a dark staining of the fruit, and production of multiple buds.

Treatment with copper is effective for control. This may be carried out by spraying the trees with 3–3–50 bordeaux mixture (p. 156), preferably in the spring just before or during the first flush of growth. Sprayed trees should not be fumigated with cyanide for several weeks before or after the treatment. Good results in the cure of exanthema may also be obtained by digging copper sulfate into the soil beneath the tree, using from one to five pounds per tree according to size.

Fumigation Injury.—On the trunk, dead strips of bark appear, usually followed by the formation of pink fungus spore pustules of species of *Fusarium*. Some of the wood tissue underneath may also be killed. Dead patches of bark on the base of the trunk just at or a little above the soil surface may occur either on one side or encircling the trunk. Such injury, from hydrocyanic-acid gas fumigation, is frequently mistaken for effects due to fungus diseases. It is especially similar to the form of injury caused by dry root rot.

Granulation.—Granulation is most common in Valencia oranges and

is often called "crystallization" although there is no formation of crystals. The juice sacs of the ripe fruit become hard and firm instead of flabby, and a more or less solid, tasteless condition results. It usually begins near the stem end of oranges which remain on the tree late in the season. No method of preventing this trouble is known.

Green Spot, Oleocellosis.—This refers to irregular spots on the rind of lemons or oranges that remain green when the rest of the surface has turned yellow. These spots have a rough or pebbly surface on account of a slight sinking of the tissue between the oil glands. This effect is produced by citrus oil liberated from the rind by bruising or any other cause. This oil is slightly injurious to the tissue. The trouble is frequently serious and develops rather commonly in green lemons or early Washington Navel oranges picked while wet or those which have been roughly handled. Fruit picked in cool, damp weather and washed immediately in hot water may also be seriously affected.

To avoid green spot, lemons or oranges should not be picked after a rain or heavy dew until the surface has thoroughly dried. Green lemons or other citrus fruits which are not fully colored should be left standing in the boxes from 1 to 3 days before being washed in hot water.

Gummosis, Brown-Rot Gummosis, Foot Rot.—In gummosis, masses of amber-colored gum break out from the trunk near the crown of the tree, with a killing of the bark below and above the ground. The foliage turns yellow and the tree may die. The disease usually occurs where excessive water is allowed to stand around the base of the tree in irrigating or where there is overirrigation, poor drainage, or deep planting. It is usually more prevalent on heavy soils. It is caused by any one of several species of *Phytophthora,* especially *P. citrophthora* and *P. parasitica.* Similar effects are sometimes produced by other fungi and various causes.

On soils suitable for citrus, gummosis may be prevented to a large extent by proper precautions at the time of planting. The ground should be carefully leveled to provide surface drainage and to avoid pockets or low spots. Different citrus rootstocks vary in susceptibility to gummosis. The sour-orange root is much more resistant than the sweet orange, but unfortunately it is not always a satisfactory stock for lemons, although a good stock on many soils for oranges and grapefruit. Trees should be planted so that the tops of the first main roots are just below the general surface of the soil after the tree has settled. The bud union of a properly budded tree will then be well above the soil level when the tree is established. It is desirable to have trees so budded that the union will be at least 10 to 12 inches above the ground. Water should never stand around the trees in groves where gummosis is prevalent. If the trees are already too deep, the dirt should be pulled away from the crown down

to the tops of the main lateral roots and may be left in a circular ridge. The basin thus made may be kept open or filled with coarse sand. Water should be kept out in irrigating. The bark at the base of the trunk may be painted with zinc-copper-lime paste made of 1 pound of zinc sulfate, ⅕ pound of copper sulfate, and 1 pound of lime to 1 gallon of water. In case gummosis has already started, all affected bark should be cut out and the exposed surfaces painted with the same material and kept exposed to the air until healing is completed. Unfavorable conditions of drainage or irrigation must be improved.

Internal Decline, Endoxerosis.—This is a disease of lemons. Affected fruits show a slight withering and drying at the blossom end and a tipping of the "nipple" to one side. The core and inner peel tissue break down and degenerate from the tip back one half the length, when the lemon usually drops from the tree. Such fruit is of light weight, poor quality, and susceptible to decay. This trouble is nonparasitic and appears to be related to low atmospheric humidity, with or without deficient soil moisture.

Uniformly good soil moisture conditions tend to prevent internal decline. Close picking is advisable, leaving no fruit to become too old or tree-ripe, regardless of size. Methods of eliminating the worst-affected fruit in the packing-house have been worked out.

June Drop, Excessive Drop.—Young oranges up to 1 inch in diameter, especially those of the Washington Navel variety growing in the interior valleys, often fall from the trees in abnormally large numbers. This happens most abundantly when the temperature is high and humidity low, and is apparently caused by the excessive loss of water from the young fruit, even when there is plenty of moisture in the soil.

In districts where June drop is serious, the planting of windbreaks and the addition to the soil of liberal amounts of bulky organic materials may help to reduce the loss. The use of nitrogenous fertilizers when the fruit is young and the maintenance at all times of a good soil-moisture condition is also advisable.

Manganese Deficiency.—Certain unthrifty conditions of citrus trees in southern California have recently been ascribed to a lack of manganese in the soil (p. 150). For further information address the Citrus Experiment Station, Riverside.

Melanose.—This is a major disease of citrus fruits in Florida. The fungus is common in California on dead twigs and on flakes of bark caused by shell bark of the lemon, but for some reason, probably the dry summers, only occasionally produces melanose on the fruit or other living parts in this state. Superficial, waxy, scabby, brown markings or blemishes are produced on the surface of young fruits, leaves, and twigs

of oranges and grapefruit. The fungus—*Diaporthe citri*—is the same as that which causes shell bark (p. 65) and stem-end rot (p. 66).

Mottle-Leaf, Foliocellosis.—The leaves are of a mottled or variegated color, with green on the veins and yellow in the areas between. In severe cases, the leaves and fruit are reduced in size and the tree stunted. Since the application of zinc to the trees, as described in the next paragraph, cures this condition, it would appear that either zinc is a necessary element in the growth of the citrus tree and is deficient in certain soils, or else it has a corrective effect upon some other influence.

It has been demonstrated that the form of mottle-leaf described above may be prevented and cured by spraying the trees with a mixture composed of 5 pounds of zinc sulfate and 2½ pounds of hydrated lime in 50 gallons of water. Dusting the trees with a mixture of sulfur and a pulverized zinc compound is also employed for the same purpose. Metallic zinc, zinc sulfate, and zinc oxide have been employed in proprietary mixtures of this sort. For late information address the Citrus Experiment Station, Riverside.

Navel-End Rot.—See "Alternaria Rot, Navel-End Rot, Black Rot" (p. 56).

Oak-Root-Fungus Disease, Armillaria Root Rot.—In orchards where this disease is present, trees turn yellow and die in certain areas, which gradually enlarge by the death of more and more trees. This common root disease, which is described more fully on page 144, is not general in citrus groves, but sometimes becomes serious in localities where native trees, especially oaks, formerly stood. It also spreads from susceptible pepper or other street trees which may be affected and from oak debris deposited by floods in river basins. The disease, caused by *Armillaria mellea,* is identified by the white, felty, fan-shaped plaques of fungus growth between the wood and bark, and masses of light-brown toadstools which come up around the crowns of badly affected trees in early winter.

The use of carbon disulfide to kill the fungus in the soil before replanting has usually been effective in the control of this disease in citrus (p. 149). Surgical treatment has been partially effective in cases where the decay has not progressed too far. No satisfactory resistant root for citrus is known.

Peteca.—Deep pits develop, especially on lemons, owing to sinking of the surface rind. The surface cells remain normal in mild cases or may collapse and dry out later, with discoloration at bottom of the pits. In later stages this trouble resembles black pit.

Phytophthora Leaf Blight.—The first symptom is semitransparent spots similar to those following heavy frosts. Dark, watery-appearing patches develop either on the edges or towards the tips of the leaves,

which fall from the tree. Irregular brown blotches may also occur on the small twigs. This condition, caused by species of *Phytophthora,* occasionally causes almost complete defoliation near the ground. One species (*P. hibernalis*) frequently attacks leaves high up in the trees after driving rain in very cold periods. See "Brown Rot" and "Gummosis" (p. 58, 61), due to the same fungus.

Powdery Mildew.—This disease has been found only on tangerine trees in California in two localities with limited injury. White patches of mildew, *Oidium tingitaninum,* occur, most commonly on the upper surface of the leaves. The leaf tissue beneath the white-fungus patches is at first a darker, watery green than the normal leaf and later loses its color and becomes yellowish.

Psorosis, Scaly Bark.—This disease causes the bark to break out in rough, scaly cankers in areas on the trunk and branches. The parts beyond the cankers gradually deteriorate and may die, which gives the tree a very ragged appearance. Peculiar flecking or stippling due to lighter areas in the young leaves is also observable as a symptom of this disease. The cause is a virus. Orange and grapefruit trees are most affected in the bark, and although lemons usually seem tolerant and do not show such indications of scaly bark, they frequently carry the virus as shown by leaf symptoms, and may sometimes deteriorate.

When not too far advanced, scaly bark may advantageously be treated by scraping off the surface layers of the affected areas for several inches in all directions beyond the visible disease. Only the green surface layer should be removed, leaving the white, inner bark. It is important to scrape the healthy-looking region around the margin as well as the scaly area itself. Disinfection is not important, but the treated areas may be covered with a fungicide like potassium permanganate (1 pound to 12½ gallons of water), or the zinc-copper-lime mixture mentioned for gummosis (p. 62). After the disease is advanced, many growers simply let it run its course, cutting off the branches when they get too badly affected and finally taking out the tree and planting a new one.

Special care should be observed not to take buds for nursery use from trees affected with psorosis, for the disease is propagated in this manner. A useful method of registration of certain trees free from the virus as bud-parents, has been instituted by the State Department of Agriculture, Sacramento. Growers may now obtain nursery trees budded from these registered trees.

Fawcett (see footnote 14, p. 56) describes two other bark diseases of orange trees which appear to be of a virus nature. These are called "blind pocket" and "concave gum disease." In both these troubles, the surface is depressed or sunken in certain areas on the sides of the limbs

or trunk. These areas are covered with live bark but the underlying wood is impregnated with gummy substance. In concave gum disease, gum usually oozes to the surface at certain seasons. Leaf symptoms similar to those of psorosis have been observed in both of these diseases, which may be phases or types of scaly bark.

These troubles should be treated by gouging out the discolored wood slightly beyond all visible staining.

Red Blotch, Adustiosus.—This disease occurs in storage, usually of lemons, in the cool season. It starts as reddish-brown, superficial discolorations suggesting a scald. In severe cases, one half to two thirds of the surface of a fruit is involved, with deeper color, and with collapse of the oil-bearing cells.

Rots.—The most important types of citrus fruit decay have been described under specific names. In addition to these, rotting caused by many different fungi sometimes occurs, especially in storage of lemons, cold storage, fruit in transit, and weak fruit on the tree. Many such forms of decay and the fungi which cause them are fully described in the book referred to in footnote 14, page 56.

Scaly Bark.—See "Psorosis, Scaly Bark" (p. 64).

Septoria Spot.—This spotting, caused by the fungus *Septoria citri,* usually occurs on fruit of orange, lemon, or grapefruit as small, shallow, light-brown depressions, often beginning when the fruit is green and immature. A narrow marginal ring remains green as the fruit colors. This is usually a minor trouble but seems to be increasing in importance in California and in some years causes considerable loss.

Shell Bark, Decorticosis.—This is exclusively a disease of lemons and is usually seen only on the trunks of trees of considerable age. As a rule, the Eureka variety is more susceptible than the Lisbon or Villa Franca. The outer bark dies, loosens, and peels off in longitudinal strips. New bark forms below and a tree may recover and develop the disease again several times in a cycle of four or five years. In severe cases some of the leaves and twigs may die, or the tree may merely show a slightly unhealthy look. The cause is a fungus, *Diaporthe citri,* which also causes the diseases called "melanose" (p. 62) and "stem-end rot" (p. 66).

The trunks of susceptible trees, when they are beginning to become affected with this disease, may be scraped to remove the dead bark and the surface treated with a fungicide as advised for psorosis (p. 64). After the disease is well advanced, it may not be economically profitable to treat the trees.

Sour Rot, Oöspora Rot.—This is a soft, putrid, slimy rot of citrus fruit, seen mostly in stored lemons where it spreads by contact. Old or weak fruit is most likely to be affected by this disease. It is caused by the

fungus *Oöspora citri-aurantii.* Handle lemons in storage as described for brown rot (p. 58). Frequent sorting and short storage are necessary for affected fruit.

Stem-End Rot, Phomopsis Rot.—This is a brown, leathery discoloration or firm rot of the rind of citrus fruits, usually starting from the stem end. It is a serious disease in some places but of very minor importance in California. The same fungus, *Diaporthe citri,* is the cause of melanose (p. 62) and shell bark (p. 65).

Stylar-End Rot.—This rot is a firm, light-colored collapse and decay of tissue on Persian limes, and sometimes on Mexican limes and lemons, at the tip or stylar end. Part of the loss may be avoided by picking before the fruit is too mature.

Thrips Injury.—Oranges and other citrus fruits sometimes show silvery-colored, scurfy markings, usually arranged as a ring around the fruit near the stem end and radial lines down the sides. This condition was thought to be the effect of a fungus until it was shown to be caused by a thrip, *Scirtothrips citri,* feeding on the surface of the very young fruit.

For control see Extension Circular 87, or consult the Citrus Experiment Station, Riverside, for latest information.

Valencia Rind Spot.—In certain seasons a serious spotting and pitting of mature fruits on the tree occurs, usually in late summer or fall. There is first a slight sinking of small areas in the rind without discoloration, then the spots become larger and of a dark-brown color. They are usually on the shoulder and near the stem end of the fruit. High temperature and high humidity seem to favor the trouble. The spots, nonparasitic in origin, often become infected with the anthracnose fungus, *Colletotrichum,* or the *Alternaria* fungus, which causes them to increase in size or even results in decay of the whole fruit.

Water Spot and Rot.—On the rind of mature, tree-ripe, Washington Navel oranges, spots appear which at first have a water-soaked appearance. These are mainly at the navel end, near wounds, or on the shoulder of the orange. These spots either dry out and become sunken and brown, or they may be infected with molds and form the starting point of decay, although like Valencia rind spot, water spot is nonparasitic in origin. The trouble usually develops after protracted periods of winter rains. The fruit from oil-sprayed groves is more affected than that from unsprayed groves. No means of control has been developed.

Wither Tip.—Dead spots occur in leaves, and twigs die back and are covered with pustules of the fungus. In California this follows weakness or low vitality or injury of tissue due to environmental or other causes, the associated fungus, *Colletotrichum gloeosporioides,* being secondary.

The fungus is very abundant most of the time in dead twigs and leaves of citrus trees killed by any cause. The dying-back and spotting stops as soon as vigorous growth is established. On the fruit the same fungus causes the disease called "anthracnose" (p. 56).

CURRANT

Blister Rust.—This disease is present in the eastern United States and Canada, the Great Lakes region, in Idaho, Washington, and Oregon, and has recently been found in the extreme northern part of California. Small, yellow rust pustules with dark-brown, hairlike projections are formed in the summer on the underside of the leaves. If badly affected, the leaves drop off. This is the so-called "alternate form" of the very important rust of the white pine and sugar pine, caused by *Cronartium ribicola*. The fungus cannot infect one pine tree by spores coming directly from another; pines become infected only by spores from currant or gooseberry.

The cultivated black currant, *Ribes nigrum,* is one of the most susceptible species, and its culture is prohibited by law in California. Of the native species of *Ribes,* the most susceptible to blister rust are *R. Roezlii, R. nevadense,* and *R. cruentum.* An effort is being made to exterminate these as well as other native species of currant and gooseberry in the vicinity of susceptible pines, in order to forestall the establishment of blister rust in this state.

Any indication of a true rust on currants should be reported immediately to the nearest agricultural official.

Cane Blight.—Portions of the canes or branches of affected bushes die, sometimes with a wilting and withering of the leaves. Spore pustules of the fungus, *Botryosphaeria ribis* and other fungi, break out on the dead bark. Diseases of this type are sometimes seen on currants in California but are not often serious. Affected canes should be cut out and burned.

Leaf Spot.—This disease causes dead spots on the leaves and, if severe, may defoliate the bush. In places with rainy summers, there is sometimes considerable damage from diseases of this type, which are caused by various fungi, but here the dry season usually keeps them in check.

Bushes may be sprayed with bordeaux mixture 5–5–50 (p. 156) if leaf spot should develop to any serious extent. This, however, would disfigure ripe fruit.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Infected bushes die with a rotting of the roots and a characteristic white fungus "felt" between the wood and bark. The disease continues spreading from bush to

bush. The currant is rather susceptible to this common fruit-tree disease, caused by *Armillaria mellea*.

If oak-fungus spots appear in a currant plantation, all the affected bushes and the next adjacent healthy ones should be dug out and burned, care being taken to get out the roots as completely as possible. For further information, see page 144.

Powdery Mildew.—A white mildew fungus, *Sphaerotheca mors-uvae*, disfigures the leaves and fruit of infected bushes.

The bushes should be dusted with dry sulfur at the first appearance of mildew. In places where the weather is cool and cloudy, a liquid spray may be preferable, using 1 per cent liquid lime-sulfur with the addition of 6 pounds of wettable sulfur (p. 160) to 100 gallons. This will also keep down red spider and help to control leaf spot and other fungus diseases if present.

DATE[15]

Blacknose.—Small cracks (checks) appear in the epidermis of affected green dates about the time the fruit reaches its maximum size. In fruit of the Deglet Noor variety, the distal end, or "nose," is chiefly affected. Where severe checking occurs, this portion becomes dark and shriveled and matures earlier than normal. Blacknose appears to be a physiological disease, but the contributing factors are poorly understood. Moderate thinning and aeration of the fruit bunch reduce injury.

Black Scorch.—The mold which causes black scorch, *Thielaviopsis paradoxa*, is most destructive on young leaves and spathes, on which it produces a black, irregular decay. The fungus is spread by means of spores which infect through wounds during periods of high relative humidity. Affected palms usually recover. Sanitation and prevention of spread by destruction of affected parts are the only control measures known.

Brown Spot.—Small, opaque, or translucent spots may appear on nearly ripe fruit when infections occur after periods of rain. The lesions may enlarge rapidly to form blisters, and the fruit becomes worthless. The effect may be due to *Alternaria citri* or to *Helminthosporium molle*. Protection of fruit bunches from rain, and aeration by the insertion of wire rings reduce loss.

Calyx-End Rot.—Two fungus molds, *Aspergillus niger* and *Citromyces ramosus*, cause a softening of the connecting tissue below the calyx of ripening fruit. Affected dates shatter easily. To prevent the trouble, protect fruit from rain.

[15] For further information about date diseases, see: Fawcett, H. S., and L. J. Klotz. Diseases of the date palm, *Phoenix dactylifera*. California Agr. Exp. Sta. Bul. 522:1–47. 43 figs. 1932. For later publications, consult the Division of Plant Pathology, Citrus Experiment Station, Riverside, California.

Decline Disease.—In date palms affected with decline disease, growth is retarded, the roots decay, and the leaves die prematurely; a few spathes may appear, but the fruit is worthless. The disease occurs in areas of soil which tend to enlarge from year to year, affecting principally palms of the Deglet Noor variety. It is caused by two related toadstool fungi, *Omphalia pigmentata* and *O. tralucida.*

In setting out a new garden, care should be taken to select thrifty offshoots from healthy trees. Infected soil may be disinfected[16] with carbon disulfide (p. 161). Certain varieties show resistance.

Diplodia Disease.—A fungus, *Diplodia phoenicum,* causes decay and premature death of leaves. Spores are produced in great abundance and cause infection through wounds. Lack of vigor in the palm is the chief contributing factor. The disease is often fatal to transplanted offshoots. Remove, when possible, all diseased tissue and apply copper-lime dust (p. 157) or a solution of 1 per cent copper sulfate.

Leaf Smut.—In this disease, small, dark, cup-shaped pustules, filled with powdery spores of the fungus, *Graphiola phoenicis,* appear on mature leaves, which become unsightly and dry prematurely. Both ornamental and fruit-bearing dates are affected. Moist atmosphere favors the disease; palms grown in the commercial areas are not affected owing to the relatively dry climate.

Affected leaves should be removed and destroyed. This may be followed by spraying with 3–3–50 bordeaux mixture (p. 156) or, to avoid spray residue, a solution of copper acetate, 3 ounces to 50 gallons of water. A spreader (p. 161) may be added to this.

Control of Diseases of Dates.—Date growing in California is a new and highly specialized industry. Studies by state and federal investigators on diseases and many other problems attending the production of this unusual crop are continually yielding new information. For latest advice concerning date production, address the Citrus Experiment Station, Riverside.

DEWBERRY

See "Blackberry and Raspberry" (p. 44)

FIG[17]

Black Spot, Mildew.—Dark-colored spots often develop on the sides of ripe figs, especially those of the Kadota variety. This condition comes on after summer rains or periods of high humidity, which sometimes

[16] See: Bliss, D. E. Soil disinfection as a means of combating decline disease in date palms. Date Growers' Institute, 12th ann. rept. (Coachella Valley), p. 13–16. 1938.

[17] For further information on fig diseases, see: Smith, Ralph E., and H. N. Hansen. Fruit spoilage diseases of figs. California Agr. Exp. Sta. Bul. 506:1–84. 47 figs. 1931.

occur in August or September in the San Joaquin Valley. If there is a good deal of moisture, considerable spotting may appear on the figs while they are still on the tree, especially if the tops are very dense. Besides this, much fruit becomes affected while in boxes in transit to the cannery. The cause of this trouble is a common mold fungus, a species of *Alternaria,* the growth of which is favored by high humidity.

Figs picked for canning should be kept as dry as possible and should not remain in lug boxes any longer than necessary.

Canker.—In figs affected by this disease, rough, more or less oval, dead areas or cankers develop around pruning cuts or the stubs of dead branches or on the sides of limbs injured by frost or sunburn. This fungus disease, caused by *Phomopsis cinerescens,* is most common on neglected or injured trees.

Affected branches should be removed and destroyed, and the cuts and tools disinfected as in pear-blight work (p. 159). Trees which have been badly neglected or abandoned are likely to harbor the disease and should be done away with.

Endosepsis.—The ripe figs are sometimes spoiled by a soft, yellowish-brown, nonfermenting rotting of the pulp, usually starting inside the eye. On the outside, around the eye and extending down the sides, there develops a pink or purple water-soaked area which becomes slightly sunken in drying. Only caprified figs are affected by endosepsis but these may be of any variety, so long as they have been entered by the pollen-bearing blastophaga wasp. The spores of the fungus, *Fusarium moniliforme,* are carried by this insect from one crop of caprifigs to another and thence to the edible fruit.

Endosepsis is prevented by: (1) keeping caprifigs and blastophagas away from the vicinity of figs like Black Mission, Adriatic, and Kadota, which do not require caprification; (2) "cleanup" of caprifigs used for pollinizing Calimyrna or any other caprified varieties. This is done by carefully removing all the mamme figs from the trees just before the insects emerge. For caprifying the profichi crop, these figs are split in two and the pieces soaked for 15 minutes in a solution of Semesan 1 ounce to 4 gallons of water. The cut figs should be gently squeezed with the hands beneath the surface of the solution to improve penetration and remove air bubbles. After draining and drying, the pieces are placed in the caprifig trees in the usual manner and, if the dipping is effective, the profichi crop will be free from the endosepsis fungus. The cut mamme figs should be removed from the trees after 4 or 5 days and redipped or destroyed. Further details of this process will be found in Bulletin 506 (see footnote 17, p. 69) or may be obtained from the county farm advisor's office in any fig-growing county. If all caprifig trees in the state could

be concentrated in a few plantings well isolated from commercial fig trees, the production of profichi free from endosepsis would be greatly facilitated. Noncaprified varieties would also be protected from contamination.

Limb Blight.—Stems which have been partially killed or weakened by freezing, die back beyond the frosted portion, and one or the other of two fungi—*Botrytis cinerea* and *Sclerotinia sclerotiorum*—develops on the affected parts. *Botrytis* is a dirty-gray mold, and *S. sclerotiorum* is the cottony-mold fungus described elsewhere in this circular (p. 136).

Affected stems should be cut back well below frozen or diseased tissue. Moldy, sticktight figs should be removed.

Mold.—The interior flesh of the ripe or dried fig may be discolored and destroyed by a growth of green, brown, black, white, or yellow mold of various fungi, especially *Hormodendrum, Aspergillus,* and *Cladosporium.* Many spores of these fungi are carried into the figs by minute insects like thrips and mites, beginning in early summer when the fruit is unripe and small.

Control of thrips and mites by dusting the trees with sulfur during the summer has been claimed to reduce the amount of mold. Good sanitation of the orchard, as recommended under "Souring" (p. 73), is very advisable. Experiments are now being made in spraying the trees to prevent mold by destroying mites. Promising results have been obtained from the use of 1–100 lime-sulfur solution (p. 160) just before the buds open in spring. The spray will be improved by the addition of rosin soap (p. 161). To prepare this spray, first add 1 gallon of rosin soap to 98 gallons of water, then pour in 1 gallon of lime-sulfur.

Mosaic.—Affected leaves are mottled, with yellow, translucent areas between the normal green portions. Young terminal leaves in spring are deformed and almost white. This condition is universal in fig trees in California but does not seem to injure them. It does not occur in seedlings, however, and has the appearance of resulting from a mild virus disease.

Nematode Root Canker.—When attacked by the meadow nematode, *Anguillulina pratensis,* the trees are stunted, loose in the ground, and often tip over. At the crown and on the surface of the roots, dark-colored spots appear (fig. 29), the bark dies and rots away and under these spots irregular cavities develop in the wood. Finally the main roots rot off, and deep, rough cankers are formed at the crown. The parasite is described under "Apple" on page 22.

In the few cases where this disease has been found in California, it appeared to have been contracted by trees in the nursery rather than by spreading in the orchard. After affected trees are destroyed with as

much of the roots as possible, no further trouble has been observed, either in the remaining orchard trees or in replants.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The fig is one of the few roots which has considerable resistance to oak root fungus, *Armillaria mellea*. It is by no means immune, however, for trees are occasionally seen which show the typical white, felty, fan-shaped fungus growth between the bark and wood near the surface of the ground. The fig and other resistant trees are more likely to be attacked in ground

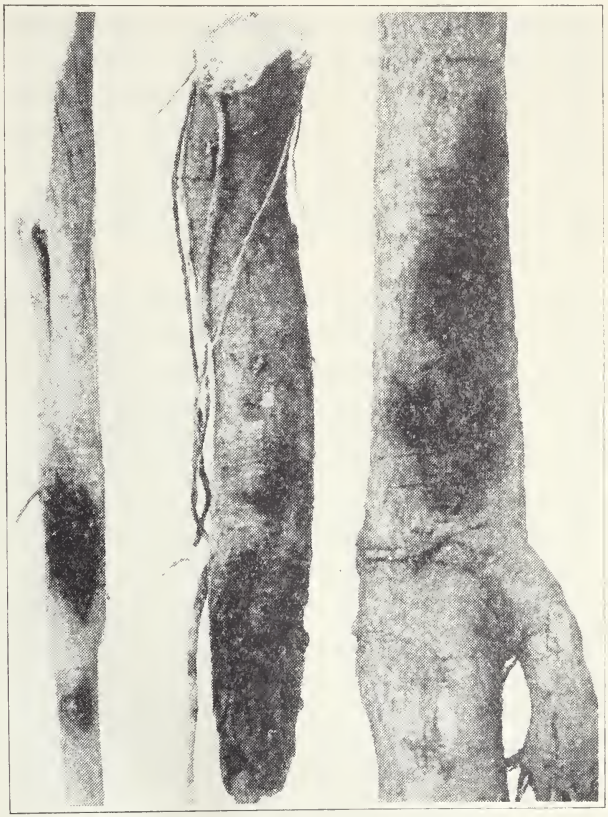

Fig. 29.—Nematode canker on fig roots.

where there is a large amount of diseased roots, such as recently cleared or partially cleared river-bottom woodland. See page 144.

Root-Knot Nematode.—This is the common garden nematode *Heterodera marioni* (p. 142), to which the fig root is a very congenial host. No doubt most of the fig trees on the lighter soils in California have this pest on the roots, where the usual galls or swellings are formed. Badly affected trees are more or less stunted, but in general the fig tree is very tolerant of this parasite.

Care should be taken not to plant nurseries of fig trees on soil infested with nematodes, or to plant in the orchard trees that show galls on the roots.

Scab, Thrips Effect.—The surface of the fruit, especially in the Black Mission variety, is often disfigured by light-colored, scabby patches. This has been attributed to thrips working on the fruit when it was young. Similar trouble occurs in oranges and prunes.

No control of this trouble has been attempted. For suggestions regarding control of thrips, see Extension Circular 87.

Smut.—Smut is one form of mold in which the inside of the fig is filled with a black, dusty mass of spores of the fungus *Aspergillus niger*. Smut is spread to a large extent by the dried-fruit beetle, *Carpophilus hemipterus,* which enters the fruit after the eyes open and the figs begin to ripen. Smaller insects also introduce some smut spores earlier in the development of the fruit.

Sanitation as recommended for the prevention of souring should tend to reduce smut. Spraying to control mold (p. 71) may also help.

Souring.—Sometimes in humid, cool, early fall weather, great quantities of ripe figs on the tree are spoiled by a wet, gassy, dripping, acid fermentation of the pulp. Souring, caused by yeasts and bacteria, is spread mainly by insects, especially the dried-fruit beetle, *Carpophilus hemipterus,* which breeds in decaying fruit or vegetables and enters figs on the tree after the eyes open. The yeasts which cause souring abound in such material, and are carried unwittingly by the beetles to ripening figs. The pomace or vinegar fly, *Drosophila ampelophila,* is another scavenger insect which breeds abundantly in sour figs and helps to hasten the spoilage of the fruit. Cool, moist weather does not cause souring but accelerates it by producing favorable conditions for the growth of yeasts.

Sanitation is of great value in the control of souring. Waste fruit or vegetable material should not be allowed to exist in the vicinity of fig orchards. This applies to windfall fruit of all kinds: decaying melons, citrus fruits, tomatoes, grape pomace, cull piles, garbage, and everything of like sort in which these beetles breed. Methods for trapping the beetles have been developed by the Office of Dried-Fruit Insect Investigations of the United States Department of Agriculture at Fresno.

Splitting.—Figs of certain varieties, especially the Adriatic and Calimyrna, have a tendency to split completely open at maturity, starting from the eye, especially in humid, cool weather. The splitting itself is nonparasitic, but when it happens, the figs usually mold or sour and are completely ruined. This trouble appears to be due entirely to climatic causes and cannot be controlled.

GOOSEBERRY

Blister Rust.—This disease, caused by *Cronartium ribicola,* is the so-called "alternate stage" of the dreaded blister rust of white pine, which is referred to under "Currant" (p. 67).

Bud Nematode.—In certain districts of California near the coast, where there is much fog and where gooseberries (an uncommon crop in this state) are grown, the young leaves are sometimes blighted and killed by colonies of hundreds of these microscopic worms, *Aphelenchoides fragariae.* They develop around the buds in surface films of moisture.

Affected bushes should be destroyed. In starting new plantations, clean stock from another locality should be used and must be planted in new soil. Never propagate by cuttings from affected plants or any from the vicinity of affected ones.

Powdery Mildew.—This typical, white, mildew fungus *Sphaerotheca mors-uvae,* often affects the fruit and leaves of the cultivated gooseberry very disastrously and is difficult to control in places where the climate is cool and moist. For control, see "Powdery Mildew" under "Currant" (p. 68).

GRAPE

Anthracnose.—This is a very common disease in most parts of the world but is not known in California, presumably on account of the rainless summers. It is caused by a fungus, *Elsinoe ampelina.* Small, sunken, dark spots with light centers appear on the leaves, canes, and berries, and produce characteristic "bird's eye" spots on the fruit.

For control of anthracnose, and most of the following fungus diseases, it is necessary to remove all diseased canes in pruning, plow the vineyard in spring to turn under disease-bearing refuse, and spray several times with bordeaux mixture. The first spraying is made with a 4–4–50 mixture (p. 156) soon after the growth starts, and is followed by applications every 2 weeks until the fruit is three quarters grown. After that, if rainy weather occurs, a clear solution must be used, like copper acetate (p. 158).

Black Knot, Crown Gall.—Rough galls form on canes and trunks aboveground, especially on frost cracks. In very severe cases, the vines may be stunted. The cause of this bacterial disease, *Phytomonas tumefaciens,* is the same as that of crown gall in fruit trees.

In some vines, the affected portion can be cut off and new growth will take its place. Avoid cutting into the knots with pruning shears and harvesting knives or shears because the disease may be spread in this manner. See under "Almond" (p. 7).

Black Measles.—See "Esca, Spanish Measles, Black Measles" (p. 77).

Black Rot.—In this disease, caused by the fungus *Guignardia Bidwellii*, brown or black spots appear on the leaves and canes. The berries rot, blacken, dry up, and become hard, wrinkled mummies which cling to the vine all winter. This is the most destructive disease of grapes east of the Rocky Mountains but has never been seen in California. Frequent spraying as for anthracnose is necessary to control black rot.

Bunch Mold.—A gray or black mold often develops in the clusters of ripe grapes and spoils many of the bunches (fig. 30). This is caused by various fungi, especially *Botrytis cinerea* and *Aspergillus niger*. Fruit in transit is sometimes attacked by similar fungi. No practical method

Fig. 30.—Bunch mold of grapes.

has been found of preventing the development of mold in bunches of grapes on the vine.

California Vine Disease, Pierce's Disease.—In this disease, apparently caused by a virus, the vines gradually weaken, the growth becomes short, dieback of the canes develops, and the whole vine soon dies for no obvious reason. In some varieties there is a yellowing between the veins of the leaves and the fruit withers and dries in summer. The disease spreads in the vineyard. This trouble, which has become rather serious in certain districts during the last seven years, resembles the disease which caused widespread destruction of vines in southern California[18] and in the Santa Clara Valley almost fifty years ago.

Affected vines should be removed when the first symptoms are seen. Replants in the same places do not seem to contract the disease.

Coulure, Shelling.—In certain varieties, notably Muscat, many of the flowers fail to set fruit, which results in the production of poorly filled bunches. This may be due in part to poor pollination or fruit setting

[18] Pierce, Newton B. The California vine disease. U. S. Dept. Agr. Div. Veg. Path. Bul. 2:1–222. 25 pl. 1892.

and partly to attacks of mildew in the blossom. Little-leaf (p. 77) may also cause shelling of the clusters in some varieties.

Thorough control of mildew and cross-pollination of varieties which require it will help to prevent this trouble. Long pruning, with flower-cluster thinning 3 to 4 weeks before blooming, is sometimes advisable when this trouble is serious. Muscat vines treated by swabbing with zinc sulfate as for little-leaf sometimes set fuller clusters of berries even when no symptoms of little-leaf are shown.

Dead Arm.—Leaves, leaf stems, canes, and flower-cluster stems affected by this disease, caused by the fungus *Cryptosporella viticola,* develop small, angular spots with yellowish margins and dark centers. Frequently they grow together and form rather large, brown areas with numerous dark spots scattered about in them. Many of the diseased areas split, which results in open, diamond-shaped cankers. In some cases the diseased areas are so numerous that the shoots are severely stunted and some of them may be killed. Generally the more vigorous shoots which have become infected continue growth, and later in the summer the diseased portion will appear only at the base of the cane. In the latter part of September or October, a large number of the diseased areas resume growth. Those on the cluster stems advance into the fruits and cause bunch rotting. Those on the canes frequently enlarge and kill a number of buds, and in some cases the fungus grows back into the wood of the arm, where it continues growth and gradually kills the arm, from which the disease obtains its name.

The only control measure for this disease is to cut out and burn all infected wood.

Downy Mildew, Peronospora.—This disease attacks leaves, young fruit, and shoots of the vine, or, in other words, all the succulent parts. On the leaves, yellow translucent spots appear, on the lower side of which frostlike patches of white mildew are visible in humid weather. On the shoots, the affected portions, especially the tips, become slightly swollen and covered with a downy growth of the fungus *Plasmopara viticola.* The berries become more or less mildewed, then turn brown, rot, and fall off. This is one of the most important grape diseases in most parts of the world but until very recently has never been observed in California. During the last few years, a fungus which appears to be identical with this has been found in considerable abundance on the native wild grape, *Vitis californica.* Even in nearby vineyards, however, cultivated grapevines were not affected. There may be a distinct strain of the fungus on wild grape.

Where downy mildew is troublesome, it is necessary to spray as described for anthracnose (p. 74).

Erinose, Blister Mite.—The upper side of an affected leaf is raised in round, hollow, or blisterlike galls, covered on the underside with a felty growth of leaf hairs. This is caused by the presence of colonies of microscopic mites, *Eriophyes vitis*. Dusting with sulfur to control powdery mildew also disposes of this disease.

Esca, Spanish Measles, Black Measles.—On one or more canes of an affected vine the leaves become yellow and spotted, wither, and fall in midsummer. The green grapes are marked with small, dark-colored spots. Finally the vine may die, sometimes suddenly, but usually after a period of gradual decline extending over several years. The cause has not been definitely established but is said to be a wood-decay fungus which enters through pruning cuts and destroys the wood in the trunk or large arms.

Esca can be controlled by spraying or swabbing the vines in winter, at least 3 weeks after pruning but before the buds break, with a solution of 4 pounds of sodium arsenite in 100 gallons of water, taking special care to wet thoroughly all old wounds. This mixture is very poisonous to animal life and injurious to green vegetation, so should be handled with caution.

Little-Leaf.—Vines in certain areas in the vineyard, or single vines here and there, that show a weak growth and very small leaves and berries are an indication of little-leaf, a nutritional disturbance. (See p. 141.)

Brushing (swabbing) the wounds and other parts of the tops of the vines annually with zinc sulfate, 2 pounds to a gallon of water, as soon as they are pruned gives excellent results in the first spring after the treatment, provided the pruning and treatment are done in December or January, before the vines bleed. If treatment by this method is not done at that time, it is better to treat by driving zinc or zinc-coated iron into the trunks than to wait another year.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Affected vines die in certain spots in the vineyard, and these areas gradually enlarge, more and more vines being killed each year. The characteristic white, fan-shaped fungus growth of *Armillaria mellea* is found between the wood and bark of the main roots. See page 144 for full description. Grapes cannot be grown on land infested with this fungus.

Phylloxera.—The vines affected with phylloxera become weakened, stunted, and die, the trouble beginning in certain spots in the vineyard. This disease is caused by a minute yellow louse, *Phylloxera vitifoliae*, which lives on the roots of affected vines and causes characteristic swellings.

The use of phylloxera-resistant roots is the only successful means of

control in infested soils. Great care should be taken not to introduce the pest on nursery stock into new plantings. According to Extension Circular 87, cuttings or rootings may be disinfected before planting by dipping in hot water, 122° Fahrenheit, for 5 minutes.

Powdery Mildew, Oidium.[19]—The leaves, canes, and young fruit affected with oidium show white patches of the fungus *Uncinula necator* which may eventually cover most of the surface and cause distortion of growth. Late in the season the color of the affected areas darkens, especially on the canes, and these spots become dark-brown or black after the white mildew has disappeared. This is the commonest vine disease in California.

Treatment for powdery mildew of grape consists in keeping all parts likely to be attacked covered with a very light coating of sulfur dust. A heavy coating may cause "sulfur burn" at temperatures over 100° Fahrenheit. The first application should be made when new green shoots are 6 or 8 inches long; a second when they average 15 or 18 inches in length; and a third when they are 2 or 3 feet long. With the late-maturing grapes, or in cool or moist localities, it is usually advisable to make a fourth application of sulfur when the berries are as large as peas, and sometimes a fifth just before they are two-thirds grown. In these later treatments, the sulfur should be dusted on the fruit and in the centers of the vines.

Red Leaf.—The leaves of certain varieties of grape sometimes turn bright red in midsummer. Various factors bring this about. One of the most serious forms of the disease is caused by a red spider, *Tetranychus pacificus,* and may be distinguished by the absence of red color in the larger veins of the leaves when viewed by transmitted light. Another common form (cause unknown) has the red color throughout the leaf, including the larger veins. The red-spider-induced red leaf causes the leaves to drop prematurely and thereby reduces the size and quality of the fruit. Early defoliation is often followed by a secondary growth in late season in which a few small terminal leaves without the red color are produced.

For information on the control of the red-spider red-leaf disease, inquiry should be directed to the Division of Entomology, College of Agriculture, Davis.

Root-Knot Nematode.—Badly affected vines become stunted and show the typical nematode galls or swellings on the roots (p. 142). The grape root is a favorite host of this, the common root knot, or garden, nematode, *Heterodera marioni.*

[19] For further details, see: Jacob, H. E. Powdery mildew of the grape and its control in California. California Agr. Ext. Cir. 31:1–17. 8 figs. 1934.

Grapevines on ordinary roots should not be planted in soil badly infested with nematodes. Information regarding resistant roots can be obtained from the Division of Viticulture, College of Agriculture, Davis.

GRAPEFRUIT

See "Citrus Fruits" (p. 56)

LEMON

See "Citrus Fruits" (p. 56)

LIME

See "Citrus Fruits" (p. 56)

LOGAN BLACKBERRY, LOGANBERRY

See "Blackberry and Raspberry" (p. 44)

LOQUAT

Fire Blight, Blight.—Affected blossom clusters, leaves, twigs, or large limbs die rather suddenly, the foliage withering and hanging to the

Fig. 31.—Loquat scab.

tree. This is the same bacterial disease as fire blight of pear, apple, and other related hosts. Affected branches should be cut out well below the blighted part and the tools and cuts disinfected. See "Fire Blight, Blight" under "Pear" (p. 101).

Scab.—Dark, velvety fungus spots sometimes develop on young fruit and leaves (fig. 31) and cause the fruits to be more or less deformed. This is caused by *Fusicladium eriobotryae* and is similar to pear and apple scab, caused by a closely related fungus.

Scab of loquats is not usually important enough to warrant any treatment. Spraying with bordeaux mixture (p. 156) as is done for pear scab might be effective, with the first application just before the blossoms open and another after the fruit is set.

NECTARINE

See "Peach and Nectarine" (p. 84)

OLIVE

Dry Rot, Shrivel Tip, Monkey Face, Sheep Nose, Bitter Pit.—Dry spots sometimes develop in the flesh of the fruit, usually toward the blossom end, which becomes shriveled and shrunken in spots or on one side

Fig. 32.—Dry rot, or sheep nose, of olive.

(fig. 32). The cause of this is not known, but it seems to be nonparasitic and has the appearance of being related to bitter pit of apples, black end of pears, and blossom-end rot of tomatoes. No method of control is known.

Exanthema, Dieback.—In this disease, the new shoots die at the tips

Fig. 33.—Exanthema of olive, showing abnormal growth and dieback of lateral shoots.

and lateral twigs are forced out which repeat the same process (fig. 33) so that the tree comes to have a very bushy, shabby appearance (fig. 34). Corky pustules develop on the bark. This is similar to diseases of the same

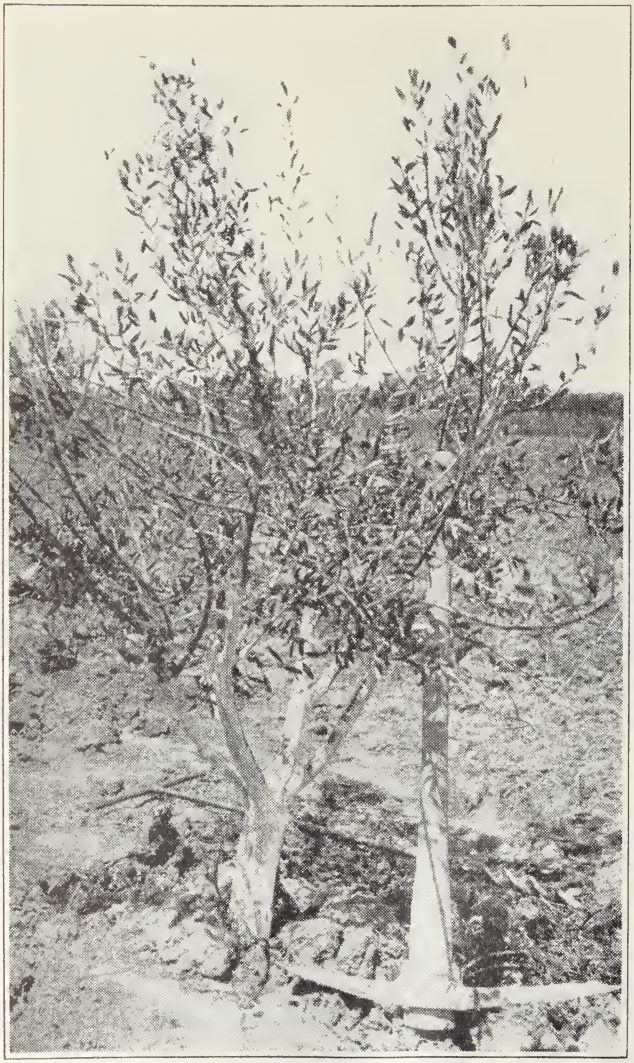

Fig. 34.—Young olive tree affected by exanthema.

name described under "Apple," "Citrus," "Pear," and "Plum, Prune."

Affected trees should be sprayed with bordeaux mixture (p. 156) or may be treated by digging into the soil at the base about 1 to 5 pounds of copper sulfate crystals, according to the size of the tree.

Knot, Tuberculosis.[20]—Rough, roundish galls or swellings (fig. 35), from very small up to several inches in diameter, frequently develop on twigs, branches, trunks, roots, leaves, or fruit pedicels, mostly at leaf scars or wounds. The causal agent is a bacterial organism, *Phytomonas Savastanoi.* Some of the worst infections develop on frost cracks. The

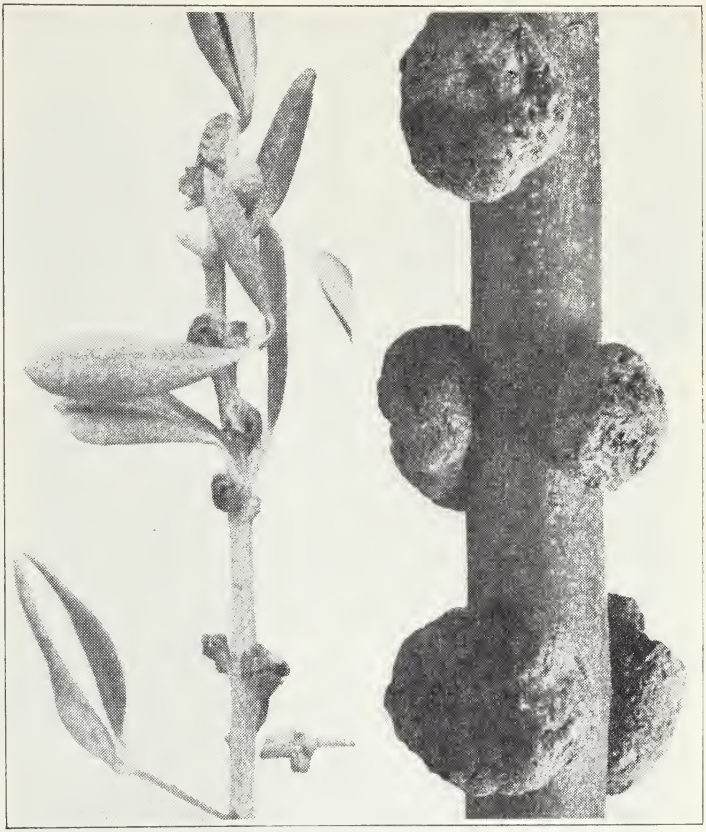

Fig. 35.—Olive-knot disease.

Manzanillo is the most susceptible variety of those commonly grown in California.

The best control is obtained by cutting out the galls very carefully at their first appearance and disinfecting cuts and tools with 1–1,000 corrosive sublimate (p. 159) or as in pear-blight treatment (p. 102). Infected twigs or small branches should be cut off entirely. Larger wood galls may be cut out with some success, but extensive, rough gall tissue

[20] For more complete information, see: Wilson, Edward E. The olive knot disease: its inception, development, and control. Hilgardia 9(4):231–64. 10 figs. 1935. (Obtainable free of charge as long as the supply lasts from the California Agricultural Experiment Station.)

is difficult to eradicate. Such cuts may be treated with corrosive sublimate and then covered with bordeaux paste (p. 157). Trees which have been worked on should be carefully watched in order to check any reappearance of the disease. In order to prevent new infections, the trees should be thoroughly sprayed with 4–4–50 bordeaux mixture (p. 156) early in November. For the best results where infection is abundant, it may be necessary to spray again in December and a third time in March.

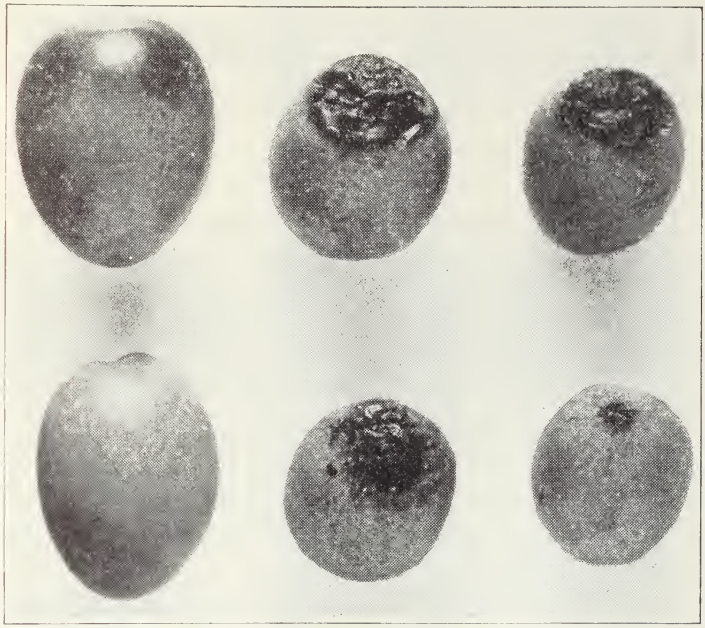

Fig. 36.—Soft nose of Sevillano olive.

Care should be taken not to plant infected nursery trees or to bring into a clean orchard any picking boxes, tools, or other equipment or materials which may have come from an orchard where the disease is present.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Trees occasionally die from a rotting of the roots and crown caused by the fungus *Armillaria mellea,* which lives in the soil in old roots of native trees. The fungus may be seen as fan-shaped, felty, white sheets between the bark and wood and also in the form of clusters of large tan-colored toadstools which come up around the bases of badly affected or dead trees in early winter. See page 144 for further description. The olive is only moderately susceptible to this disease, but affected trees succumb in time.

Surgical treatment as described on page 147 is successful in prolonging the life of olive trees attacked by oak root fungus, if the disease is not too far advanced.

Ring Spot, Peacock Spot.—This disease, which is due to a fungus, *Cycloconium oleaginum,* causes blackish, more or less concentric rings on the leaves of olives, especially those that are weakened or old and about to drop. It is not serious enough to require treatment.

Soft Nose, Blue Nose.—The disease referred to by this name is known mainly on the Sevillano variety. Ripe or nearly ripe fruit turns to a bluish color in a large area at the blossom end. The spot at first looks like a bruise but soon turns dark and shrivels (fig. 36) and ruins the fruit for pickling. It is worse on young trees than on older ones. This trouble, which is probably nonparasitic, cannot be controlled by any known method but occurs only in occasional years.

ORANGE

See "Citrus Fruits" (p. 56)

PEACH AND NECTARINE[21]

Bacterial Canker, Bacterial Gummosis.—In trees affected with bacterial canker, the bark dies in elongated areas or cankers, the trouble often starting from wounds or pruning cuts. Gum usually exudes from such cankers, which frequently girdle and kill single limbs or even whole trees. In other cases, the affected bark is brown, moist, and sour-smelling, and forms no gum. This type of the disease is often called "sour sap" and sometimes attacks the young fruiting wood (fig. 37), especially in the Phillips Cling variety. As a rule, peaches are less subject to this disease than plums or cherries (p. 109 and 49), in which it is caused by the same organism, *Phytomonas cerasi.*

No effective control is known for bacterial gummosis, although, if it is not too far advanced, considerable benefit may be derived from cutting away all the diseased bark and disinfecting as in pear-blight work (p. 102). Bordeaux paste (p. 157) should then be used to cover the cuts.

Blackheart, Verticilliosis.—Some of the young branches drop their leaves and die with a dark discoloration running in streaks through the wood. This fungus disease, caused by *Verticillium albo-atrum,* is more abundant in apricots than in peaches. Many other plants are affected; see general discussion (p. 151). If affected branches are cut off, the tree will usually recover.

Blight, Shot-Hole Disease.[22]—In this disease, caused by a fungus *Coryneum Beijerinckii,* small, circular, reddish spots appear in early spring on the fruiting twigs at or between the buds. These develop into

[21] For further information on peach culture, with descriptions and illustrations of diseases, see: Philp, Guy L., and Luther D. Davis. Peach and nectarine growing in California. California Agr. Ext. Cir. 98:1–62. 22 figs. 1936.

[22] For further information on this disease, see: Wilson, E. E. The shot-hole disease of stone-fruit trees. California Agr. Exp. Sta. Bul. 608:1–40. 13 figs. 1937.

elongated, sunken, brown cankers and exude copious amounts of gum in rainy weather. Many buds and much of the fruiting wood is killed before growth starts, in years when the disease is bad. When late rains occur in spring, the leaves and even the fruit may be peppered with small, round, dead spots.

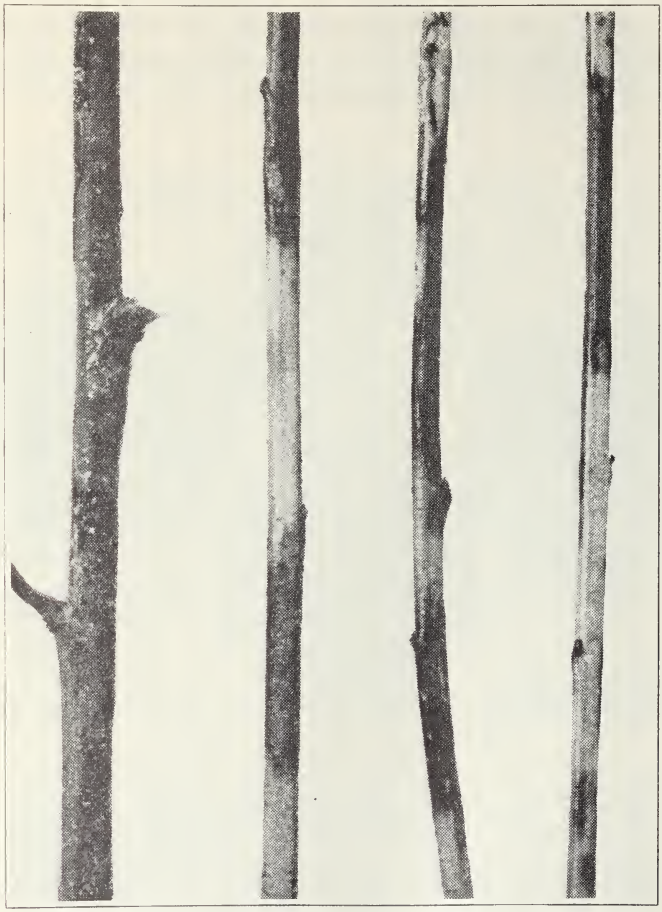

Fig. 37.—Peach twigs (Phillips Cling variety) spotted and killed by bacterial-gummosis organism.

This fungus disease is easily controlled by spraying with 5–5–50 bordeaux mixture (p. 156) in the fall. Spraying should be done about November 15 (table 4), before heavy rains have fallen. A better coverage is obtained after the leaves are off and after pruning, but spraying should not be delayed beyond the middle of November on this account.

Brown Rot.—The first sign of the disease in spring is the withered, brown blossoms covered by grayish, powdery, spore masses. Young

leaves and twigs may also be killed. As the fruit ripens, it may be attacked and develop a brown, medium-soft rot with gray spore growth on the surface (fig. 14, p. 30). Some of these fruits dry on the tree and hang on all winter in a mummified condition. At the time the blossom buds begin to swell in the spring, a new crop of spores is produced on these mummies and also on dead twigs which were killed by the fungus the previous year. These spores infect the new blossoms and twigs. Either of two fungi—*Sclerotinia fructicola* and *S. laxa*—may be the cause.

All the old mummified fruits should be removed and all blighted twigs

TABLE 4

SPRAY PROGRAM FOR PEACH DISEASES

Time	Spray and strength	Disease	Remarks
Oct. 15–Nov. 1	Lime-sulfur 6–100*	Rust	For periods when rust is very abundant
Nov. 15–Dec. 1	Bordeaux 5–5–50†	Blight Leaf curl	The most important spray for blight and usually effective for leaf curl
Just before buds swell	Bordeaux 5–5–50 or lime-sulfur 10–100	Leaf curl	Too late for blight and too early for brown rot
Pink-bud stage	Bordeaux 5–5–50‡ or lime-sulfur 8–100	Brown rot	Best time for brown rot; some control of mildew and twig borer is obtained if lime-sulfur is used
At intervals in spring and early summer	Lime-sulfur and wettable sulfur 1–6–100 or sulfur dust	Mildew Rust Brown rot	Start when disease appears and repeat every 10–14 days if necessary

* For directions see page 160.
† For directions see page 156.
‡ Add 1½ pounds basic lead arsenate for twig borer. See Extension Circular 87.

pruned out before the trees start blooming. This will do away with the most abundant source of infection. To prevent the new blossom infection, the trees should be sprayed with 5–5–50 bordeaux mixture (p. 156) in the "pink bud" stage, or just when the ends of the petals are projecting from the bud scales (table 4). Or lime-sulfur solution 8–100 (p. 160) may be used at this time for both brown rot and peach twig borer. This is a little late to control leaf curl, but the spray may do some good for late infections with blight and for mildew. If arsenic is preferred for twig borer, 3 pounds of basic lead arsenate may be added to 100 gallons of 5–5–50 bordeaux for the pink-bud spray. No satisfactory control treatment is known for brown rot of the fruit in California. Sulfur dust applied at intervals during the summer may be tried. This will also help to control mildew and rust (table 4). Canning varieties should not be sulfured after about 4 weeks before harvest.

Crinkle, Dimples, White Spot.—The surface of affected peaches when nearly full-grown is rough and marked with slight, roundish elevations and depressions, the latter being of a lighter color (fig. 38). In cross section the depressions are seen to be due to a narrow strip of dry tissue just beneath the surface. This trouble has appeared during certain seasons in the Tuscan variety, and is apparently due to some climatic or soil effect.

Crown Gall.—Badly affected trees are stunted and of a pale color. Rough, woody, roundish enlargements or galls of various sizes are found

Fig. 38.—Peaches showing "crinkle."

on the roots, crowns, and often on trunks and limbs. The trouble is due to *Phytomonas tumefaciens*.

See page 7 under "Almond," for full discussion of crown gall. The peach root is very susceptible to this bacterial disease. In new plantings much care should be taken to avoid infected nursery stock.

Delayed Foliation, Dormosis.—In certain seasons, growth fails to start at the proper time in spring and the trees remain bare and apparently dormant until well into the summer. The leaves and new shoots may eventually develop in a weak, straggling manner, or the top may die back. Walnuts, apples, and other fruit trees are similarly affected. This condition occurs in the warmer sections of the state, in seasons following warm, frostless winters when there has not been enough cold weather to break the rest period of trees and stimulate new growth.

Peaches of the peento type and their hybrids, such as the Babcock and C. O. Smith varieties, are not affected in this manner.

Fruit Gumming, Split Pit.[23]—Clear, transparent gum breaks out on the surface of the young fruit and hardens into good-sized masses. Effects of this nature may be produced by injuries, insect punctures, *Coryneum* (peach blight) infections, and other causes, but the most typical disease occurs mainly in the Phillips Cling peach and seems to be due to

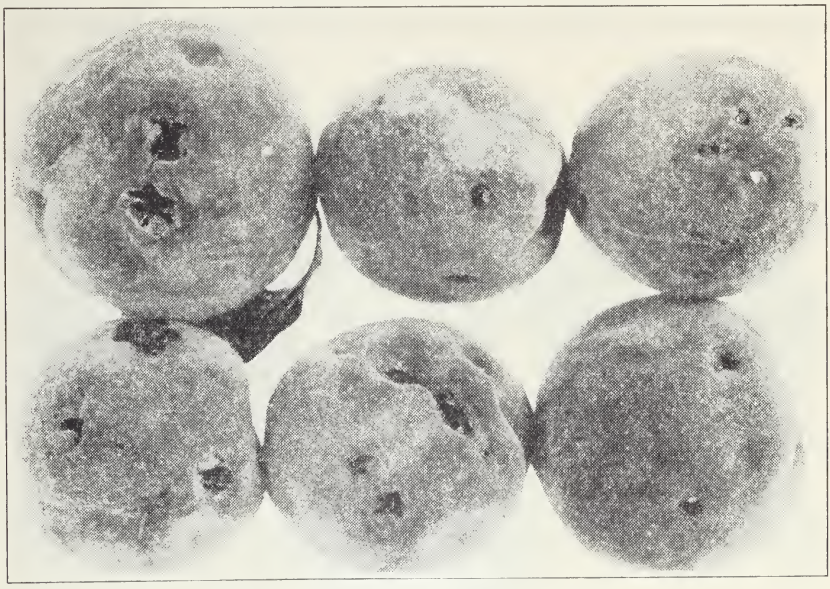

Fig. 39.—Peaches showing hail injury.

a physiological characteristic or weakness peculiar to this variety. This form of fruit gumming appears very early, before the pit hardens. It is more abundant when the crop is light. Affected peaches usually have the condition known as "split pit," in which the stone is more or less cracked and the embryo degenerates into a gummy mass.

To prevent fruit gumming of Phillips Cling peaches, in years of a light crop, thinning should be delayed fully 5 weeks after the pit begins to harden. In years of heavy crop, it should be done at least 10 days earlier than this.

Hail Injury.—Peaches sometimes are much deformed, with numerous scars and pits (fig. 39) and masses of clear, hard gum on the surface. This is the effect of hail injury when the fruit was young.

Internal Browning.—Occasionally in certain years or places, some-

[23] For further information, see: Davis, Luther D. Delayed thinning as an aid in controlling the gumming of the Phillips Cling peach. California Agr. Exp. Sta. Cir. 341:1–14. 11 figs. 1937.

times in one part of the orchard, the ripe fruit shows a dark discoloration in the flesh, visible through the skin. In peaches picked for canning, this darkening becomes more pronounced after the fruit has stood in boxes for a few hours, as in shipment to the cannery. The trouble seems to be connected with some soil condition.

Leaf Curl.—In affected trees, the leaves in spring develop red, much-crinkled, thickened distortions, covered on the surface with a white, mealy bloom. The ends of the shoots may become deformed in the same manner, and sometimes the fruit shows the disease in red, warty protuberances (fig. 40). Leaves affected by this fungus, *Taphrina deformans*, drop off, and the tree develops another crop of leaves which are not dis-

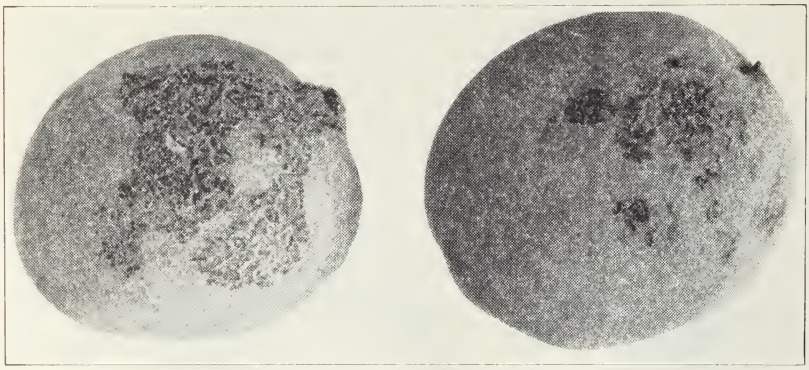

Fig. 40.—Peach leaf curl fungus on fruit.

eased. The loss of the first leaves, however, is very injurious to the fruit crop.

Peach leaf curl can be entirely prevented by spraying the trees thoroughly with 5–5–50 bordeaux mixture (p. 156) or 1–10 lime-sulfur (p. 160) just before the buds begin to swell in early spring. In orchards affected by other diseases, this time is too late for control of blight and too early for brown rot, twig borer, and mildew (table 4, p. 86). Leaf curl cannot be controlled if the spray is delayed until the proper time for destroying the last three. But it can be fairly well handled by the late fall spray used for blight, so that growers are inclined to make the November 15 application for the control of both blight and leaf curl, as indicated in table 4. This is usually satisfactory, especially in orchards which are thoroughly sprayed every year.

Little-Leaf.—This disease gives the tree a yellow, frizzled look, with pale, narrow leaves and scanty crops of small fruit. The trouble, which affects many other kinds of trees (p. 141), is most pronounced on peaches in light, sandy soils in the San Joaquin Valley. It is nonparasitic.

Spraying with zinc sulfate solution in the dormant season as recom-

mended for apple (p. 21), gives good control. This also controls blight (*Coryneum*) if applied before December 15, but does not prevent leaf curl.

Little Peach.—In this virus disease, the foliage is yellow and the fruit very small and late in ripening. The disease spreads rapidly through an orchard and kills the trees within about four years. Little peach has been most serious in Michigan and other northern states and has never been known in California. Prompt eradication of affected trees is the only known method of control.

Fig. 41.—Rosette disease of Muir peach: *A*, on leaves; *B*, on blossoms.

Mosaic.[24]—Foliation in spring is retarded on trees affected with mosaic, and the young leaves are yellow, dwarfed, and deformed. Twig growth is shortened or "bunchy," flowers may be mottled in color, and the fruit roughened and deformed. These symptoms are not displayed uniformly by all varieties of peaches. As a rule, those of the J. H. Hale and Elberta type are the most severely affected, while the clingstone canning varieties are more tolerant. The disease, caused by a virus, is spread by budding or grafting and by some unknown natural method, possibly insects, from tree to tree. An orchard may be ruined within a few years after mosaic is introduced.

There is no known remedy or treatment for this disease except to destroy affected trees as soon as they show mosaic. Efforts are being made

[24] For further information, see: Hutchins, Lee M., E. W. Bodine, and H. H. Thornberry. Peach mosaic, its identification and control. U. S. Dept. Agr. Cir. 427:1–48. 32 figs. 1937.

to eradicate the disease in California and, in the meantime, to hold it within the present affected area.

Muir Rosette.—In trees of the Muir variety, the growth of fruit spurs and twigs is sometimes shortened and the leaves (fig. 41, *A*), blossoms (fig. 41, *B*), and fruit (fig. 42) borne in dense clusters or rosettes. The

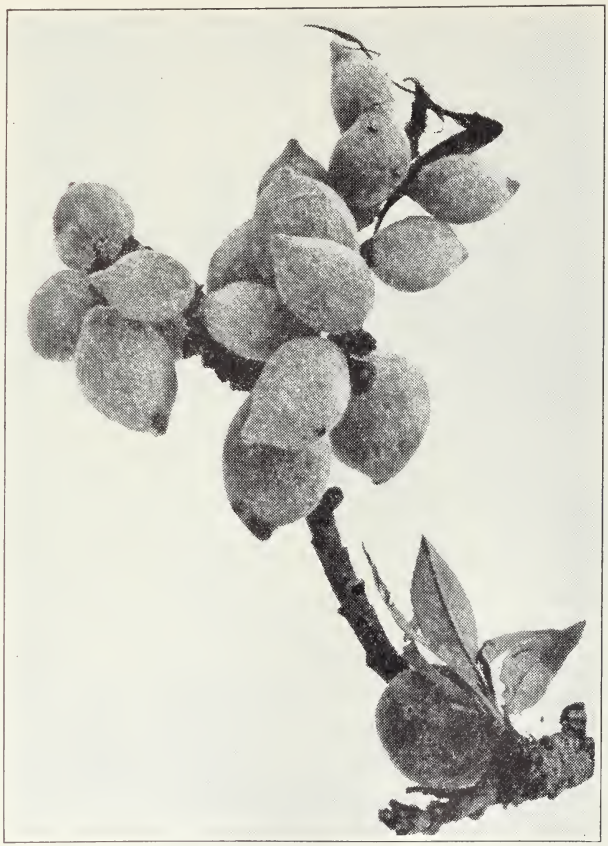

Fig. 42.—Rosette disease on fruit of Muir peach.

leaves are darker green than normal, the tree stunted, and the fruit very small. This condition somewhat suggests the disease called "phony peach" or other peach virus diseases of the eastern states. Thus far it has been seen only in a few old orchards of the Muir variety and it is not at all serious.

It would be wise to destroy affected trees and be careful not to take buds for propagation from any which show this condition.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The trees in an affected area of the orchard become yellow, sickly, and finally die, or may

collapse suddenly without showing much preliminary distress, the leaves and fruit withering in midsummer. The fungus, *Armillaria mellea,* attacks the larger roots and crown of the tree and forms its characteristic, white, felty, fan-shaped sheets of mycelium between the bark and wood. Clusters of tan-colored toadstools come up around the base of dead trees after the first fall rains. Trees succumb to the disease in gradually en-

Fig. 43.—Peach powdery mildew: *A,* on leaves; *B,* on fruit.

larging circles in the orchard, usually starting in spots where native trees once stood.

No resistant root for peach trees is available at present. The best chance seems to be to double-work on a resistant myrobalan, if one is found. (See p. 144.) Soil treatment with carbon disulfide shows promise for eradicating *Armillaria* (p. 149).

Phony Disease.—This very serious disease has thus far been confined to the southeastern United States, extending west to Texas and north to Illinois. It is not known in California. The loss in Georgia alone has been more than a million trees. Symptoms are shortened internodes, a large number of lateral twigs, and flattened, abnormally dark-green leaves, which give the appearance of compact, dense growth with luxuriant foliage. Young trees are decidedly dwarfed. The fruit is much reduced in size and quantity, highly colored but of poor flavor, and commercially worthless. After several years of the disease, the trees are usually ragged, with much dying-back of twigs and branches, but the leaves are greener than those of normal trees. The virus or causative factor is confined to the roots, and the trouble is not transmitted in buds or grafts from an affected tree. But healthy trees or scions grafted to the roots of phony trees, or root-grafted with pieces of affected roots, develop the disease. In nature, phony peach spreads rapidly from tree to tree and orchard to orchard by some unknown method.

No method of control for phony peach has been found except by systematic orchard inspection and prompt eradication of affected trees. The shipment of peach nursery stock into California from parts of the country affected with this and other serious diseases is prohibited by law.

Powdery Mildew.—The young leaves, twigs, and fruit (fig. 43) show a covering or patches of white fungus growth, and more or less distortion. Later the mildewed fruit blotches turn brown and become scabby and malformed. Powdery mildew of peach is due to *Sphaerotheca pannosa* var. *persicae.*

Timely applications of sulfur, either liquid or dry, effectually prevent

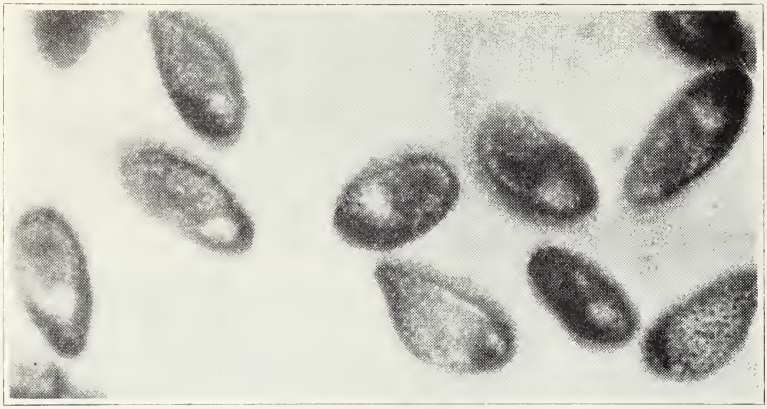

Fig. 44.—Spores of peach-rust fungus, enlarged about 800 times.

this disease, which usually starts soon after the fruit is set. Spraying with lime-sulfur for control of brown rot or twig borer (see "Brown Rot," p. 85 and table 4) may be of some value in mildew prevention. In places where mildew is bad, this may be followed as soon as the fruit is set with lime-sulfur 1–100 to which is added 6 pounds of wettable sulfur (p. 160). This spray may be repeated every 10 to 14 days as long as it seems necessary, or the trees may be dusted with dry sulfur as for brown rot. Such applications of sulfur will help to prevent rust and brown rot of the fruit.

Root-Knot Nematode.—Badly affected trees are stunted and the finer roots are covered with small, roundish galls or swellings. The peach root is very susceptible to this common pest, *Heterodera marioni,* an eelworm which flourishes in the sandy type of soil often devoted to this fruit.

Tests by the Division of Pomology have shown that the apricot root is less susceptible than the peach to nematode attacks. Even more valuable is the discovery of certain peach types which are resistant. More specific

information can be obtained from the Division of Pomology, College of Agriculture, Davis. For general discussion of the root-knot nematode, see page 142.

Rosette.—This is a virus disease of the southeastern United States and has never been known in California. The new leaves of affected trees are compressed into tight clusters or rosettes; they become yellow and

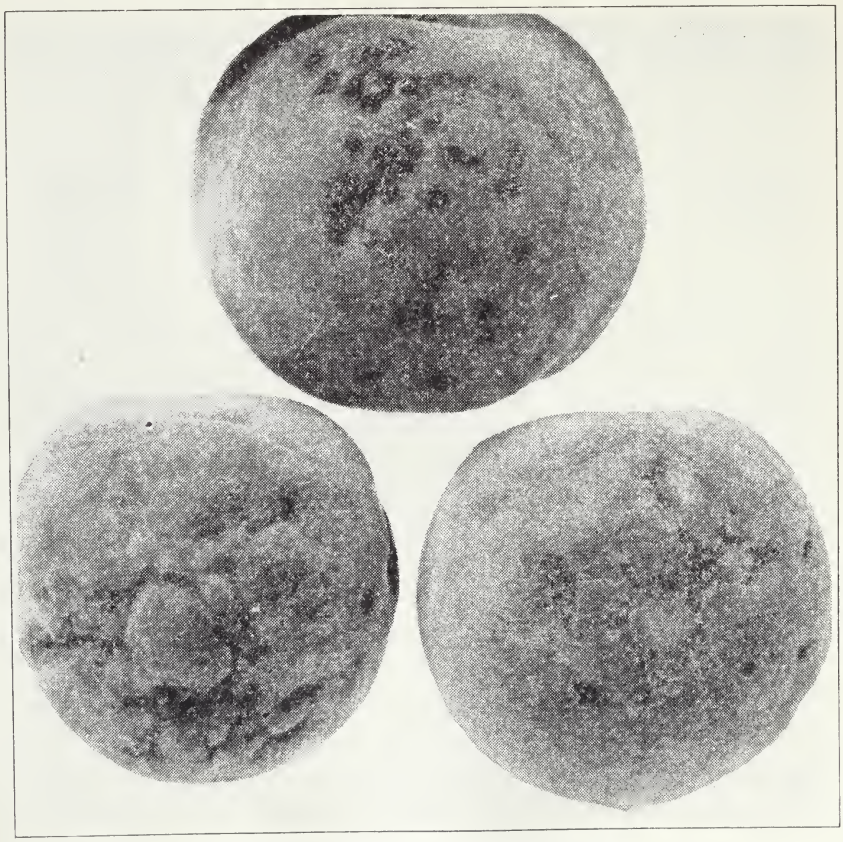

Fig. 45.—Effect of peach rust on fruit.

rolled, spotted with red, and fall prematurely. The trees bear no fruit and usually die within a year after the trouble appears. No control method is known except as in "Yellows" (p. 96).

Rust.—Yellow, angular spots appear on the leaves, with powdery pustules of red spores (fig. 44) on the underside. Infection may also occur on the fruit and cause round, sunken, green spots, which disfigure and ruin the peaches for canning (fig. 45). On the twigs, oval blisters appear before the leaves unfold in spring. This disease has occasionally caused severe defoliation and fruit injury to canning peaches, especially

midsummer varieties, but this is not a frequent occurrence. The same fungus, *Tranzschelia pruni-spinosae,* attacks apricots, almonds, and prunes.

Rust alone is best controlled by spraying trees with lime-sulfur solution, 6 gallons to 100 gallons of water in early fall (October 15 to November 1). If the disease starts in the spring and threatens to become abundant on leaves and fruit, it may be checked by spraying with the same material, 1 gallon to 100 gallons of water at intervals during early summer. In ordinary seasons, the fall spray with bordeaux mixture recommended for control of peach blight (p. 85), combined with use of dilute lime-sulfur and either wettable or dry sulfur in spring for mildew and brown rot (table 4), is sufficient to keep rust in check.

Scab.—This is one of the worst diseases of peaches in the eastern part of the country, but is extremely rare in California, probably on account of the rainless summers. Circular, superficial, black spots up to ¼ inch in diameter appear on the fruit, especially toward the stem end. These spots, caused by the fungus *Cladosporium carpophilum,* run together and cause cracking or deformity of the peach. The leaves and young twigs are also attacked. Spraying or sulfuring several times in early summer is necessary to control scab in regions where the disease is prevalent.

Sims Spot.—This trouble, which has occurred abundantly the past three years, is characterized first by a flattening of the fruit on each side of the blossom end. Section through the fruit at this point shows dry, more or less pithy spots or cavities, frequently located at a considerable distance beneath the surface. Later the spots increase in size, and from the outside appear dark brown or black. Secondary rots often follow, but numerous cultures of the early stages have been made without finding a fungus or bacterium. The trouble develops during midsummer, usually after hot weather. This may be a trouble similar in cause to Kelsey spot of plums. Although the Sims variety is apparently somewhat more susceptible than others, the trouble has been found on Gaume, Johnson, Palora, and Hauss varieties. No method of prevention is known.

Sour Sap.—Peach trees or some of their branches frequently fail to start in spring or suddenly die after starting, with a fermentation and discoloration of the bark and more or less gummosis. This condition is often caused by bacterial canker (p. 84) or by phytophthora canker (p. 8), and is sometimes the effect of too much soil moisture as described under "Almond," page 11.

Split Pit.—In this disease, the pit cracks and breaks up irregularly in the young fruit. The embryo usually is aborted and gummy. Fruit gumming (see p. 88) frequently occurs. Delayed thinning as recommended for fruit gumming may tend to reduce the tendency to split pit.

Thrips Effect.—Peaches, especially in the foothill districts, sometimes show rough, irregular, shallow markings or scars on the surface, deforming the fruit and somewhat suggesting pear scab. This is the effect of thrips, *Frankliniella californica* or *F. tritici*, which fed on the fruit when it was young. See Extension Circular 87.

Wood Decay.—The peach tree is very susceptible to decay and breaking down of the branches. This is caused by various bracket fungi like *Polystictus versicolor* (fig. 80) and usually follows sunburn, borers, or poor pruning. See general discussion on page 152.

Yellows.—Peach yellows is a very serious disease in the northeastern United States but has never been known in California. The affected tree becomes weak and sickly and develops wiry, spindling, yellow sprouts and suckers on the main limbs. The leaves are rolled and yellow, the fruit premature in ripening, misshaped, highly colored, and with red streaks in the flesh. Affected trees die within a few years. The disease, caused by a virus, is spread by budding or grafting and by an insect, the leafhopper *Macropis trimaculata*.

Prompt and complete eradication of all affected trees is the only known method of control. Entrance of nursery stock from affected districts into California is prohibited.

PEAR

Black End.—In this disease, the surface of the nearly mature pears becomes hard and smooth about the blossom end. The sepal lobes darken,

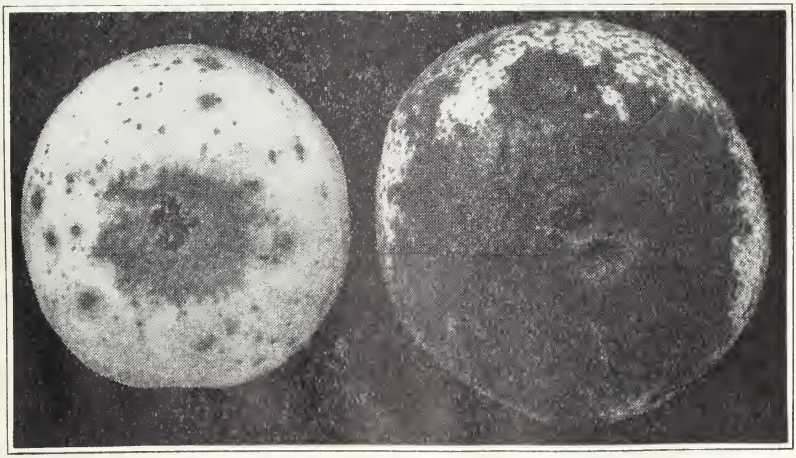

Fig. 46.—Black end of pear.

small black spots appear in the end tissue, and many of these spread and coalesce until the whole end of the pear is black and dry (fig. 46). The

Bartlett is the principal variety affected, and the trouble appears chiefly on trees upon roots of the Japanese (*Pyrus serotina*) species or its hybrids. Black end of pears seems very similar to blossom-end rot of tomatoes and some of the troubles of olives.

The Japanese root for pears is undesirable on account of this trouble.

Fig. 47.—Blast of pear on blossoms.

Trees already on this root which are persistently bad with black end may be cured by inarching with French pear (*Pyrus communis*) seedlings and cutting off the connection with the original Japanese root after the inarches are well established. This is not very practical, however, on orchard trees. It is probably better to replace such trees with new ones on *P. communis* stocks. Those having resistance to fire blight (p. 105) are most desirable.

Blast.—This bacterial disease may kill the dormant buds and occa-

sionally spreads at blooming time; in extreme cases it destroys a large proportion of the blossoms. Blast of blossoms (fig. 47) is particularly bad on the Winter Nelis variety. Unlike fire blight, which the disease resembles in some respects, blast does not usually kill the twig beyond the blossom spur and does not produce bacterial exudate. Infection may take

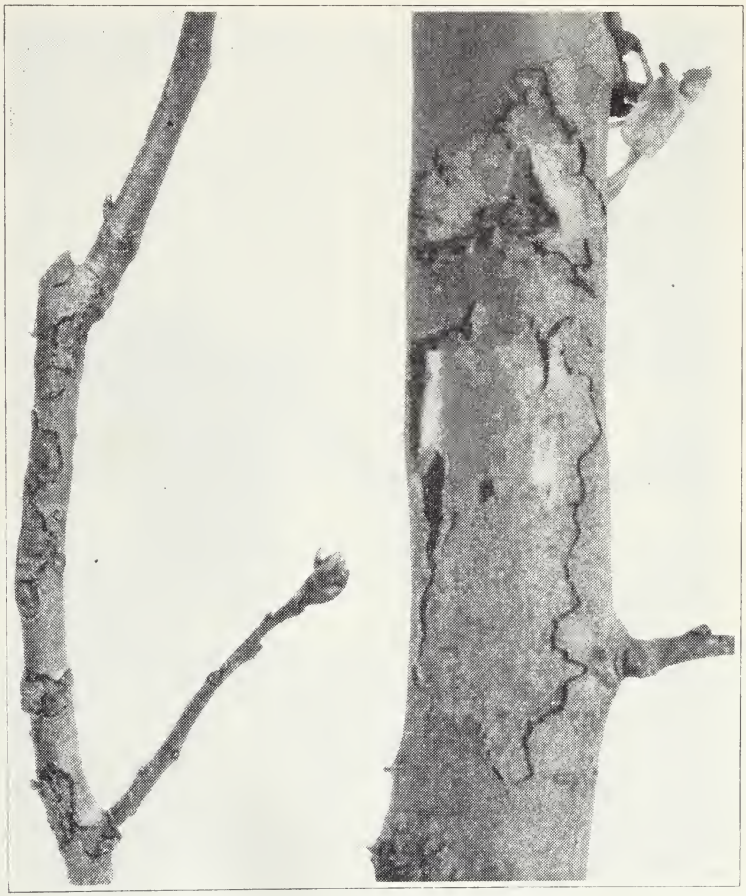

Fig. 48.—Blast of pear on twig and branch.

place in the dormant season through wounds, including those on cluster bases; sometimes cankers of considerable size (fig. 48) are produced, but they are more superficial than blight cankers. The affected bark turns light brown to tan in color and eventually sloughs off, often without killing the inner bark. Blast of pear is caused by *Phytomonas syringae*—essentially the same organism as that which causes blight of lilac in some places, blast of pear and apple in the eastern states, blast and black pit of citrus, and bacterial gummosis of stone fruits in California.

No adequate control is known. Keeping the trees in good vigor may lessen the injury, at least in Bartlett. Probably the removal of cankers on the pear and severely affected stone fruits in the vicinity will be helpful.

Blight.—See "Fire Blight" (p. 101).

Blister-Mite Effect.—A blister mite, *Eriophyes pyri,* causes yellowish, blisterlike spots or swellings on young pear leaves and fruits (fig. 49). These later turn dark, and the foliage and fruit is more or less de-

Fig. 49.—Blister-mite effect on pear leaves and fruit; often mistaken for a fungus disease.

formed. The same mite also causes bud blight, discussed later. This trouble is properly an entomological subject, but it is often mistaken for a fungus disease. See Extension Circular 87.

Brown Rot.—Pears from the coast districts in boxes or storage sometimes show a fast-spreading, brownish rot, with a dusty, light-gray fungus, *Sclerotinia fructicola* or *S. laxa,* on the surface, just as in apricots and peaches. Blossom blight also occurs (fig. 50) especially in the early-blooming Madeleine variety. This effect is easily mistaken for that of fire blight. The disease is not common enough in pears to warrant any attempt at control.

Bud Blight.—Affected fruit buds turn brown early in the winter and frequently flare open. During the winter the buds are dry and drop readily when touched. At pruning time many of the buds fall off. At bloom-

ing time many of the cluster buds fail to open at all, others open with only one or two blossoms and the bloom is weak, often fails to set, and frequently drops. The cause of this condition is not detectable to ordi-

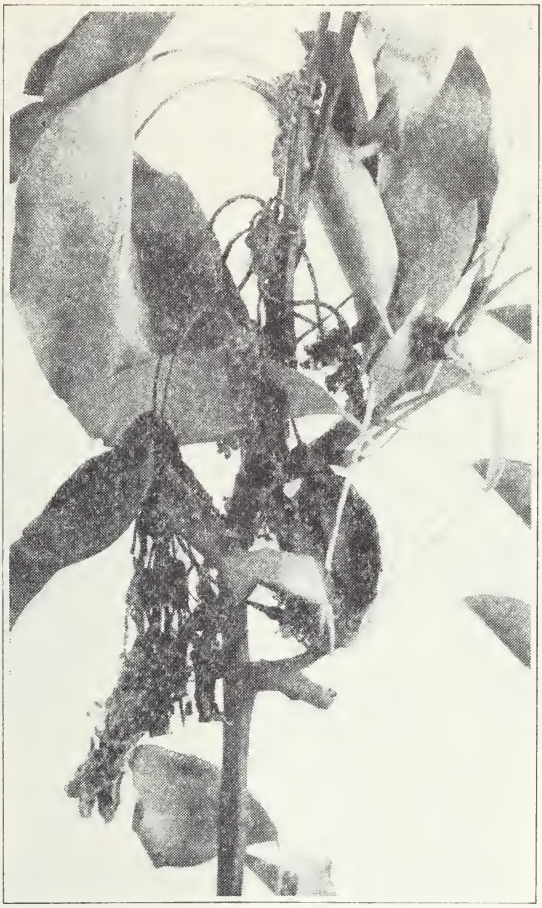

Fig. 50.—Pear blossoms killed by brown-rot fungus.

nary observation but is believed to be the ordinary pear leaf blister mite, *Eriophyes pyri,* as described in Extension Circular 87 and Circular 324.[25]

Chlorosis, Lime-induced Chlorosis.—In this disease, the leaves, either on certain limbs or the whole tree, are bright yellow and the trees more or less stunted and unfruitful. In pronounced cases of chlorosis in certain soil areas, many different kinds of plants often show the trouble, although other crops may flourish and do well. The trouble referred to here is due to an excess of lime in the soil, which interferes with the ab-

[25] Borden, Arthur D. The pear leaf blister mite as a cause of fruit-bud injury. California Agr. Exp. Sta. Cir. 324:1–8. 3 figs. 1932. (Out of print.)

sorption and utilization of iron by the plant. For further discussion see page 135.

Crown Gall.—Rough, roundish swellings develop on the main roots or at the base of the trunk attacked by crown gall. The pear is not much troubled with this common bacterial disease of most fruit trees, caused by *Phytomonas tumefaciens*. Galls are seldom seen on pear nursery stock, but all affected trees should be discarded.

Exanthema, Dieback.—The trees affected by exanthema, have a dwarfed, yellowish, unhealthy look. The terminal buds die, which forces out lateral twigs, and these in turn die back. This produces a bushy and stunted growth (see figs. 33 and 34, showing the same disease on olive, pp. 80 and 81). The leaves turn brown at the margins.

This trouble has been cured by injecting 5 to 10 grams (according to the size of the tree) of powdered copper sulfate (bluestone) into holes bored 2 to 3 inches deep in the base of the trunk and spaced at 3- to 4-inch intervals around the circumference. The method is the same as that described for the application of ferrous sulfate in treatment of chlorosis on page 136. Care must be taken not to let the copper sulfate come in contact with the cambium. The holes should be plugged with grafting wax or some similar material. In light types of soil, 1 to 5 pounds of copper sulfate spaded into the soil around the base of the tree has cured exanthema. Good results have also been obtained by spraying the leaves with 5–5–50 bordeaux mixture (p. 156).

Fire Blight, Blight.[20]—Infected shoots and blossoms become watery, darken rapidly, then wilt and die (fig. 51). Usually small, milky to brownish beads of gum appear on blighted parts. The dried, black, blighted leaves and blossoms stick tightly to the twigs. Infections on trunks, roots, and branches (cankers) commonly appear around the bases of blighted shoots or blossom spurs or at points where the bark has been cut or broken. Large branches or even whole trees may be girdled and killed. The interior of diseased bark is at first watery, then reddish mottled, and later brown to black. The disease may advance for some distance in the outer bark before the inner bark is killed. A number of plants related to the pear are also affected by blight, particularly the apple, cotoneaster, hawthorn, loquat, photinia, pyracantha, and quince. The blight organism, *Phytomonas amylovora*, may overwinter on any of the plants mentioned above, but by far the most common spring source is the pear tree itself. The germ is carried from holdover cankers to blossoms either by splashing rain or by such insects as flies and ants. The principal spread of blight in the orchard is from blossom to blossom by

[20] For further information, see: Thomas, H. E., and P. A. Ark. Fire blight of pears and related fruits. California Agr. Exp. Sta. Bul. 586:1–43. 7 figs. 1934.

insects. The germ may be spread among the young shoots by such sucking insects as aphids and the tarnished plant bug.

Control is tedious and difficult and best attempted only by an operator who is experienced and painstaking. Before the blossoms open, all overwintering cankers or twig infections must be removed from the orchard and other susceptible trees (see list in preceding paragraph) in the

Fig. 51.—Pear twig killed by fire blight.

vicinity. After new infections appear, the trees should be inspected at least once a week as long as blight is found. Infected blossom spurs, shoots, and small branches are best cut off some distance below the blighted tissue, for the bacteria, in tender tissue, are often several inches in advance of any visible symptoms. Cutting through the blighted part rather than beyond it is probably the most common cause of failure in control work. On vigorous trees, the cuts should not be made less than 12 inches below the nearest discolored inner bark. The tools and wounds should be treated with a disinfectant. For this purpose, the following formula is recommended: corrosive sublimate (mercuric chloride) 1

ounce, mercuric cyanide 1 ounce, distilled water 3½ gallons, glycerine ½ gallon. This solution is poisonous to animals.

Cankers may be treated in any of three ways. In all cases the treatment should extend several inches beyond the visible margins of the cankers.

1. A zinc chloride solution[27] is brushed or poured onto the surface of

Fig. 52.—Frost ring on young pears.

the bark. The bark should be thoroughly wet, and with rough bark it is desirable to remove the outer scales before the application is made. The most satisfactory strength of solution should be determined by trial in the individual orchard. The prospective user should consult Extension Circular 20 or 45 (now out of print) if a copy is available.[28] This method

[27] Zinc chloride solutions are composed of zinc chloride dissolved in a *solvent* consisting of 7 pints of denatured alcohol, 2 pints of water, and 3 ounces of hydrochloric acid, making approximately 9 pints of solvent. It must be prepared in glass or enamelware and stored in tightly corked bottles. The solution is poisonous to animals.

9 pounds of zinc chloride in 9 pints of solvent makes a 52 per cent solution.

6 pounds of zinc chloride in 9 pints of solvent makes a 43 per cent solution.

4 pounds of zinc chloride in 9 pints of solvent makes a 33 per cent solution.

The solutions may also be prepared by first dissolving the zinc chloride in the 2 pints of water by boiling, then adding the acid, and lastly pouring this mixture into the denatured alcohol.

Another method of preparing the weaker solutions is to dilute the stronger solution with the solvent or with denatured alcohol.

[28] Day, L. H. Pear blight in California. California Agr. Ext. Cir. 20:1–40. 17 figs. 1928. (Out of print.)

Day, L. H. Zinc chloride treatment for pear blight cankers. California Agr. Ext. Cir. 45:1–13. 1930. (Out of print.)

These may be consulted at many city and county libraries in California that have the Experiment Station publications on file.

may be used to treat rapidly and effectively the numerous small cankers which develop on trunks and branches in severe outbreaks of blight.

2. The method known as "scarification" consists in shaving off the affected outer bark, after which the exposed inner bark and wood are treated with the mercuric disinfectant given above. This method is par-

Fig. 53.—Phytophthora canker of pear.

ticularly applicable to cankers which are extensive in area but not yet deep-seated.

3. The method often called "scraping" is similar to the preceding except that the affected bark is removed entirely down to the wood. This method is preferred by many workers for dealing with large cankers in fall or winter.

Any practice, such as light pruning, light watering, or growing an intercrop, that reduces the vigor of the tree growth will diminish somewhat the severity of the disease.

The most promising resistant stock for top-grafting at present seems to be Old Home trunk on French root or, if obtainable, on its own root.

Frost Ring.—Young pears sometimes show a roughened or russety band around the blossom-end half, often with longitudinal cracks in the surface (fig. 52). The cause of this condition, which suggests insect or

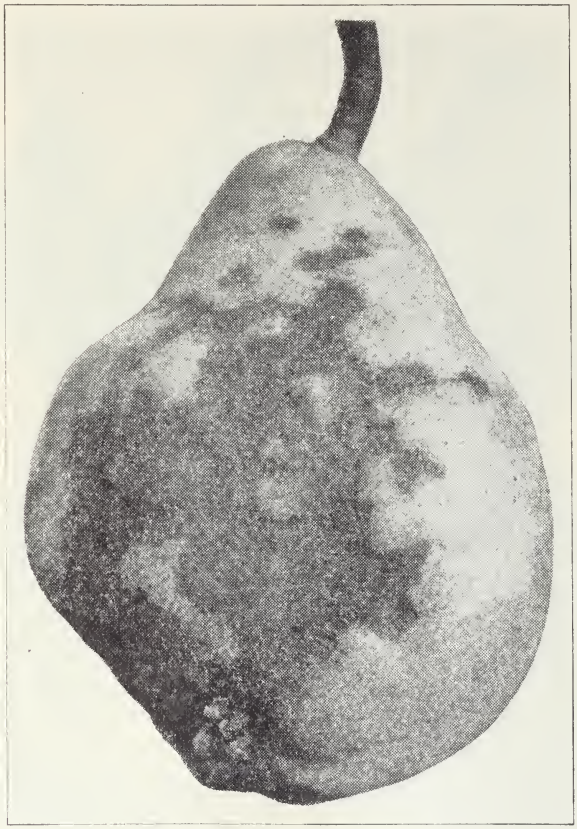

Fig. 54.—Pear-scab effect.

fungus attack, was long a mystery, but it is now known to be the result of frost injury to the very young fruit in the blossom.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The French pear root (*Pyrus communis*) is one of the most resistant to oak root fungus, *Armillaria mellea,* which is very destructive to most fruit and other kinds of trees and shrubs by attacking the roots. Although not absolutely immune, the pear on this root may be planted with comparative security in infested soil. *P. serotina* and *P. ussuriensis* are more susceptible to *Armillaria* than *P. communis;* the quince root is more susceptible than any of the pears. Pear trees on French root which contract

the disease have usually been weakened by gophers, crown gall, or some other injurious influence.

Phytophthora Canker, Pythiacystis Canker.—On the trunks of heeled-in nursery trees, oval-shaped, dark-colored, dead spots sometimes appear on the smooth green bark (fig. 53). These spots, in wet weather and if the trees are covered with soil, may extend to several inches in length and may girdle and ruin the stock. If such trees are planted, the cankers stop growing, the fungus, a species of *Phytophthora,* dies out

Fig. 55.—Pear stigmonose, exterior view.

in them and, if not too badly injured, the tree sends out growth below the lowest point where it is girdled or from the uninjured sides.

Trees affected with this trouble will be more or less crippled in the manner suggested in the preceding sentence but may eventually recover, so that the grower may use his own judgment whether or not to plant them. In nurseries where this disease is serious (almond and peach trees are also sometimes affected), care should be taken when heeling in stock to cover only the roots with soil. In districts of heavy winter rainfall, some nurseries carry the stock in covered buildings or basements and cover the roots with shavings or "shingle tow" instead of soil.

Powdery Mildew.—Young fruit sometimes becomes covered with typical, white, powdery mildew. This dries down and leaves a hard, brown, scabby area on the pear. The fungus, a species of *Podosphaera,* has been observed particularly on the Comice variety in foggy places or seasons; it is not general.

If control is necessary, use sulfur sprays as advised for powdery mildew of apples (p. 22).

Rust.—Affected leaves are somewhat swollen and show pale-yellow rust spores in little pits on the underside. The fungus, *Gymnosporangium libocedri,* has another stage on incense cedar which is much more common in California than that on pear. No control methods are needed.

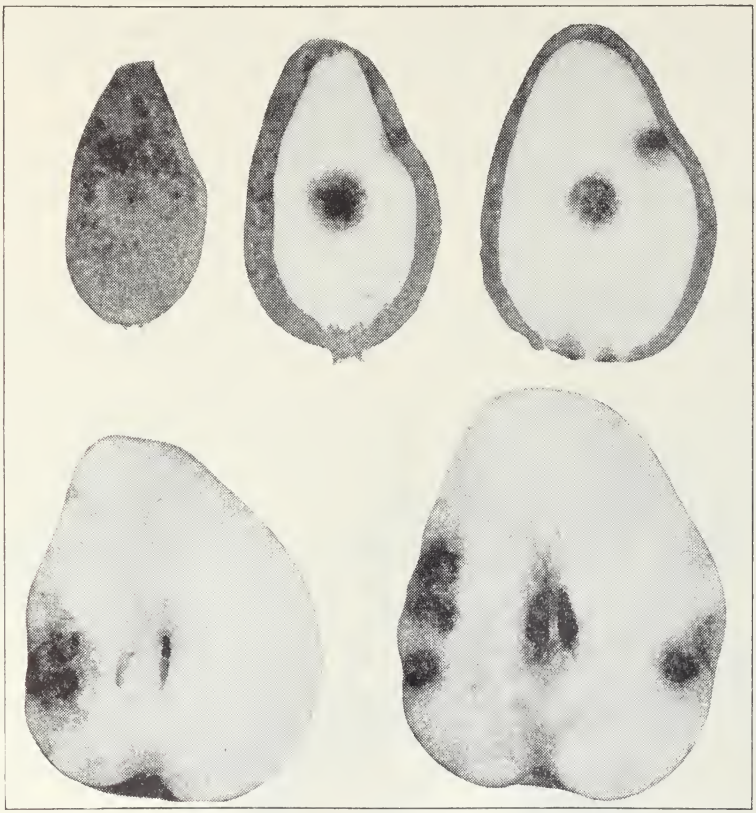

Fig. 56.—Pear stigmonose, sections of affected fruit.

Scab.—The first symptom is dark, velvety mold patches, consisting of the fungus *Venturia pyrina,* on young fruit and leaves (fig. 10, p. 25). Fruit badly affected by this fungus drops; on that which remains, the dark areas become hard, rough, and cracked, and the fruit much deformed (fig. 54).

Spray with lime-sulfur 1–50 (p. 160) or bordeaux mixture 3–3–50 (p. 156) just as the cluster buds first start to open. Repeat just before the first individual flowers open and, in severe cases, again as the last of the petals are falling. Bordeaux mixture—applied early in the blossom period—is sometimes beneficial in reducing blossom blight.

Stigmonose, Stony Pit.—The surface of affected fruit when full-grown is rough or warty, with numerous slight protuberances and hollows between (fig. 55). In the center of each protuberance there is a hard, gritty, discolored core suggesting an insect puncture (fig. 56). The Anjou and Bosc varieties are particularly susceptible. This trouble was formerly attributed to the sting of the tarnished plant bug or other insects, but there is doubt about this. In some cases at least, affected fruit seems to be correlated with peculiar twig symptoms on the same tree, which might indicate a virus disease. A recent report from Oregon states that a similar trouble has been transmitted by budding.

So far as experience goes at present, trees affected with this disease cannot be cured, but Bartlett and some other varieties may be top-worked upon them and produce normal fruit.

PECAN

Crown Gall.—In this bacterial disease, caused by *Phytomonas tumefaciens,* swellings or galls develop on the larger roots and at the crown of

Fig. 57.—Little-leaf of pecan.

the tree, which becomes stunted if badly affected. The pecan is not extremely susceptible to crown gall but sometimes shows it.

Trees with galls on the roots should not be planted, even though all the affected roots can be cut off. If galls develop at the crown of trees

after planting, they may be cut out and the wounds treated as described for almond on page 7.

Little-Leaf, Rosette.—The leaflets on affected trees are slender, yellow, and "frizzly-looking" (fig. 57), and the leaves are borne in clusters or rosettes on weak, slender shoots. Treatment with zinc has been found effective in curing this trouble. The methods recommended for walnuts (p. 133) may be tried for pecans.

Oak-Root-Fungus Disease, Armillaria Root Rot.—The pecan root appears to be very resistant to this fungus disease, caused by *Armillaria mellea*. See page 144.

PLUM, PRUNE

Bacterial Canker, Bacterial Gummosis.—Infected trees or main branches fail to show life in the spring or wither and die soon after growth has started. Dead areas or cankers (fig. 58) are found on the trunk or branches, with more or less gumming about the margins. These start from infections in the buds, fruit spurs, or bark (fig. 59). Young trees are more affected than older ones. In many varieties of plums, and to a less extent in prunes, the disease in some districts is very sporadic; it becomes epidemic in certain seasons. In this condition it is often designated as "sour sap." Cherries, apricots, and to a lesser extent peaches and almonds, are also susceptible to bacterial canker, which is caused by *Phytomonas cerasi*.

No effective method of control has been found for this disease. Affected limbs may be removed and cankers cut out as in fire blight of pear (p. 103), but, since the disease works mainly in the winter, most of the damage has usually been done before it is discovered. If the bodies of young plum trees were thoroughly sprayed every year in November with a heavy bordeaux mixture (p. 156), beginning the first winter after planting, much benefit would probably be obtained in preventing bacterial canker.

Blackheart, Verticilliosis.—On certain branches of young trees affected with blackheart the leaves wilt and wither in late summer and the branches die. Dark, discolored streaks are found in the wood. The whole tree is not always killed by this fungus, *Verticillium albo-atrum*, but may send out new branches and entirely recover in subsequent years. The disease in prune or plum trees is not so common or severe as in apricots (p. 30). See page 151 for further discussion. Young Sugar prunes and myrobalan seedlings are rather susceptible. The latter may contract the disease in the nursery and carry it to new soil.

Affected branches should be cut off down to the trunk. If vigorous new shoots come out the following year, the tree will probably recover.

Black Knot.—The characteristic symptom of this disease is the large, elongated, rough, black knots or swellings all over the smaller branches, which greatly injure and disfigure the tree. This is a common disease of plum and cherry in eastern states but in California has only been seen in wild species in the mountains and foothills, where it is very common in certain localities, as in Yosemite Valley. It is caused by a fungus, *Dibotryon morbosum*.

Fig. 58.—Bacterial canker of plum.

Where wild plums or cherries are of any value, the knots should be very thoroughly cut out as soon as they appear. If this is not sufficient to keep the disease in check, the trees may be sprayed with lime-sulfur 8–100 (p. 160) just as the buds are swelling.

Brown Rot.—This is the same fungus disease as in the apricot, peach, and cherry, caused by *Sclerotinia fructicola* or *S. laxa*. Symptoms in the prune and plum are similar to those in other hosts. In the blossom-blight phase of the disease (fig. 15, p. 31), the blossoms are blasted and withered just as they are opening, and a grayish mold can be seen on the dead

parts. Killing of the tissue runs down into the twigs, with the exudation of drops of gum. In the fruit-rot stage, the nearly ripe fruit shows a rotting of the flesh with the same mold appearing on the surface. Plums and prunes are much less subject to the disease in California than apricots.

Fig. 59.—Bacterial canker of plum, new infections.

but in moist localities or wet seasons and on clustered varieties like the Sugar prune, considerable brown rot sometimes develops on the fruit.

The treatment recommended for brown rot in apricots (p. 33) may be used for prunes in places where it seems necessary.

Cracking.—In the French prune, in some years, a large percentage of the fruit shows a splitting and cracking open of the flesh on the sides or ends just before ripening. This appears to be due to some injury to the young prunes and is caused, in part at least, by attacks of thrips or aphids when the fruit is very small. Control of these insects is the logical method of prevention. See Extension Circular 87.

Crown Gall.—Large roundish galls develop on the roots and at the

base of the trunk. Badly affected trees are weakened and stunted by this bacterial infection, caused by *Phytomonas tumefaciens*. All the roots (peach, almond, myrobalan, and plum) on which plums and prunes are commonly propagated are very susceptible to crown gall.

Nursery trees showing any galls on the roots and clean trees from lots in which a large percentage were affected should not be planted. Trees which fail to grow properly the first year should be examined and if the roots are badly galled, such trees should be pulled and replaced with healthy ones. For further information, see under "Almond" (p. 7).

Diamond Canker.[29]—In the French prune, the trunk and larger limbs of trees affected with this disease become covered with cankers which consist of thick, corky swellings in the bark. The trees at first have a tendency to bear heavier crops of larger prunes than normal but finally they become weakened and much stunted and crippled. Diamond canker itself does not kill the trees, but they eventually succumb to borers, wood decay, sunburn, and similar troubles. The cause is not known, but may be a virus.

The cankers may be cut out when they first appear if they are not too numerous. Disinfecting the cuts does not seem to be necessary. With trees in which the cankers are too numerous to cut out, especially if in the trunk, one may expect that the progress of the disease will be very slow and the tree will probably produce fairly good crops of prunes for many years. It may be best, therefore, to do nothing until the tree is too far gone to produce profitable crops, then pull it out and replant. Of the commonly planted prune varieties, only the French is susceptible to diamond canker. Nurserymen should take care not to propagate with buds from diamond-canker trees.

Dieback.—Trees sometimes die back suddenly and severely in the tops (fig. 60), and in some areas of the Sacramento Valley large numbers of well-grown French prune trees have been killed. The leaves are browned and scorched, with dead areas in the blade as well as at the margin. The trees produce a very heavy crop of fruit the year before dieback occurs. The disease is apparently nonparasitic. Soils in which this trouble has been found are usually low in available potassium, but such deficiency does not seem to be the direct cause of the trouble.

Heavy pruning, to reduce the fruiting surface and prevent overbearing, is of benefit in preventing this disease. Fertilization with potash is not effective.

Exanthema.—Young trees affected with exanthema have a stunted, bushy growth, with scorched, yellowish leaves. This is caused by the

[29] Smith, Ralph E. The diamond canker disease of the French prune in California. California Agr. Ext. Cir. 67:1–22. 14 figs. 1932.

death of the terminal buds and the consequent forcing out of lateral shoots, which in turn die back before they make much growth (fig. 33, p. 80). The bark of some of the smaller branches shows a rough, corky condition (fig. 61).

Fig. 60.—Dieback of French prune trees, associated with overbearing and deficiency of potassium in soil.

Applications of copper, either to the soil, through holes in the trunk, or by spraying with 5–5–50 bordeaux mixture as recommended for pears (p. 101) are effective in curing this disease in prune trees.

Gum Drops, Shot-Hole Borer.—Small globules of clear, white gum break out from the twigs and branches all over the tree (fig. 62). These glisten in the sun like raindrops. The cause of this is a small beetle, the shot-hole borer, *Scolytus rugulosus,* which breeds in the bark. Sickly

trees and healthy ones adjacent to them are most likely to be attacked. The French prune is very susceptible; other prunes, plums, cherries, and apricots are sometimes affected.

Badly injured trees or branches should be removed and burned; no

Fig. 61.—Shoots of French prune tree affected with exanthema, showing swollen buds, abnormal growth, and roughened bark.

dead wood should be left in or near the orchard. See Extension Circular 87.

Hail Mark.—Hail occurring while the fruit is green causes pitting and spotting with irregular lesions (fig. 63) which turn brown and may become infected with mold fungi. These spots heal over more or less and may give the impression of being due to some fungus disease.

Kelsey Spot.—The green fruit of the Kelsey variety often shows a

sunken, dark-colored spot on the side in summer. The tissue beneath is dead and dry and sticks to the pit. This trouble is apparently caused by high temperature and seems similar to shrivels, or drought spot (p. 117), which occurs also on other fruits.

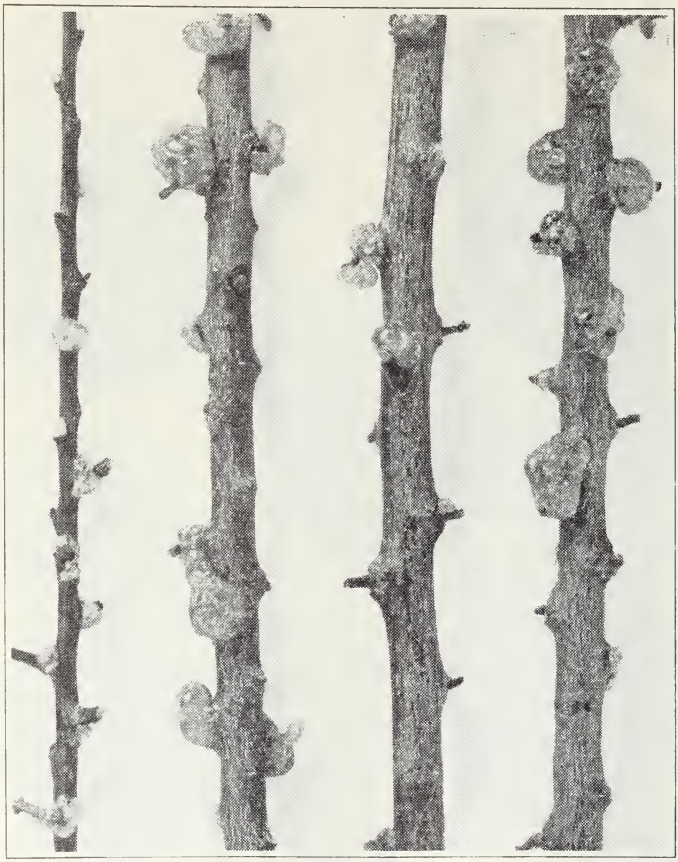

Fig. 62.—Gumming on shoots of French prune produced by shot-hole borer.

Little-Leaf.—On affected trees, the leaves are pale and narrow and the growth weak. The symptoms are more fully described on page 141.

True little-leaf, which affects many kinds of trees, is nonparasitic and may be cured by the application of zinc. The method of spraying with zinc sulfate in the dormant seasons, as recommended for apples (p. 21), gives satisfactory control. Good results have also been obtained by driving small pieces of galvanized iron into the bark.

Oak-Root-Fungus Disease, Armillaria Root Rot.—Trees infected with oak root fungus, *Armillaria mellea,* become weak and sickly and

finally wither and die. The trouble starts in certain spots in the orchard and keeps spreading, killing more and more trees. The characteristic, white, felty growth of the fungus is seen between the wood and bark of the roots and base of the trunk. Large clumps of light-tan toadstools come up around the base of badly affected trees in late fall.

For treatment see page 144. There is a fair chance of finding a resist-

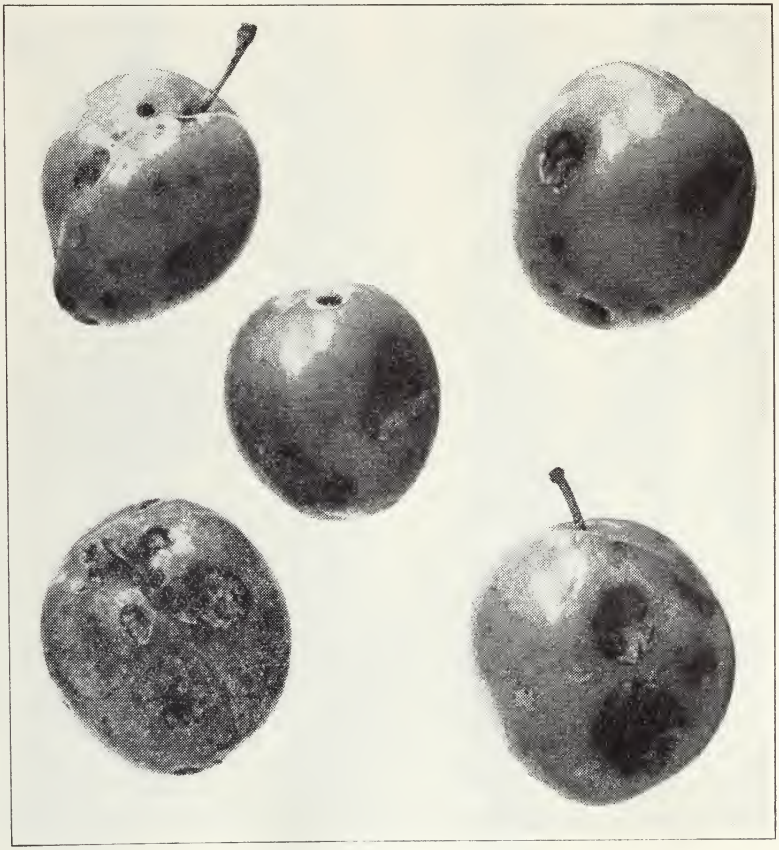

Fig. 63.—Hail marks on plum.

ant root for prune trees among some of the myrobolans, strains or individuals of which show considerable resistance. Tests are being made in many places. For further information address the Division of Plant Pathology, College of Agriculture, Berkeley.

Plum Pockets.—The fruit becomes puffy and enlarged to several times its natural size by the attack of the fungus, *Taphrina pruni*, which is similar to that which causes peach leaf curl. The disease is very rare on cultivated species in California and seldom seen except on one of the native plums, *Prunus subcordata*.

Rust.—This rust, which also attacks the peach, apricot, and almond, is seen on plums and prunes mainly in the black-rust stage. Late in fall, the undersides of the leaves become covered with dark-brown or black spore pustules of the fungus *Tranzschelia pruni-spinosae*. The attack comes so late that little or no damage is done and no treatment is neces-

Fig. 64.—Thrips mark on prunes, often mistaken for a fungus disease.

sary. The alternate stage of this rust on anemone is seen occasionally in California but seems to be of no importance in the perpetuation of the fungus.

Shrivels, Drought Spot.—Before maturity, one side or the lower end of the fruit sometimes becomes shriveled and dark-colored in depressed spots where the flesh is dead and sticks to the pit. This may be due to sunburn or drought. Kelsey spot (p. 114) seems to be of a similar nature.

Sour Sap.—Trees sometimes die or fail to develop in spring, with a discoloration and fermentation of the inner bark. Young trees are more commonly affected, occasionally in very large numbers. Single branches or whole trees may show the trouble. Sour sap may be due to bacterial canker, phytophthora canker, excess of soil water, or other causes. Many other kinds of fruit trees are affected. See this disease under "Apricot" (p. 39).

Thrips Effect.—The affected fruit, especially of prunes, is marked with scabby spots and lines and is much disfigured and deformed (fig.

64). Cracking and gumming also occur. This is caused by pear thrips, *Taeniothrips inconsequens*, a small insect which works on the blossom and the very young fruit. See Extension Circular 87.

Tragedy Canker, Pustular Canker.—The trouble has been seen only on trees of the Tragedy variety of prune. On twigs and smaller branches,

Fig. 65.—Pustular canker of Tragedy prune.

small, diamond-shaped or elongated pustules break out in the bark (fig. 65) of affected trees. The growth is stunted and partially killed. The cause and method of control are unknown; possibly it is a virus disease.

POMEGRANATE

Smut.—The inside of a mature, infected fruit contains a mass of black, dusty, mold spores. This disease is not a true smut but is like the so-called "smut" of figs (p. 73) and is caused by a similar but not the same fungus, another species of *Aspergillus*. There is no apparent way of preventing this condition.

PRUNE

See "Plum, Prune" (p. 109)

QUINCE

Aerial Gall.—At each node or joint on the stem, a rough, warty swelling of the bark develops. This condition is universal on quinces in California and appears something like aerial crown gall or hairy root in apples. No damage seems to result. The cause is unknown.

Black Rot.—The nearly ripe fruit is attacked by a black, rather dry rot of the flesh (fig. 66). Small black dots which are the spore pustules of the fungus *Physalospora obtusa* are seen on the surface of the affected

Fig. 66.—Black rot of quince.

tissue. This is the same disease as black rot of the apple (p. 15), which is serious in the eastern part of the country. It is not important in California on either apple or quince.

Botrytis Rot.—The flesh of mature quince fruit is sometimes attacked by a fungus, *Botrytis cinerea,* which causes a brownish, rather firm rot; but the disease is seldom serious. The dirty-gray, spore-dusty fungus grows out on the surface.

Brown Rot.—*Sclerotinia fructicola* and *S. laxa,* which are better known as fungus parasites on apricot, peach, and other stone fruits, sometimes attack the quince and cause a blossom blight and also a fruit rot, as on other hosts. Brown rot is not important on quince.

Fire Blight, Blight.—When attacked by the fire-blight organism, *Phytomonas amylovora*, twigs and branches with leaves, blossoms, or fruit attached wither suddenly and die, as in the same bacterial disease of pear, apple, and related fruits.

Affected branches should be cut out and burned, with antiseptic precautions as described for this disease under "Pear" (p. 101).

Powdery Mildew.—The leaves and sometimes the fruit become covered with a white growth of mildew. The causal fungus has not been determined, but its attacks are not serious.

RASPBERRY

See "Blackberry and Raspberry" (p. 44)

STRAWBERRY[30]

Black Root.—Affected plants gradually fail, wither, and die. The cortex or outer layer of the root is the first to turn black, usually in spots or areas here and there on the surface. Finally the whole root dies and blackens, as in brown-core rot. A disease of this sort is fairly common in California and may be due to the fungus *Corticium vagum* or other causes.

Brown-Core Rot.—Plants infected with this disease fail to start or begin dying in spring. The roots of diseased plants show at first a dark, reddish-brown discoloration at the core while the cortex or bark remains white; later the entire root decays. The roots of the planting stock are sometimes affected with this disease, and it may be spread by this means. Large areas of plants which were very vigorous and productive the previous year may become seriously affected with brown-core rot during the winter and die early in summer. Some plants show signs of recovery in June or July but seldom amount to anything. Heavy winter rainfall or poor drainage favor this trouble, which is caused by a fungus of the water-mold type, a species of *Phytophthora*.

In a field affected with this disease, thorough drainage may help to prevent its spread. No other method of control is known. The planting of infected stock should be avoided.

Chlorosis.—In chlorosis (p. 135), the leaves become uniformly pale yellow or almost white. This occurs typically on soil which contains large amounts of lime and is not caused by a parasite. Land on which this trouble develops is unsuited to strawberries.

Crinkle.—In this disease, the leaves are crinkled and deformed in shape, somewhat stunted, and flecked with small, yellow spots irregularly scattered over the surface. All runners from an affected mother

[30] For further information, see: Thomas, Harold E. The strawberry industry of California. California Agr. Ext. Cir. 113:1–92. 32 figs. 1939.

plant develop the disease. Varieties of the Banner or Marshall type are most susceptible. Crinkle closely resembles yellows in some respects and is also similar in that it is a virus disease and the strawberry aphid is the only known agent of spread. In California it is observed mainly in plants shipped in from the north and does not seem to be spread in this state or to occur in planting districts here.

Care should be taken that only disease-free plants are set out. New plantings should be carefully watched, and any affected plants that show up in the field should be immediately pulled out and destroyed.

Crown Rot.—The plants sometimes die from a rotting or killing of the crowns. Any of a number of organisms may be responsible. The cottony mold fungus, *Sclerotinia sclerotiorum* (p. 136), often has this effect on strawberry plants, especially in wet spring weather. In this case the snow-white mold growth of the fungus is visible. The gray mold fungus, *Botrytis cinerea,* sometimes attacks the stem and leafstalk bases and produces a thick, gray-brown, dusty growth. Southern root rot, *Sclerotium Rolfsii,* may attack strawberry plants and spread from plant to plant through the soil as a whitish mold; it forms around affected plants numerous small, round sclerotia which look like mustard seed. The oak root fungus, *Armillaria mellea,* which attacks many kinds of tree fruits and some other crops, also occasionally attacks strawberries. All of these fungi infest the soil and help to shorten the life of a strawberry patch. Little can be done to control them.

Certain insects like the strawberry crown moth, *Aegeria rutilans,* the strawberry leaf beetle, *Paria canella,* and the strawberry root weevil, *Brachyrrhinus ovatus,* also attack the crowns and roots, and their effects may easily be taken for diseases. See Extension Circular 87.

Cyclamen Mite.—In plants attacked by cyclamen mite, *Tarsonemus pallidus,* the center leaves are dwarfed, peculiarly wrinkled with fluted edges, and often bronzed or reddened at the base. The plants are stunted, and whole fields may fail completely at an early age on account of this serious pest. The mites live and multiply on the young unfolding leaves of the crown, where they cannot be reached with any spray. Being too small to be readily seen with the naked eye, their effects may easily be taken for a disease.

Efforts should be made not to introduce this pest into new plantings. If there is any danger that new plants are infested with the mite, they may be immersed for ½ hour in water held at a temperature of 110° Fahrenheit or kept in a water-saturated atmosphere for 1 hour at the same temperature. Time and temperature must be accurately measured. For further information, consult the Division of Entomology, College of Agriculture, Berkeley.

Dwarf, Crimp.—This trouble is not abundant in California but is occasionally found on plants shipped in from the southern states where the disease is common. Plants attacked by this bud nematode, *Aphelenchoides fragariae,* become dwarfed, with small, narrow leaflets of a darker green color than normal. The nematode lives in great numbers in the buds and is too small to be seen with the naked eye.

Affected plants should be destroyed and the land used for some crop other than strawberries for several years. Care should be taken not to put out any strawberry plants that may carry this pest.

Fruit Rot or Mold.—Gray mold, caused by *Botrytis cinerea,* is the principal trouble of this sort in California. Sometimes during wet spring weather large quantities of berries, both green and ripe, rot on the plants from this cause, and are covered with the dusty-gray, fungus growth. Careless picking or rough handling at such times may cause the berries to mold and rot in the baskets.

Rhizopus rot, also called "wet rot," "leaks," and "bread mold," caused by *Rhizopus nigricans,* is more common on picked fruit; it forms an abundant, coarse mold, at first white, then turning black, which rapidly spreads over and rots the fruit in baskets, and produces a wet, dripping type of spoilage.

Strawberries, especially in wet weather, should be picked and handled very carefully (see Extension Circular 113, mentioned in footnote 30, page 120). Every berry which shows the slightest spotting or defect should be rejected. All fruit which has molded on the plant should be picked and dropped in the furrow.

Leaf Burn.—The leaves occasionally show burning and browning around the margins and yellowing or other abnormal discolorations. The roots of such plants are usually discolored and more or less rotted and dead. The plants are killed or badly stunted. The strawberry plant is very sensitive to alkali and other salts in the soil or irrigation water, and much trouble of this sort is due to such conditions.

When plants show the above symptoms, the soil and water should be tested for injurious salts. Strawberry growing should not be attempted unless an abundant supply of good water is available.

Leaf Spot.—The leaves of infected plants show small, dead spots with brownish-red borders and white centers. If this fungus trouble, caused by *Mycosphaerella fragariae,* is severe, the foliage may be ruined, but it very seldom becomes serious in California.

The practice of removing and burning all the old leaves in winter helps to keep down this disease. Spraying the crowns and ground with dormant-strength lime-sulfur (1 gallon to 9 gallons of water) (p. 160) immediately after the cleanup will be of value in controlling this and

other diseases and pests. In rainy climates, spraying with bordeaux mixture 4–4–50 (p. 156) every 2 weeks in summer is recommended, but this is not necessary here and would greatly disfigure the fruit.

Nubbins.—This trouble is characterized by imperfect, misshapen, and poorly filled-out berries similar to those seen in the disease described by the same name under "Blackberry and Raspberry" (p. 44). This has been attributed to thrips, poor pollination, and other causes. The trouble is common in the Nich Ohmer variety during the summer months.

Powdery Mildew.—In this disease, a white, powdery mildew (*Sphaerotheca humuli*) develops on the leaves, stunts them, and causes them to roll inward. Sometimes the leaves may be affected in this way by the fungus without showing much of the white mildew. The fruit may also be mildewed. This is not often serious in California.

No treatment except the winter cleanup described under "Leaf Spot" (p. 122), is available for this disease. Sulfur, the usual material used for mildews, cannot be used on strawberry leaves without causing serious burning.

Root-Knot Nematode.—When plants are attacked by the root-knot, or common garden nematode, *Heterodera marioni*, small, roundish swellings develop on the roots and the plants may be stunted (p. 142). Strawberries should not be planted, either for fruit or growing plants, in land infested with nematode. Planting stock which shows any infestation should be discarded.

Verticillium Wilt, Verticilliosis.—The outer leaves of affected plants wither, turn brown, and die, and often the entire plant collapses. Large areas where most of the plants are affected may develop in the field. New side shoots often appear from some of the affected plants but many of them die completely. This disease is usually not seen in early spring but begins to show up with hot weather, when plants begin to wilt and die and continue dying until late fall. Strawberry plantings on land which has recently been in tomatoes or potatoes are most likely to be affected, since this soil fungus, *Verticillium albo-atrum*, attacks those crops severely. The Marshall or Banner strawberry varieties are less susceptible than Nich Ohmer and other common sorts. See page 151 for further discussion.

Nothing can be done to check this disease in established plantings. Land which has recently been in tomatoes or potatoes should be avoided for strawberries. Breeding experiments to produce resistant varieties of strawberries are being conducted at the Deciduous Fruit Field Station at San Jose.

Yellows, Xanthosis.—Yellows is most severe in the central-coast district of California and affects plants of the Banner or Marshall type

more than Nich Ohmer, Klondike, and Missionary. Dorsett and Blakemore are moderately susceptible. The plants are stunted, the leaves reduced in size and yellow at the margins. The yield is greatly reduced and the fruit does not reach full size or quality. All the runners from an affected plant have the disease. The plants are not killed but never recover beyond a temporary improvement in hot weather, and the profitable life of a planting is greatly shortened. The disease is caused by a virus and is spread from plant to plant by the strawberry aphid.

In new strawberry plantings, every effort should be made to get plants which are free from the yellows disease. Plant growers in California and Oregon are coöperating with state and county authorities in an effort to produce stock which is free from this and other diseases and which can be officially certified to that effect. Late plantings (after April 15) usually escape the yellows disease the first season because the heavy infestation by aphids has almost disappeared at that time. Plantings of clean stock at a distance of at least 2 or 3 miles from other strawberries stay healthy longer than those close to old fields affected with yellows. If all plants which show symptoms of this disease are pulled out promptly and thoroughly from the very first, the life of the patch may be considerably prolonged. Roguing after the disease is well established is of no value. Many new seedling varieties of strawberries have been developed by the Division of Plant Pathology and are being tested for resistance to this and other diseases.

TANGERINE

See "Citrus Fruits" (p. 56)

THIMBLEBERRY

See "Blackberry and Raspberry" (p. 44)

WALNUT[31]

Alkali Injury, Boron, Salt.—Walnuts are very sensitive to alkali or toxic salts in the soil or irrigation water. Each salt has a more or less characteristic effect such as the yellow leaf margin produced by boron, and the brown, dead edges seen on foliage of trees affected by sodium chloride; but in general the trees show an unhealthy look, usually with pale-green foliage, and if much affected, the leaves are burned at the edges and drop prematurely.

If injurious salts are contained in the irrigation water, nothing can be done to save injured trees except to obtain a source of better water. If the toxic substances are being brought up in the soil from below by a high water table, then the water level must be lowered by some method of

[31] For further information on walnut culture, with descriptions and illustrations of diseases, see: Batchelor, L. D. Walnut culture in California. California Agr. Exp. Sta. Bul. 379:1–109. 38 figs. Revised by L. D. Batchelor and O. Lee Braucher. 1936.

drainage. If the surface soil already contains harmful amounts of injurious ingredients, this condition can only be remedied by copious irrigation with reasonably pure water, combined with adequate drainage. The use of nitrogenous fertilizers, stable manure, materials like bean straw or alfalfa hay, and green-manure crops is also helpful.

Blight, Bacteriosis.[32]—Walnut blight is characterized by black, dead spots on young nuts (fig. 67), green shoots (fig. 68), and leaves (fig. 69).

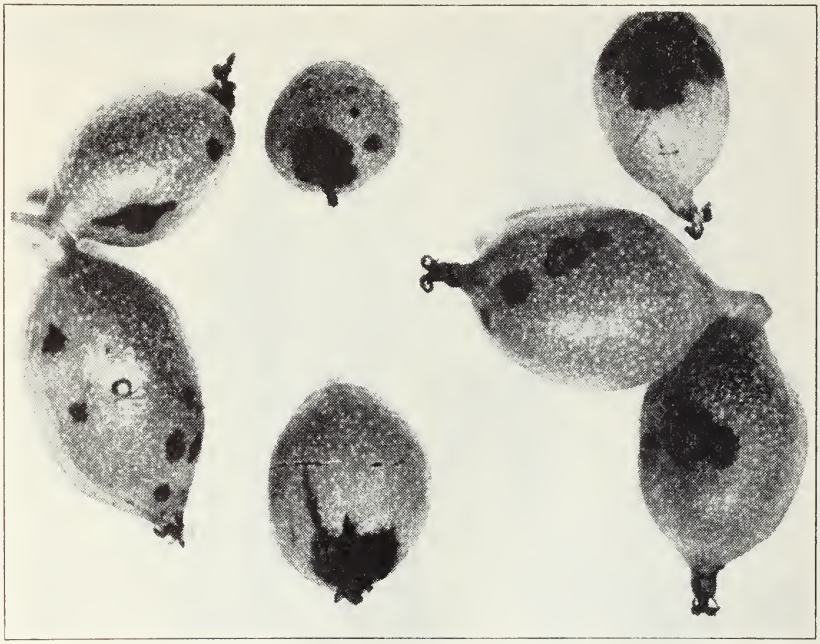

Fig. 67.—Walnut blight on young nuts.

Many nuts fall prematurely, but others which reach full size are more or less blackened and destroyed (fig. 70), both as to the husk and shell and the kernel within. The injury to the tree from this disease, caused by *Phytomonas juglandis,* is much less serious than the loss of crop.

Control of walnut blight has been obtained by spraying the trees with bordeaux mixture when the first leaves and catkins are partially developed but before many of the rudimentary young nuts have appeared. The 8–4–50 formula (p. 156) has been recommended for California as a whole, but under conditions less favorable to the development of the disease, a spray of half this strength sometimes gives good control. A

[32] For fuller discussion of this disease, see:

Rudolph, B. A. Bacteriosis of the English walnut and its control. California Agr. Exp. Sta. Bul. 564:1–88. 17 figs. 1933. (Out of print.)

Rudolph, B. A. A new blight control spray. Red cuprous oxide. Diamond Walnut News: 22(2). 4 p. California Walnut Growers' Association, Los Angeles. 1940.

second application of spray, when the nuts are about the size of large peas or small olives, has been recommended in the past. While such a spray gives additional control, there is considerable danger of spray burn when it is used. Either application of spray may burn the trees when conditions conducive to such injury, climatic or otherwise, are present. Spray burn may lead to an increased percentage of nuts of inferior grade due to shriveled kernels. This effect is more pronounced in older trees and on those which have been sprayed after the growth is well advanced, as for instance when given a second spraying as above sug-

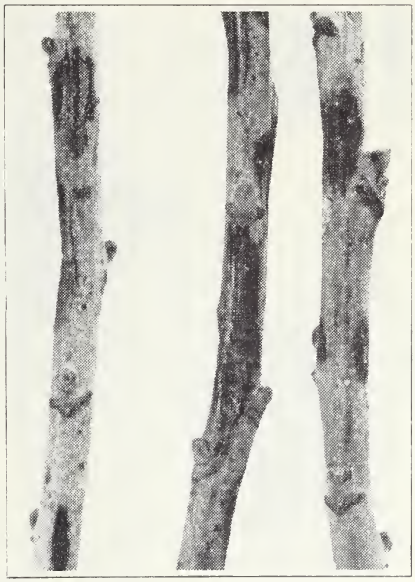

Fig. 68.—Walnut blight on shoots.

gested. On account of these bad effects of bordeaux mixture on walnuts, many other fungicides are being tested for control of blight in the hope of finding something which will be effective and also free from danger of undesirable effects under any circumstances. The best results to date have been obtained by the use of a spray composed of 1 pound of red cuprous oxide (see p. 158) and 1 pint of Orthex[33] in 50 gallons of water. Trial of this spray is suggested to growers who have had injury to walnuts from bordeaux mixture. Another walnut-blight spray which is recommended in Oregon is copper oxalate,[34] 2 pounds in 50 gallons of water. Control of blight was obtained with this spray in experiments in

[33] A commercial spreader made by the California Spray Chemical Co., Richmond, California.

[34] This material may be obtained from the Mountain Copper Company, Martinez, California.

California but the quality of the nuts appeared to be injured. The time of application in all cases should be the same as that for bordeaux mixture.

It is a matter of common observation that walnut trees of different varieties and different individual seedling trees vary greatly in the degree to which they are affected by blight during any one season. On account of this apparent difference in susceptibility, efforts have been going on for many years to find blight-resistant and otherwise satisfac-

Fig. 69.—Walnut blight on leaves.

tory varieties. That these efforts have had little success indicates that the problem is much less simple than it appears. Whether any actual *resistance* to the disease has been found is doubtful. Varieties or trees which have less blight than others generally prove simply to have *escaped* the disease by some fortuitous circumstance. This is usually dependent on the fact that the new growth and young nuts of trees which start developing comparatively late in spring come out at a time when the rainy season is nearly over and there is consequently less humidity to favor infection. Such late-starting varieties do not solve the blight problem, however. As a rule, their late spring development is correlated with a corresponding late maturity of the crop in the fall and this is undesirable from a marketing standpoint. Furthermore, these late varieties are

by no means blight-free since in some seasons there are periods of summer humidity when the disease develops abundantly. In regard to other qualities, also, no entirely satisfactory late-starting variety has thus far been found, especially for southern California. It is significant that the more recent walnut plantings in that part of the state have been almost exclusively of an early-maturing, blight-susceptible variety. Meantime, the need is as great as ever for a high-producing, high-quality, really blight-resistant walnut.

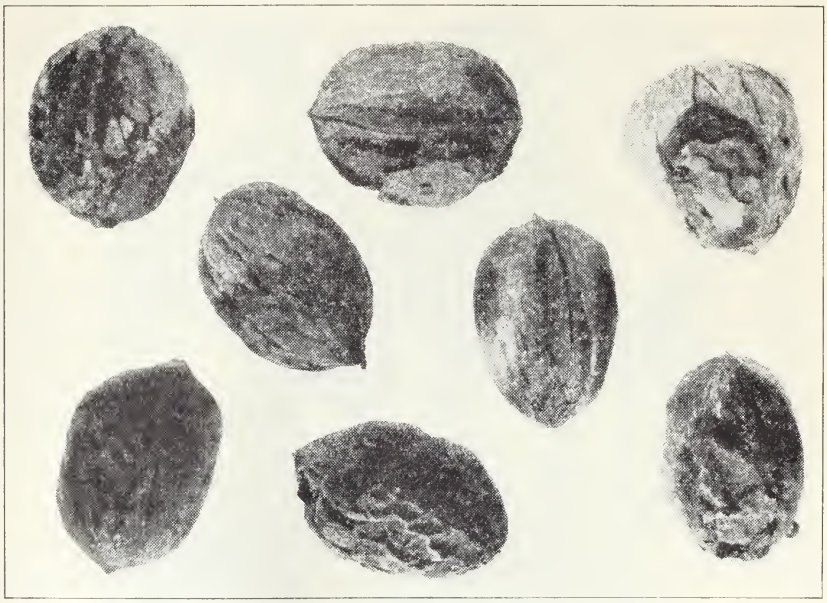

Fig. 70.—Full-grown walnuts ruined by blight.

Chlorosis.—The foliage of affected trees is of a bright-yellow color and the growth more or less stunted and deformed. Typical chlorosis is caused in trees of many kinds by the presence in the soil of excessive amounts of lime, which prevents the normal functioning of iron in the tree. The walnut is a lime-loving plant, but in some districts where the lime content of the soil is very great, the foliage of walnut trees shows the same yellow color as that of pears and other species. For treatment see page 135.

Crown Gall.—The walnut, including all the species used for root-stocks is rather susceptible to this common bacterial disease, caused by *Phytomonas tumefaciens*. Large rough swellings develop on the roots, at the crown, and at places higher up on the tree, especially at the point of grafting on top-worked trees. Rough, slow-healing graft unions and points of injury are most likely to become infected.

Galls, if not too far advanced, may be cut out in such a way as to remove all diseased and closely adjacent tissue. The wounds should then be disinfected with corrosive sublimate 1–1,000 (p. 159) and covered with bordeaux paste (p. 157) or white lead paint.

Crown Rot.—Affected trees become somewhat stunted, with sparse, yellowish foliage, and may set a heavy crop of nuts. They often collapse in midsummer, the leaves withering and falling and thus leaving the nuts exposed. Such trees are usually dead by the next season. Examination below ground shows that at the crown, just below the graft union, the bark is affected by a soft, black, spongy decay which eventually girdles and kills the tree. This disease, which is caused by a fungus of the water-mold type, *Phytophthora cactorum,* is more likely to occur on heavy, poorly drained, winter-flooded, or overirrigated soil, especially in places where the water stands around the trees and where the graft union is deeply buried.

The southern California black walnut (*Juglans californica*) is the most susceptible of the usual rootstocks, the northern California species (*J. Hindsii*) next, while the English walnut (*J. regia*) has more resistance. Since, however, the latter is not so good a rootstock for general purposes as *J. Hindsii,* it is better to avoid crown rot by other methods.

Land should be properly leveled to avoid low spots or standing water. Wherever this disease is feared, graft unions should be well aboveground so as never to be covered with soil. Water should not stand about the trunks of the trees. If crown rot has already appeared, the dirt should be dug away from the base of the tree and the crown left exposed to become thoroughly dried out. On trees which are not too far gone, all the affected bark may be cut out, the wounds disinfected with corrosive sublimate 1–1,000 (p. 159), and then covered with paint or bordeaux paste (p. 157).

Delayed Foliation.—See page 140.

Dieback, Winter Injury.—Branches, large limbs, or even whole trees occasionally fail to start in spring and are found to be dead and the bark and cambium dry and discolored. Trees from one to ten years of age are the most affected. Badly injured ones usually sprout from below. Dying-back of the tops of walnut trees may be caused by high water table, alkali, boron, or other injurious salts and various other causes, but the typical trouble described above usually results from freezing of immature growth by early fall frosts. Winter drought also causes or accentuates the same type of injury, especially on soils underlaid with gravel.

In places where young walnut trees make a rapid, vigorous development and where the first killing frost finds them in a succulent, immature condition, it may be impossible to prevent severe injury of this type in

certain seasons. Unless conditions are too unfavorable, however, young walnut trees usually outgrow this tendency after one or two setbacks. If the top is entirely killed or badly crippled, it may be necessary to replant or graft a sucker from the root. Winter drought injury may be prevented by irrigating in November if the subsoil is dry at that time. Trees not too badly injured should be severely pruned to remove all dead and weakened wood. Such trees should be whitewashed to prevent sunburn.

Fig. 71.—Erinose on black walnut leaves.

Erinose, Blister Mite.—"Erinose" is the name given the condition in which roundish, cupped galls form on the leaves, smooth and convex on the upper surface (fig. 71), hollow and covered with brown, feltlike hairs beneath. The cause of this comparatively harmless condition, which may be easily mistaken for a fungus or bacterial infection, is a microscopic mite, *Eriophyes tristriatus* var. *erinea*. See Extension Circular 87.

Girdle, Black Line.—The disease occurs in certain districts only, on English walnut grafted on black walnut, mostly on trees twenty years of age or older. It is not confined to any one variety. The leaves of the

whole top or those on certain branches turn yellow, then brown, and fall prematurely. The stock usually throws out suckers and the top dies. Examination shows a black line of dead tissue at the union between the top and rootstock where the growth of the last few years has failed to unite, resulting in a girdling of the tree or branch. This results in a dying of

Fig. 72.—Leaf scorch of walnut.

the black walnut bark, beginning at the union and progressing downward. No explanation for this trouble has been found.

The tops or branches of trees which show this condition may be cut off and some of the black walnut suckers which grow from below the union may be grafted with scions of the desired variety of English walnut to make a new top. Inarching such suckers on the old top does not seem promising on account of the area of dead bark which will be left at the original union.

Leaf Scorch.—Dead, brown spots or areas of considerable size sometimes appear in the leaf between the veins (fig. 72). The more badly affected leaves fall off. This injury usually appears on trees growing in

Fig. 73.—Little-leaf of black walnut.

soil underlaid with gravel at times of hot, drying winds, and is nonparasitic in origin. Careful irrigation to keep a good soil moisture condition is all that can be done to prevent this trouble.

Little-Leaf, Yellows.—In little-leaf, weak, yellow shoots develop with

narrow, pale, poorly formed leaflets (fig. 73). The northern California black walnut is very susceptible to typical little-leaf, and the English walnut is often affected in varying degrees with trouble of this nature.

True little-leaf can be corrected by the use of zinc, but black walnut trees on sandy soil are sometimes so badly affected as to be practically hopeless. Walnut trees which show little-leaf may be treated with 5 to 15 pounds of zinc sulfate placed on the soil around the tree within 2 feet of the trunk in early winter. Another method is to drive pieces of galvanized iron 1½ inches apart in rings around the trunks, 6 to 9 rings to each tree. Glazier's points may be used in small trees.

A somewhat similar trouble on English walnuts responds to applications of copper sulfate (bluestone). To cure this type of disease, from 1 to 10 pounds of copper sulfate crystals, according to the age of the tree, should be sprinkled on the soil about the base of the tree and thoroughly spaded in.

Manganese Deficiency.—Certain unthrifty conditions of walnut trees in southern California have recently been ascribed to a lack of manganese in the soil (see p. 150). For further information address the Citrus Experiment Station, Riverside.

Melaxuma, Black Sap.—An inky, black liquid oozes out of the bark in spots on the trunk or main limbs of affected trees. The bark beneath these spots becomes discolored, softens, dies, and thus forms a slightly sunken canker. This may eventually extend entirely around the limbs and cause their death. The same fungus, *Dothiorella gregaria,* attacks and kills many small twigs and fruit spurs, mostly in the interior of the tree or on old, weak growth.

To control, cut out cankers that have not gone too far on the trunk and large limbs. Branches that are girdled or nearly so should be removed. In treating cankers, all dead and discolored bark should be cut away, to a little beyond the margin. Wounds should be disinfected with corrosive sublimate 1–1,000 solution (p. 159) and covered with bordeaux paste (p. 157).

Mold.—The kernels of nuts which have been harvested and dried are sometimes discolored and moldy. Various fungi may cause this. Nuts which are harvested early and dried promptly are much less affected by this trouble and have lighter-colored meats than those which remain longer on the tree and the ground. Sufficient irrigation in late summer and control of aphids also helps to reduce the percentage of moldy and other off-grade nuts.

Oak-Root-Fungus Disease, Armillaria Root Rot.—In orchards where this disease is present, trees look sickly and finally die from a rotting of the main roots, and the disease spreads from tree to tree. The fungus,

Armillaria mellea, is seen in felty, white, fan-shaped sheets between the bark and wood and sends up clusters of tan-colored toadstools about the base of dead or badly affected trees. The English walnut root is very susceptible, but the various species of black walnut are among the most resistant of cultivated trees.

Many trees on black walnut root resist this fungus indefinitely in infested soil. Others, if attacked, may be saved or preserved for a long time by surgical treatment at the base and on the main roots. Trees should be grafted high enough to have the union well aboveground, and less mortality occurs if they are grafted while young. Budding may cause less shock to the tree than grafting. See page 144 for more details.

Perforation.—The hard shell of the walnut sometimes fails to develop properly; areas are left where it is defective or entirely lacking, and the kernel is covered only by the thin inner lining of the shell. The trouble is nonparasitic, and no definite method of prevention is known. Perforation is more abundant some years than others and is more common in the nuts from thrifty young trees than older ones. Certain trees show it more than others.

Sunburn.—High temperatures and exposure to the sun cause the green husk of the nut to blacken and die on the exposed side. This prevents the husk from separating cleanly from the nut and makes it a worthless "sticktight." High temperature also causes the kernels to become dark-colored, even when the husk shows no visible burning. Sunburn is more likely to occur after sudden changes from low to high temperatures.

There is no way of preventing sunburn except to be sure that the trees have plenty of water. Walnuts cannot be successfully grown commercially in hot climates because of this trouble.

YOUNG BLACKBERRY, YOUNGBERRY

See "Blackberry and Raspberry" (p. 44)

DISEASES AFFECTING MANY CROPS

ALKALI, BORON, SALT[35]

Plants injured by alkali or other excess salts usually look yellow and sickly and the leaves show burning at the margins and between the main veins. The twigs 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. Recently boron has been found to be present in the soils and waters of some localities 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, a letter should be addressed to the Division of Plant Nutrition, College of Agriculture, Berkeley, describing the case and asking for instruction about taking samples.

Faulty soils can be corrected to a certain extent by chemical treatment, washing with fairly pure water, and drainage. Harmful irrigation water cannot be improved by any practical method.

CHLOROSIS

In chlorosis, the leaves become yellow, pale, or nearly white and the plant is often stunted. Chlorosis is a general name for an unhealthy condition of this sort which may be caused by almost anything which is injurious or unfavorable to the plant. One of the most characteristic types in California is the so-called "lime-induced chlorosis" which is due to an excess of lime in the soil.[36] In this case the foliage of trees, shrubs, and other plants in certain areas has a bright yellow color, the growth is poor, and fruit production scanty. Lime interferes with the absorption and utilization of iron by the plant. If this is the cause of the trouble, it may usually be determined by an examination of the soil in which the roots are growing. A simple test for lime may be made by pouring a little hydrochloric (muriatic) acid or lemon juice onto the soil. If it foams strongly, it probably contains enough lime to cause chlorosis. The lime is often found near the surface, but in some cases it may be necessary to

[35] For more complete information on this subject, see:
Kelley, W. P. The reclamation of alkali soils. California Agr. Exp. Sta. Bul. 617:1–40. 15 figs. 1937.
Eaton, Frank M. Boron in soils and irrigation waters and its effect on plants, with particular reference to the San Joaquin Valley of California. U. S. Dept. Agr. Tech. Bul. 448:1–132. 32 figs. 1935.

[36] For more complete information on this subject, see: Bennett, J. P. The treatment of lime-induced chlorosis with iron salts. California Agr. Exp. Sta. Cir. 321:1–12. 1 fig. 1931.

test samples from a depth of 6 feet or more. For a more accurate determination, samples of soil may be taken to a chemist. A lime content of 1 per cent or over is likely to cause chlorosis of certain trees. The pear and lemon are among the most susceptible plants. Acacia, apple, apricot, avocado, cherry, cypress, eucalyptus, grapefruit, orange, peach, pine, plum, prune, raspberry, rose, and many other trees and shrubs are known to show chlorosis in high-lime soils. Strawberries and other herbaceous plants are sometimes affected.

Other causes of chlorosis are: alkali or harmful salts in the soil or irrigation water; root injuries by fungi, insects, or rodents; drought or excess water; and lack of certain food materials in the soil.

Lime-induced chlorosis can be remedied by the application of iron. There are several different methods of doing this: (1) Ferrous sulfate (copperas) may be spaded or trenched into the soil around the roots, preferably in late winter or spring just before the leaves appear. The quantity may be estimated by allowing 1 pound of ferrous sulfate to each inch of diameter of the tree trunk. This method is laborious and expensive. (2) Spraying the foliage with a solution of ferrous sulfate is sometimes practiced; 1 ounce of ferrous sulfate per gallon of water should be used. Spraying should not be done during hot, sunny weather and must be repeated from time to time as new leaves appear. (3) For treatment of woody trees, injection of iron salts through holes in the trunk is usually the most practical method. In applying this treatment, ¼- to 7/16-inch holes are bored in the larger roots, in the trunk above or below ground level, or in branches. The holes should be bored at intervals of 3 to 4 inches around the root, trunk, or branch and from 1 to 3 inches deep. In the bottom of each hole is placed from 1/100 to ⅛ ounce of ground ferrous citrate, and the mouth of the hole is then closed with wax. The number and depth of holes and the dosage varies for trees of different sizes. Anyone intending to apply this treatment should obtain a copy of Circular 321 (mentioned in footnote 36) or write to the College of Agriculture, Berkeley, for full directions.

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, and develops an abundant growth of pure-white, cottony, fluffy mold upon the affected tissue (fig. 74). 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, toad-

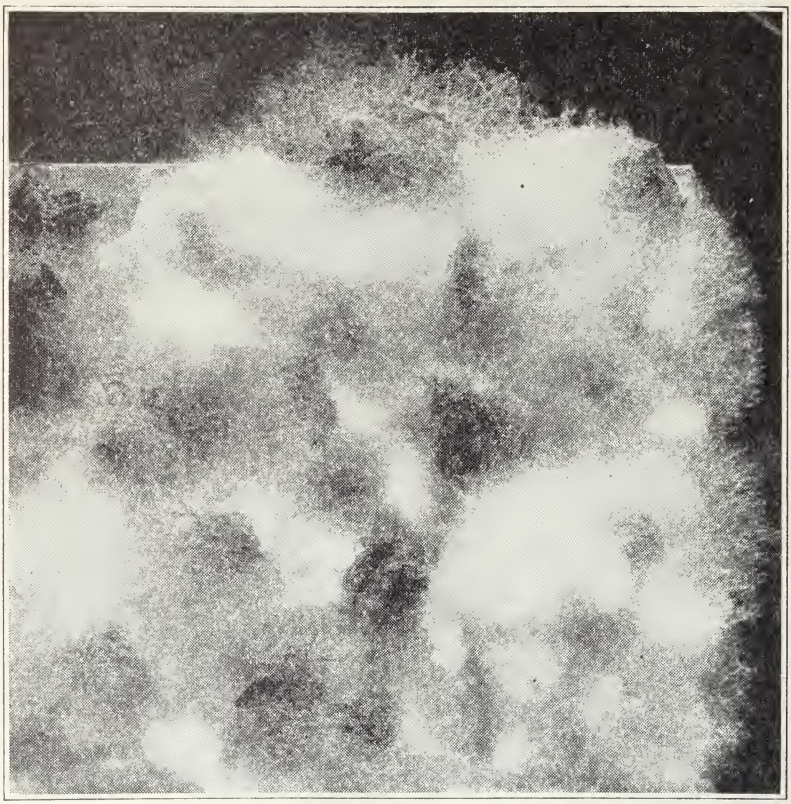

Fig. 74.—Cottony-mold fungus. (From Ext. Cir. 118.)

stoollike bodies with hollow, disk-shaped tops, about ⅛ to ¼ inch in diameter on the surface of the ground (fig. 75). 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 by direct contact with the cottony-mold growth; parts entirely aboveground, such as blossoms or fruits growing on the tree, which are sometimes attacked, can 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 usually per-

sist long enough to attack other plants growing later in the same places. Sometimes in greenhouses the soil becomes permanently infested with the cottony-mold fungus and must either be changed or disinfected before susceptible plants can be grown again. Treatment with steam or with formaldehyde (see "Damping-off," the following section) is effective.

Fig. 75.—Sclerotia (the black bodies) of the cottony-mold fungus developing apothecia (funnel- or toadstool-shaped protuberances) in which spores of the fungus are produced at the surface of the ground. (Natural size.) (From Ext. Cir. 118.)

DAMPING-OFF

Young seedlings often rot at or below the surface of the ground, fall over, wilt, and die. The disease, called "damping-off," begins 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, Fusarium,* and others that cause this trouble.

Treatment before Planting.—The prevention of damping-off[37] in the seedbed 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 inch or half inch (or less with very fine seeds) may be of pure sand. For growing seedlings in flats, a mixture of ⅓ soil, ⅓ peat moss, and ⅓ sand is recommended.

In places where there has been much trouble with damping-off, the soil

[37] 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.

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.[38] 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.

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 pow-

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

dered 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 organic mercury dusts (p. 159) are similarly employed. Manufacturers' directions should be followed.[39]

Treatment after Planting.—Immediately after the seed is planted, the surface of the soil may be sprinkled with formalin, 1 part 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 the 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 Infected Seedbeds 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. 156). Some of the proprietary mercury compounds mentioned above are recommended for this purpose and should be used according to directions on the package. Dry, powdered zinc oxide (p. 161) 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.

DELAYED FOLIATION, DORMOSIS[40]

With most kinds of deciduous fruit trees, a certain amount of exposure

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

[40] For further information, see: Chandler, W. H., M. H. Kimball, G. L. Philp, W. P. Tufts, and Geo. P. Weldon. Chilling requirements for opening of buds on deciduous orchard trees and some other plants in California. California Agr. Exp. Sta. Bul. 611:1–63. 1937.

to low temperature in winter is required to "break the rest" as it is called or, in other words, to cause the tree to start into growth after the dormant season. In occasional seasons following a mild winter, especially in southern California, trees like the apple, apricot, cherry, peach, pear, and walnut fail to develop foliage or bloom and to commence growth at the usual time in spring. At such times, some trees may remain entirely bare until well into summer, while others show very irregular, weak, straggling development. Trees affected in this manner may eventually die back to the main crotches before resuming normal growth.

Little can be done to remedy this trouble after it has developed. Badly affected trees may be sprayed with whitewash to protect the leafless, exposed branches from sunburn. Claims have been made that spraying with certain oil or chemical sprays in early spring help to break the rest period. In districts where delayed foliation is of frequent occurrence, susceptible kinds of trees should not be planted. In some cases (see the discussion of this trouble under "Peach and Nectarine," p. 87) certain varieties are available which are resistant to this trouble. In general, late-starting and late-blooming varieties are more subject to delayed foliation than earlier ones.

LITTLE-LEAF[41]

Little-leaf affects many kinds of fruit, nut, and ornamental trees, and also grapevines. The most striking symptoms, showing soon after growth starts in spring, are rosettes of small, narrow, stiff leaves, especially at the ends of the branches, and yellow mottling of these and other leaves on the trees. In the most severe form, all leaves are mottled and the twigs die back some each year, the whole tree sometimes dying in two or three years.

In California, trees with alfalfa grown in the orchard nearly always show improvement, but they are rarely cured completely. Applications of zinc in some form always cure the disease, unless trees are too far gone for recovery. In somewhat acid soils like those in which pecans are grown in the gulf states, a pound or two of zinc sulfate spread on the soil may be enough to cure a large tree. In some California soils, however, 20 pounds or more of zinc sulfate placed within 2 feet of the trunk may be required to cure a tree, and the benefit may last only a year or two. Unless the soil is sandy and neutral or acid in reaction, it may be better to try some other method of applying zinc, such as: (1) spraying the foliage with a mixture of about 10 pounds of zinc sulfate and 5 pounds of hydrated lime in 100 gallons of water; (2) spraying in the dormant season with 25 to 100 pounds of zinc sulfate to 100 gallons; (3) swabbing

[41] For more complete information, see: Chandler, W. H. Treatment with zinc for little-leaf of deciduous orchard trees. 4 p. California Agr. Exp. Sta. 1935. (Mimeo.)

fresh pruning cuts with zinc sulfate 2 pounds to 1 gallon of water; or (4) driving pieces of zinc or galvanized iron or galvanized nails into the trunk. The best method in each case is mentioned under individual hosts.

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

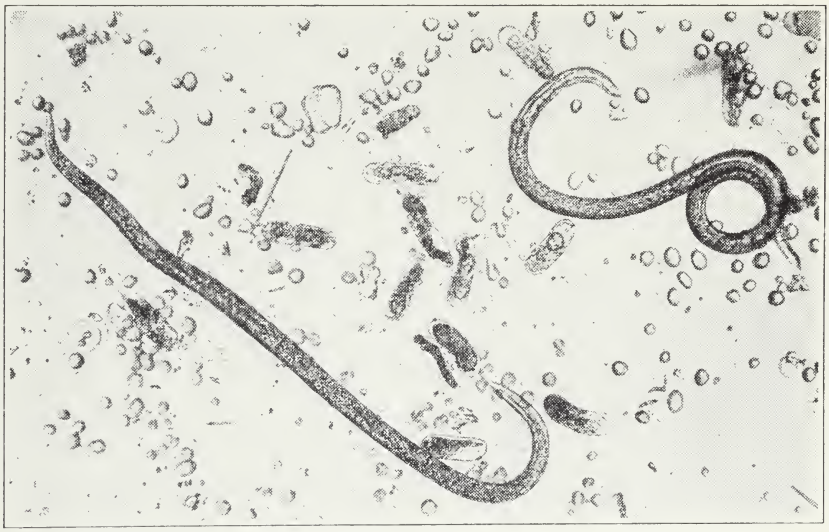

Fig. 76.—The narcissus stem nematode, with young worms and eggs. (Enlarged nearly 150 times.) (From Ext. Cir. 118.)

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 $\frac{1}{32}$ inch (fig 76). These again attack plants when favorable conditions and hosts are available.

The root-knot, or common garden, nematode, *Heterodera marioni*,[42] 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

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

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 corn, sorghum, milo, and kafir, as well as wheat, barley, oats, and rye are highly resistant; and some of these may be grown as a winter crop followed by summer 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. Nematode-resistant fruit-tree roots would be very desirable, but few are available at present. See "Root-Knot Nematode" under individual hosts. *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[43] lists about 50 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 41) discusses this phase of the subject in detail and states that the most promising of these substances are carbon disulfide 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, gloxinia, and others, producing 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. Strawberries, alfalfa,

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

and garlic are among these, as well as narcissus, hyacinth, phlox, and others. 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.

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 their parts, bulbs, or tubers. 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 this respect, since nematode infestation is likely to cause them serious losses in rejected stock.

OAK-ROOT-FUNGUS DISEASE, ARMILLARIA ROOT ROT

This disease is one which attacks and kills many different kinds of plants, especially trees and shrubs. Affected individuals usually show a certain amount of distress before they suddenly collapse and die during dry weather. Sometimes a tree dies suddenly without previous symptoms, and at other times it lingers along making a certain amount of recovery but finally succumbs. From the behavior of individual trees, it might not be possible to distinguish between this trouble and certain others, such as injury by gophers or certain insects, excess water, or other root rots unless the underground part of the plant is examined. In orchards, hedges, and closely planted areas, the disease usually develops from a center, spreading year after year from one tree or plant to another so that in time extensive areas become killed out. Replacements of susceptible species within the affected area ordinarily die within a few years.

Symptoms.—Trees attacked by oak root fungus, *Armillaria mellea*, when examined at the root, show characteristic symptoms. When an affected root is examined by cutting into the bark, the whole substance is found invaded by white or creamy mycelium (fig. 77) in the form of large, conspicuous sheets of fungus growth. In late stages the normal consistency of the root is entirely changed, being first watery and then soft and decaying. The white mycelium is an invariable sign of the disease. It is *never* found in nature on the surface of the root but is always buried within the bark. There is often associated with the white mycelium a gelatinous or gummy material, and in many of the affected trees the margin of the invaded bark gums copiously. The odor of this decayed bark is not sour or putrid but has a sharp, rather agreeable, mushroom smell.

The fungus also penetrates into the sound wood and causes it to become decayed with a uniform white rotting.

Fig. 77.—The oak-root-fungus disease (armillaria) on an oak tree, showing white mycelium and toadstools. (From Ext. Cir. 118.)

The spores of the oak root fungus are produced on toadstools or mushrooms, which are often seen in large clusters about the base of an affected tree (fig. 77). They are usually found in California only in the period

from October to February. The toadstools are light-tan color on the top, with tiny brown scales, varying considerably according to the dryness of the atmosphere. The lower surface (gills) of the toadstool is white or dull white and produces spores, which often appear below the toadstool as a white powder spread over the ground. On the stalk below the top or cap of the toadstool is a delicate ring. The spores which make up the powder beneath the toadstools are capable of growing and reproducing

Fig. 78.—Rhizomorphs of the oak root fungus on the outside of a root. (From Ext. Cir. 118.)

the fungus, but apparently there is little danger of infection of living plants by these spores. While they probably become established only in rotting stumps or similar situations, it seems advisable that the toadstools be destroyed to eliminate all possibilities of establishing new fungus areas.

Rhizomorphs are dark-brown, cordlike, fungus strands which grow out from the infected wood (fig. 78). They often cling to the dead roots or wood in the soil. They may grow for several yards through loose soil, but the length is usually limited, especially in firm soil. They resemble roots but are smooth and shiny and branch in a different manner. When the tip of the growing rhizomorph, which is white, comes in contact with a susceptible root, it penetrates the surface and spreads out in the bark

and cambium into the white fan-shaped sheets of fungus mycelium (described earlier) and causes the rapid death of the invaded part. If conditions are not favorable for their development, rhizomorphs may not form and therefore are not always present.

Susceptible and Resistant Plants.—Nearly all species of trees and shrubs may be attacked. The fungus has also been observed attacking rhubarb, strawberries, iris, calla, and hollyhock, and sometimes the rhizomorphs penetrate potatoes and cause a rot; but annual or short-lived plants are not often injured. A few kinds of trees and shrubs are resistant, and it is very important that all such be determined as promptly as possible, since in many places there is no feasible way of growing susceptible species on infested land. The French pear root is seldom injured by this fungus. The fig and the various black and hybrid walnuts are considered highly resistant but occasionally die from the disease. The apple, cherry, olive, and citrus roots are more resistant than peach, almond, and apricot but not enough so to help the grower very much. The myrobalan has some resistance, and among its different strains or types there may be some which are very resistant to oak root fungus; nothing of this sort as yet, however, can be positively recommended. The persimmon root is very resistant and also the pecan, as far as experience is available. Of shade and ornamental trees, the following have shown resistance: *Acacia decurrens* var. *mollis, A. verticillata, Prunus ilicifolia, P. Lyoni,* and *Sterculia diversifolia;* also various species of eucalyptus and bamboo. A more extensive list of resistant ornamental trees and shrubs can be obtained from the Division of Plant Pathology, College of Agriculture, Berkeley.

Surgical Treatment.—In some affected trees, surgical treatment may be successful. Usually the disease is not discovered until too late. If the roots of the healthy-looking trees immediately surrounding the armillaria spot, those which in all probability will next become affected, are exposed by removal of the soil, the fungus may be detected as it comes in on those roots. Usually only the roots on the side of the tree adjacent to the spot need be examined. All affected roots or diseased parts should be cut out and removed (fig. 79). In case of large roots that give support to the tree and cannot be removed, the diseased bark may be cut off, the surface painted with a disinfectant, and the root allowed to dry by exposure. All wounds should be treated with some disinfectant. An alcoholic solution of corrosive sublimate (p. 159) has given satisfactory results and may be made as follows: 1 part corrosive sublimate, 250 parts denatured alcohol, 750 parts distilled or rain water. This solution should not be held in a metal container. If feasible, it is a good plan to allow the roots to remain exposed for a month or more after treatment to dry out

thoroughly. This kills the fungus without serious harm to the tree roots. If this procedure of opening the crowns and exposing the roots is followed each year, it is possible to prolong the life of the tree for several years and prevent the infested area from increasing in size as it would without such treatment.

Isolation.—Since this parasite spreads through the roots and soil to

Fig. 79.—Surgical work on root of prune tree to arrest progress of oak-root fungus. Diseased bark has been removed in white portion. (From Ext. Cir. 118.)

infest more and more land and kill more and more trees until the orchard is ruined, it is very desirable to restrict the spread as much as possible and at least hold the fungus within the area already infested. It may be necessary to dig out 1 or even 2 rows of good trees around the edge of the oak-root-fungus spot or a solid block may be removed in a badly affected part of the orchard. Some annual crop may then be grown in the cleared area. *Trenching* around the affected area to stop the spread of the fungus has been sometimes recommended. Recent experimentation indicates that this is an unsatisfactory means of controlling the spread unless the

trench is left continuously open and this is seldom feasible. When the ditch is filled with soil, the rhizomorphs rapidly grow through the uncompacted earth and infect healthy roots on the opposite side. Twigs and debris, often mixed with the soil returned to the trench, facilitate the growth of the fungus through the soil by affording it nourishment. Trenching is therefore not recommended as a satisfactory means of control and is to be used only where it can be left open permanently and dug sufficiently deep that no roots grow under it.

A solid wall or *barrier* of some kind in the trench has been suggested, but this is seldom practicable. A barrier of galvanized sheet iron has been successfully used in one case to wall off the fungus and may have promise where the cost is not prohibitive. A trench was dug to a depth of about 7 feet and lined on the side opposite the infected area with sheets of galvanized iron having bent interlocking edges. Care must be taken that the barrier is located beyond the infected area and that no rhizomorphs or diseased roots are outside this wall; otherwise it would be useless. The galvanized iron should extend from the bottom of the trench to or above the surface of the ground. To protect the iron against corrosion, it may be painted with hot asphalt or asphalt emulsion.

Soil Disinfectants.—Carbon disulfide has been used for killing the fungus in the soil and under proper conditions is capable of doing so. All living trees and vegetation are killed at the same time, but the fumes soon disperse so that the area can be replanted. It is usually best to take out all trees and shrubs in the affected spot before treatment, and in an orchard this means that at least one and possibly two rows of apparently healthy trees around the edge must be sacrificed to get to the limits of the infestation. If any diseased roots are discovered on such trees, they should be traced back for several feet and removed, and the soil should be treated beyond the point where the last trace of the fungus was found. Care should be taken that diseased roots are not scattered but are collected and thoroughly dried. Blasting is not recommended since pieces of affected roots may be blown to considerable distances and set up new points of infection. In using carbon disulfide, all roots in the first foot of soil should be very carefully removed; below that depth no special care is necessary, after pulling the trees, to get out all the roots in the infested area. In the lighter types of soil, satisfactory results have been obtained by applying 2 ounces by weight (equals 1⅘ ounces liquid measure) of carbon disulfide in staggered holes in rows 18 inches apart each way. The 2-ounce dose is sufficient to kill the fungus to a depth of 5 or 6 feet, but if many roots penetrate below this depth, a heavier dose will be necessary. The holes should be immediately plugged with soil and tamped. Since this material is heavier than air, it should not be applied

at too great a depth, otherwise a satisfactory kill will not be obtained at the surface of the ground. For light sandy soils, the depth of application should be about 8 to 10 inches and in moderately heavy soils not more than 6 to 8 inches.

It is essential that all of the affected area be thoroughly treated if the spread of the fungus is to be stopped. Treatment of the hole made in the removal of a diseased tree is not sufficient. Determining the extent to which the fungus has penetrated the soil or extended on the roots is difficult. Consequently, for safety, the treatment should be extended somewhat beyond the probable limits of fungus penetration even though apparently healthy vegetation must be sacrificed. If the application of carbon disulfide is closer than 6 feet to a healthy tree, there is danger of injury; there is probably danger in going closer than the drip of the branches.

Results to date indicate that spring and summer applications are the most certain to cause a kill of the fungus. The surface of the ground should be moistened to a depth of 4 or 5 inches either before or *immediately* after applying the material to prevent loss of the gas from the surface of the soil. The carbon disulfide may be applied to small areas with a suitable measuring device by emptying it into a hole made with an ordinary crowbar driven into the ground to the desired depth. Hand devices to inject a measured quantity into the soil are also available on the market at reasonable prices. For the treatment of large areas, power equipment in the form of a subsoiler, drawn by a tractor, may be purchased or rented from the carbon disulfide manufacturers on the Pacific Coast.

SOIL DEFICIENCIES

It is a well-known fact that plants require for their 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, potassium, 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 failures which seem to be connected with a lack of one of the other two elements (see "Dieback" under "Plum, Prune," p. 112). Certain obscure plant troubles which are characterized by very specific pathological symptoms (see "Little-leaf," p. 141;

"Exanthema," p. 17; and "Drought Spot," p. 16) seem to be due to deficiencies of some of the less-common or so-called "micro" elements, or at least they are corrected by supplying them. Chlorosis, due to lack of available iron, is another example. Symptoms caused by excess of certain substances (see "Alkali, Boron, Salt," p. 135), may not be unlike those due to deficiencies.

In cases where plants fail to develop normally 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 more specific 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 in the preceding paragraph. 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.[44]

VERTICILLIUM WILT, VERTICILLIOSIS[45]

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 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.

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 irriga-

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

Proebsting, E. L. Fertilizing deciduous fruit trees in California. California Agr. Exp. Sta. Bul. 610:1–29. 1937.

[45] For more complete information, see: Rudolph, B. A. Verticillium hadromycosis. Hilgardia 5(9):197–360. 1931.

tion 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.

WOOD DECAY[46]

In wood decay, the heartwood of trunk or branches rots and disintegrates, which weakens the tree so that limbs break off or die; resistance to insects, diseases, and injuries is lowered; the life of the tree is shortened; and it is more likely to be tipped over by heavy winds. Decay of this sort is caused in most cases by some of the so-called "bracket fungi," which are closely related to toadstools or mushrooms. Certain insects, like beetle larvae and termites, complete the destruction of the wood. The brackets, or sporophores, that grow out on the surface of affected trees are characteristic of various fungus species (fig. 80), and contain the spores of these organisms. The decaying wood is permeated by the mycelium, or spawn, of the fungus, and it is this which causes the real damage. Most of these fungi are saprophytic or only very weakly parasitic. That is, they live mainly in the heartwood, which is dead, and injure the tree indirectly by gradually wearing down its strength and vitality.

Wood-decay fungi are not able to enter trees through the sound, living bark but usually get in through wounds, pruning cuts, insect injuries, sunburn, fire scars, frost lesions, dead branches, cankers, and similar openings. Infection is by spores carried by wind, birds, or insects from sporophores on the same or other trees or from dead wood.

Since wood decay usually begins in wounds or dead or weakened tissue, it naturally follows that prevention must lie along the lines of avoiding these conditions as much as possible and protecting such wounds as do occur, in order to prevent infection and promote healing. In orchard and shade trees, wood decay starts most commonly in pruning cuts, in the stubs of broken-off and dead branches, or in places where the bark has been killed by sunburn and other injuries. Borers are also often re-

[46] For further information on this subject, see:

Collins, J. Franklin. Treatment and care of tree wounds. U. S. Dept. Agr. Farmers' Bul. 1726:1–38. 24 figs. 1934.

Blair, Millard F. Practical tree surgery. 297 p. 89 figs. Christopher Publishing Co., Boston, Mass. 1937.

sponsible for the beginning of wood decay. To prevent this trouble, trees should be shaped up as early as possible to avoid making large cuts. Heavy limbs should be supported by cables or wires, or, when loaded with fruit, with props to prevent breaking down. Broken, badly diseased, or dead branches should be cut off. All cuts should be made with sharp

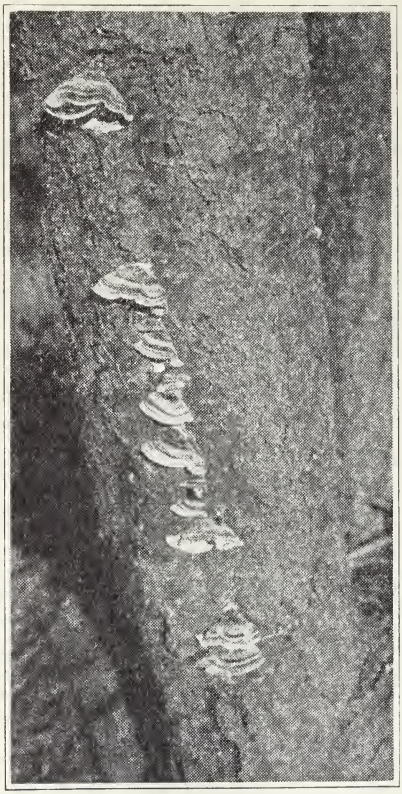

Fig. 80. Sporophores of a wood-decay fungus. (From Ext. Cir. 118.)

tools close to the trunk or supporting limb, and no projecting stubs or torn-down splinters left.

It is also possible to accomplish a good deal with trees affected with wood decay by treatment to prevent further progress of the disease and remedy damage already done. In the case of patches of wounded, injured or diseased bark on the sides of the trunk or large limbs, it is sometimes possible to cut this out, leave the wood exposed, and save the tree or limb if the lesion is not too large, say less than half the circumference. In such cases, the affected bark should be cut out with a very sharp tool, making a clean, even edge where sound bark is reached.

All cuts of much size where the wood is exposed should be treated and covered in some manner. The ideal tree paint has not yet been developed, although a great variety of materials has been recommended. The marginal healing of wounds is often more rapid if no dressing at all is applied, but, unless the cut is a very small one, the exposed wood is almost certain to crack and become infected with wood-decay fungi. As a matter of fact, even if the surface is painted, there is scarcely any sort of covering which will remain intact on a good-sized cut long enough to prevent cracking until the wound is entirely healed over, if only one application is made. Whatever dressing is used, the work must be watched from year to year and repainted as often as necessary to keep open cracks from forming. Most of the work which is done to protect wounds is wasted on account of lack of this precaution. On the other hand, if a thick, greasy, moisture-retaining, nondisinfecting covering is put on, it may hold in the moisture and furnish an ideal place for the development of fungi.

The substances most commonly used by professional tree workers are crude creosote and asphaltum, the former as an antiseptic and also as a solvent for the latter, which is used as a covering. Hot, melted asphaltum covers well but is rather troublesome to use, has no antiseptic properties, and sometimes injures the cambium. A water emulsion of asphaltum (Tree Seal, Tree Heal, Pioneer Asphaltum Emulsion) is extensively used for tree work and is satisfactory as far as covering wounds is concerned, but the wood under it often rots. Asphaltum dissolved in crude creosote makes a favorite tree paint, using about ¼ to ½ creosote (by weight). The quickest method of mixing is first to melt the asphaltum and then stir in the creosote. The latter is very inflammable and should not be exposed near an open flame. Creosote is injurious to some kinds of trees, particularly when it comes into contact with exposed living tissue. The peach, plum, cherry, and prune are especially sensitive to this substance, and one should proceed cautiously in these cases. There is much variation in different grades and types of material found on the market under the name "creosote." Gasoline is also used for dissolving asphaltum. Another paint is made by melting asphaltum and, before it cools, adding linseed oil and turpentine until the right consistency is obtained. This has no antiseptic effect and may run in hot weather; it is also sometimes injurious. Before applying any of these liquid asphaltum mixtures, the cambium and a strip about ½-inch wide on either side of it should be painted over with heavy shellac.

Ordinary lead paint may be used for a wound covering and is perhaps as good as anything for small cuts. But it is not antiseptic and some kinds of trees are injured by it.

With any paint which does not disinfect, the cut may first be treated

with corrosive sublimate solution 1–1,000 (p. 159), or copper sulfate (bluestone) 1 ounce to 3 quarts of water. The effect of these substances does not last very long, and unless the surface covering is kept intact, they are practically useless.

Another paint having disinfecting properties is made by mixing powdered, commercial, "one-package" bordeaux mixture (p. 156) or powdered copper carbonate with raw linseed oil. This makes a good disinfectant and covering, but on large cuts the wood is apt to crack beneath it.

Several commercial tree paints are on the market, such materials being offered by some of the large paint companies.[47] Whatever paint is used, the main point is to keep the surface covered and the wood disinfected and protected from cracking until the cut or wound is entirely healed over. This result is seldom attained, and it is unfortunate that there is no effective, cheap, one-application material for this purpose.

Sunburn should be prevented as much as possible by keeping the trunks of young trees covered with whitewash. "Outside white" cold-water paint is one of the best and most convenient materials for this purpose. This may be purchased in the form of dry powder to be mixed with water. The same treatment should be applied to trees which have had their tops reduced by top-grafting, frost injury, or any other cause. Trees which have wood decay and dieback resulting from sunburn, weakness, and insect attacks due to drought, poor soil, or neglect, naturally cannot be restored to a sound state as long as these conditions continue.

Cavities already formed in trees by wood decay, if not too far advanced, may in skillful hands, be excavated, treated, and filled in such a manner as to arrest their progress, permit healing of these wounds, and strengthen the trees to withstand storms. Cement is the material most commonly used for filling although in some cases other materials are used, like rubber, magnesite, or asphaltum mixed with sawdust. Cavity work requires a high degree of skill and experience (not to mention honesty) and should not be attempted by the novice. Much of the work of this sort which has been carried on has done more harm than good. Directions are given in the publications listed in footnote 46 (p. 152).

[47] A black, antiseptic, asphalt-base paint put out by the Bartlett Manufacturing Company of Detroit, Michigan, has been well recommended for tree work; the material called "Oronite Roofing Paint" is popular in California for the same purpose.

FUNGICIDES AND OTHER CHEMICALS USED IN THE CONTROL OF PLANT DISEASES[48]

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

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 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 onto 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 Mixtures.—Several commercial brands of bordeaux mixture in a powdered or paste form are on the market. These are

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

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 the 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 fungicide is prepared by thoroughly mixing together finely pulverized copper sulfate 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 and is also showing promise as a spray material, suspended in water. (See "Blight, Bacteriosis," p. 125.) 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 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 also claim to be less liable to cause burning than bordeaux mixture. It is impossible in a publication of this sort to evaluate these preparations fairly, most of them being 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.

There are also cases where bordeaux mixture causes burning or injury to the plant.

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, Mercuric Chloride.—This is 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 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. Mercuric chloride, often called "mercury bichloride," 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, Ceresan, etc.).—A number of mercury preparations are on the market which have much value for seed and bulb treatment, soil disinfection, and control of damping-off. These 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.

Pear-Blight Disinfecting Solution.—The mixture mentioned on page 102 for disinfecting tools and wounds in connection with the removal of pear-blight infections is of value in similar work on other diseases. The formula is as follows:

Corrosive sublimate (mercuric chloride)..	1 ounce
Mercuric cyanide	1 ounce
Distilled water	3½ gallons
Glycerine	½ gallon

This solution is poisonous to animals.

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 several types and many brands of dusting sulfur, 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. The apricot, cantaloupe, and strawberry are particularly susceptible to sulfur, and it is seldom safe to dust or spray any of these plants with this fungicide.

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.

It is a very caustic material and is used either 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.

Carbon Disulfide.—This volatile, inflammable liquid is used as a fumigant against insects and also in the treatment of soil against the oak root fungus, *Armillaria mellea*. For the latter purpose, pure carbon disulfide should be used and not the water emulsion which is now available.

ZINC

Zinc Chloride.—This is a white, water-absorbing powder which is used in the treatment of fire-blight cankers in fairly large limbs according to the formulas given on page 103.

Zinc, Metallic.—Pulverized metallic zinc in the form of a fine, gray powder is sometimes used for dusting citrus trees to cure mottle-leaf. (See p. 63.) This may be mixed with sulfur.

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.

Zinc Sulfate.—This material, which is used in the treatment of little-leaf and also as a fungicide (p. 62), comes in the form of white, efflorescent crystals which are soluble in water.

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 manufacturers' 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 amount. 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-sulfur.

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 insecticide 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 spray when the ground is too muddy for wheeled vehicles, airplanes are sometimes used. For 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. Airplane spraying has no value for the ordinary grower, but large operators are applying it with considerable success for treating orchards as well as for dusting crops with sulfur or other dry materials. Further information on this subject may be obtained by writing the Division of Plant Pathology, College of Agriculture, Berkeley.

ACKNOWLEDGMENTS

In the present circular much new information has been contributed by staff members of the Division of Plant Pathology at Berkeley, Davis, and Riverside, and others of the College of Agriculture who are especially acquainted with the diseases of certain crops, and to whom acknowledgment is due for such assistance. The extensive collection of records and photographs left by the late Elizabeth H. Smith, covering more than twenty-five years of observation of plant diseases in California, has been of great service in this connection. In a number of cases information taken from the Plant Disease Reporter[49] has been utilized.

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

INDEX

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