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DISEASES OF FIELD CROPS

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CONTENTS

DISEASES OF FIELD CROPS

RALPH E. SMITH[1]

INTRODUCTION

DISCUSSED IN THIS CIRCULAR are diseases of crops which may be classed as cereals, forage plants, and other field crops. Similar circulars on diseases of truck crops, diseases of fruits and nuts, and diseases of flowers and other ornamentals, are being issued. Beans, beets, and corn, grown sometimes as field crops and sometimes as truck crops, are, for convenience, included in both this circular and the one on diseases of truck crops, even though some duplication of material results.

The main purpose of this circular and the others in this series on diseases[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

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[2] 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 120, *Diseases of Fruits and Nuts.* 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.

up trying to fight adverse conditions and change to some other kind of plant that is easier to grow on his farm.

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 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, mildews (fig. 16, p. 24), smuts (figs. 11 and 12, p. 18 and 19), and rusts (figs. 31 and 38, p. 51 and 62) 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 (figs. 36 and 43, p. 60 and 69) 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 (see footnote 2, p. 3), to which reference is made in each case.

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

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

If there is difficulty in diagnosing a disease, help can be obtained from the county farm advisor or it may be desirable to send specimens to the

Division of Plant Pathology, University of California, Berkeley, or Davis. 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 the culture of many 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 on 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. Several references on insects or plant diseases are of general interest in California.[3]

[3] Among these, the following may be mentioned:

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

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

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

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

DISEASES BY CROPS

ALFALFA[4]

Bacterial Blight.—Brown, elongated, dead spots on the stems of alfalfa plants form the symptoms of this disease. The spots may be small and shallow or some of them large and deep enough to kill the stems. Similar but roundish spots may appear on the leaves. Bacterial blight,

Fig. 1.—A group of alfalfa plants affected with bacterial wilt. The dwarfed condition of the plants and the abnormality of the leaves are clearly evident when compared with the healthy plants shown in the background. (Courtesy of F. R. Jones, United States Department of Agriculture; from Cir. 326.)

caused by *Phytomonas medicaginis,* is common in California but attacks alfalfa only after freezing weather, so that the effects are not seen much except in the spring on the first cutting. After a cold winter, there may be a considerable loss in the alfalfa hay crop on account of this disease. The later cuttings are not affected. No method of control is known.

[4] For further information, with descriptions and illustrations of diseases see:

Madson, B. A. Alfalfa production. California Agr. Ext. Cir. 35:1–47. 3 figs. Revised 1933. (Out of print.)

Weimer, J. L., and B. A. Madson. Alfalfa diseases in California. California Agr. Exp. Sta. Cir. 326:1–19. 7 figs. 1932. (Out of print.)

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

Bacterial Wilt.—The name "wilt" does not describe this disease very well because wilting is not a characteristic symptom. Affected alfalfa plants are stunted, with shortened internodes and small, pale-yellow

Fig. 2.—Root of alfalfa plant affected with bacterial wilt, showing the characteristic dark-brown areas found on the inside of the bark and sometimes on the wood. Such spots have never been found on plants affected with alfalfa dwarf. (Courtesy of Jones and McCulloch; from Cir. 326.)

leaflets (fig. 1), and gradually die. When the bark is peeled back from the taproot, the outermost part of the woody cylinder shows a straw-yellow to brownish-yellow color as contrasted to the normal white of

healthy plants. Sometimes reddish-brown, cankerlike lesions or pockets are formed in the woody tissue just beneath the bark of the taproot (fig. 2). The causal organism is *Phytomonas insidiosum*. This disease, which at present is most abundant in the San Joaquin Valley, thins the stand of alfalfa and shortens its life one half or more. It may be spread by irrigation or flood water, agricultural implements, animals, workmen, hay, or almost anything which moves from an affected alfalfa field

Fig. 3.—Spore mat of the cotton-root-rot fungus in an alfalfa field. (Courtesy of the Arizona Agricultural Experiment Station.)

to one where bacterial wilt is not present. All varieties of alfalfa grown in California are susceptible.

There is no way of controlling bacterial wilt when it once gets into a field, but certain methods may be suggested for delaying its spread and development. Water should not be allowed to run from an affected field onto a new one. In harvesting hay, the younger stand should be cut first so as not to spread the disease by running the mower from the old field to the new. When the stand becomes too thin to be profitable, the field should be plowed and all the alfalfa plants killed out just as completely as possible. Some other crop should then be grown on the land for at least two years.

Cotton Root Rot, Texas Root Rot, Ozonium Disease.[5]—The affected alfalfa plants wilt and die on account of a rotting of the roots. The disease starts in a small spot in the field and works outward, killing the plants in a circular area. When moisture is abundant, the fungus, *Phymatotrichum omnivorum,* may sometimes be seen on the surface of the soil at the margins of the affected areas; there it forms a moldy coating which is at first white and then buff-colored (fig. 3).

Texas root rot attacks cotton, alfalfa, and a great many other plants, shrubs, and trees and is a very serious trouble in some of the states southeast of California in localities with high summer temperatures. It has appeared in alfalfa fields at a few isolated points in the desert region of southeastern California, and report should be made at once to the county agricultural commissioner if any suspicious cases are seen.

There is a California quarantine against bringing into the state any plants with roots and soil attached, from districts where this disease occurs.

Cottony Rot, Stem Rot.—In this disease, some of the stems wilt and rot off near the surface of the ground, and an abundant, cottony, snow-white mold, *Sclerotinia trifoliorum,* covers the affected parts and the surrounding vegetation and soil. Roundish, black bodies sometimes larger than sweet-pea seed, develop in this mold and on or inside the affected stems. The disease is most common in wet weather or in thick stands of heavily irrigated alfalfa. A similar fungus causes cottony rot of lemons, green rot of apricots, and stem rot of many other plants. See "Cottony Mold" (p. 66). No control treatment is practicable.

Crown Rot.—Affected plants become sickly and stunted and die, the stand is thinned, and its life shortened. A dry rot causes hollowing of the crowns and main roots. Alkali, poor drainage, and high water table contribute to this effect, but there appears to be some other, more specific cause at present unknown. This or a similar disease has recently been attributed to the fungus, *Stagonospora melilotii.*

Crown Wart.—Rounded, fleshy, irregular tumors (fig. 4) develop at the crowns of affected plants near the surface of the ground, the plants are gradually weakened, and the life of the stand shortened. This fungus disease, caused by *Urophlyctis alfalfae,* resembles crown gall of fruit trees. Crown wart is common but not very destructive in California. Do not replant badly affected fields with alfalfa for several years.

Dodder, Love Vine.—This parasitic plant, a species of *Cuscuta,* forms

[5] For a complete account of this disease see:
Streets, R. B. Control of Phymatotrichum (cotton or Texas) root rot in Arizona. Arizona Agr. Ext. Cir. 103:1–80. 1938.
Streets, R. B. Phymatotrichum (cotton or Texas) root rot in Arizona. Arizona Agr. Exp. Sta. Tech. Bul. 71:293–410. 1937.

a mat of yellowish threads that entwine the alfalfa plants and cause serious injury. The parasite has minute flowers, and seeds about the same size as those of alfalfa.

The best prevention is to avoid planting dodder seed with the alfalfa. The State Department of Agriculture, Sacramento, maintains a laboratory for testing seeds for purity, to which samples may be sent. Small patches of dodder may be killed by mowing the affected alfalfa and, when dry, burning it in place with other dry material or kerosene. If the roots have been killed, the spot may be reseeded afterwards.

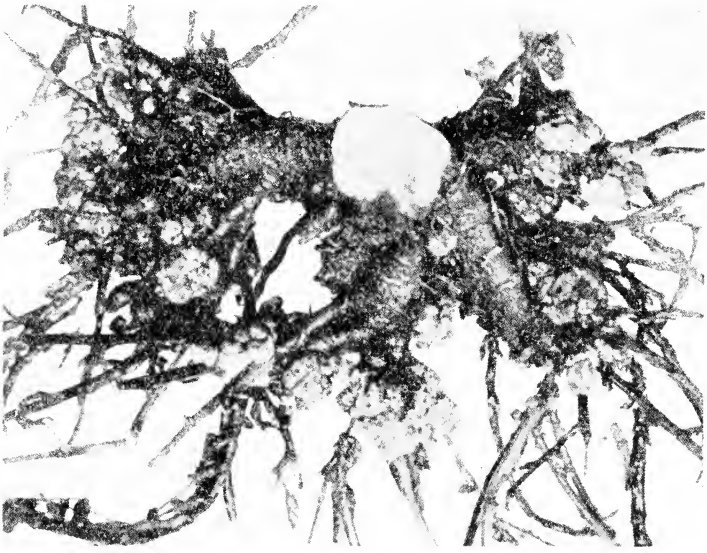

Fig. 4.—The crown of an alfalfa plant, showing the warts, or galls, produced by the crown-wart fungus. (Courtesy of Jones and Drescher; from Cir. 326.)

Downy Mildew.—In this disease of alfalfa, the upper leaves become partly yellow with the edges turned down. The lower sides of the leaves develop a delicate, fuzzy, violet-colored fungus growth, *Peronospora trifoliorum*. The disease is common in winter and spring but not very destructive. It disappears with dry weather.

Dwarf.—Affected plants usually show a few normal stalks and numerous short, fine stems with small leaves coming from the crown (fig. 5). The yellow color of the leaves which characterizes bacterial wilt is usually absent in this disease; in fact, the color is apt to be of a darker green than normal. Roots show yellow, discolored bands or streaks in the wood. This disease, which is apparently caused by a virus, is found mostly in southern California. Badly affected fields should be handled as advised under "Bacterial Wilt" (p. 7).

Fusarium Wilt.—Affected plants turn yellow, wither, and die as in other diseases of this type. The fungus, *Fusarium oxysporum* var. *medicaginis,* is found in the brown, woody tissue of the crown and stem. Such

Fig. 5.—Healthy and diseased plants taken from a four-year-old field of Chilean alfalfa affected with alfalfa dwarf. Note the dwarfed growth and small leaves of the diseased plants. The roots of plants affected with dwarf are usually as large as those of healthy plants. (From Cir. 326.)

treatment as is practical is described under "Handling Alfalfa for Disease Control" (p. 14).

Leaf Spot.—In leaf spot, the commonest alfalfa disease in California, the leaves are marked with definite dark-brown spots (fig. 6) and fade and drop early if the disease is abundant. The stalks and leaf stems may

also show similar spots. Small, dark-colored, raised disks or blisters in the centers of the spots distinguish this disease from all other fungus spots on alfalfa leaves. The organism that causes this disease is *Pseudo-*

Fig. 6.—Characteristic leaf spot of alfalfa: *A*, upper surface of leaves; *B*, lower surface of leaf. These spots are usually larger than rust spots and differ somewhat in color, so that the two diseases can be readily distinguished. (From Cir. 326.)

peziza medicaginis. Early cutting of heavily infected fields before the leaves begin to fall is recommended.

Mosaic.—Plants affected with mosaic, a virus disease, are slightly

dwarfed and the leaves somewhat mottled. It is seen mostly in the first crop, and is not serious.

Root-Knot Nematode.—Although alfalfa is not seriously damaged, farmers should understand that it is by no means immune to this omnivorous pest (*Heterodera marioni*), and should not be planted in a rotation designed to starve out nematodes. (See general discussion p. 68.)

Rust.—Alfalfa is attacked by a true rust, *Uromyces striatus,* which causes powdery, dark-brown dots on the leaves, mostly on the undersides (fig. 7). The diseased leaves drop off and, if rust is abundant, the hay

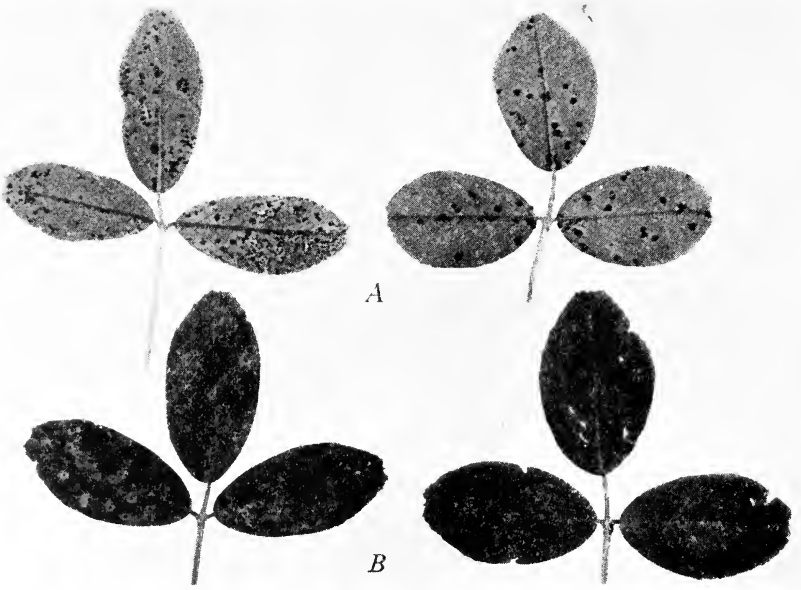

Fig. 7.—The appearance of rust: *A,* lower surface of leaves; *B,* upper surface. Rust pustules are usually most conspicuous on the undersides of the leaves. (From Cir. 326.)

crop is much reduced both in quality and quantity. The same treatment is recommended as for leaf spot.

Stem Nematode.—This nematode, or eelworm, *Ditylenchus dipsaci* (see p. 68), lives in the stems of the alfalfa aboveground, with the effect that some of the stalks and branches are short, swollen, and deformed (fig. 8). The yield is reduced and the life of the stand shortened. This parasite is a strain of the bulb nematode, which attacks narcissus and other flowering bulbs. Other strains of the same species attack garlic, strawberries, cereals, certain weeds, and other plants. The strain from one host does not usually pass to another: the alfalfa stem nematode, for instance, does not attack bulbs or strawberries, although the worms in the different hosts seem to be of the same species.

Alfalfa seriously affected with nematode should be plowed up and the land kept in a cultivated crop for at least three years with special care to completely kill out every plant of alfalfa.

Yellow Leaf Blotch.—This is a leaf-spot disease caused by the fungus *Pyrenopeziza medicaginis*. It is distinguished from ordinary leaf spot, which is caused by a different fungus (p. 11), by the fact that the spots

Fig. 8.—Effects of stem nematode on alfalfa.

are of a bright yellow or orange color, with little black dots, mostly on the undersides. The disease is not usually serious in California but may occasionally cause enough defoliation to lessen the crop. For control, see the following paragraph.

Handling Alfalfa for Disease Control.—Generally speaking, in California, the foliage diseases of alfalfa are worst on the early crops before the end of the rainy season. After this cutting is disposed of, diseases like rust, leaf spot, and downy mildew usually disappear. When the stand becomes weakened by these or other diseases, the only treatment is to keep the plants growing as well as possible by good irrigation, cultiva-

tion, or renovation, and applying stable manure. When the stand gets too thin to be profitable and has to be ploughed out, every alfalfa plant should be destroyed and, if possible, the land should be kept in some clean-cultivated crop for two or three years.

BARLEY[6]

Bacterial Blight.—The disease attacks the young leaves in the form of small, water-soaked spots which enlarge into irregular, brown blotches

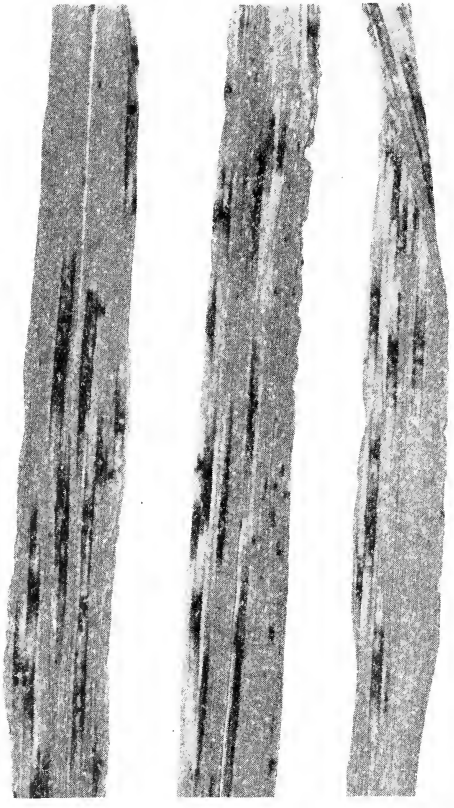

Fig. 9.—Net blotch of barley. (From Bul. 511.)

or stripes. Small gray drops or beads of bacterial exudate ooze out and dry on both surfaces. The cause is *Phytomonas translucens.*

This disease is not a serious one in California. Seed treatment for other

[6] For further information on barley diseases see:

Johnson, A. G., R. J. Haskell, and R. W. Leukel. Treat seed grain. U. S. Dept. Agr. Misc. Pub. 219:1–7. 4 figs. Revised 1937.

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

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

diseases (p. 21) helps to control it, especially if a mercurial fungicide is used.

Covered Smut and Loose Smut.—See "Smut" (p. 17).

Mold.—See this disease under "Wheat" (p. 58).

Net Blotch.—In net blotch, small, light-brown spots appear on the leaves of barley (fig. 9) and wild barley grass after the first fall rains, and sometimes considerable damage to the plants is caused by this fungus, *Helminthosporium teres.*

No control is possible except by using resistant varieties. Tennessee Winter is the most resistant California variety. Seed treatment is not effective.

Powdery Mildew.—A grayish-white mildew sometimes appears on the leaves in moist weather, and weakens and stunts the plants. The same fungus, *Erysiphe graminis,* attacks other grains and grasses.

There is no special method of control. A number of resistant varieties are known, some of which are now being used for breeding purposes in order to develop resistant types adapted to California conditions.

Root Rot.—See "Wheat" (p. 59).

Rust.—Two types of rust, caused by different species of fungi, attack barley. Stem rust, caused by *Puccinia graminis* var. *tritici,* attacks the leaf sheaths enclosing the stem and produces long, dark-red pustules of dusty spores (figs. 31 and 38, p. 51 and 62). This is not a serious disease of barley in California, although forms of the same fungus are very destructive to wheat. Leaf rust, caused by *P. anomala,* produces small, light-red, dusty pustules which may almost cover the leaf surface. This disease sometimes causes severe injury to barley, and also attacks wild barley grass.

The most promising control method for cereal rusts lies in the development of resistant varieties. In the case of leaf rust of barley, no good resistant varieties for California are available at present. For latest information, consult the Division of Agronomy, College of Agriculture, Davis.

Rusty Blotch.—This disease is characterized by irregular, large, rusty-brown spots of a fungus, *Helminthosporium californicum,* which appear on the leaves late in spring and cause considerable injury. Seed treatment is not effective. Chevalier barley is immune.

Scald.—This disease severely attacks the leaves and sometimes the head which show spots with brown margins and bleached centers (fig. 10). The affected leaves die and wither and the grain is shriveled. Early-sown barley is the most severely attacked. This is the most destructive disease of barley in California, and is caused by a fungus, *Rhyncosporium secalis.*

Seed treatment is not effective. The varieties Sacramento, Vaughn, and Abyssinian are reported to be resistant. Recently more resistant varieties useful for breeding have been discovered.

Smut.—There are two types of smut—covered and loose (fig. 11)—

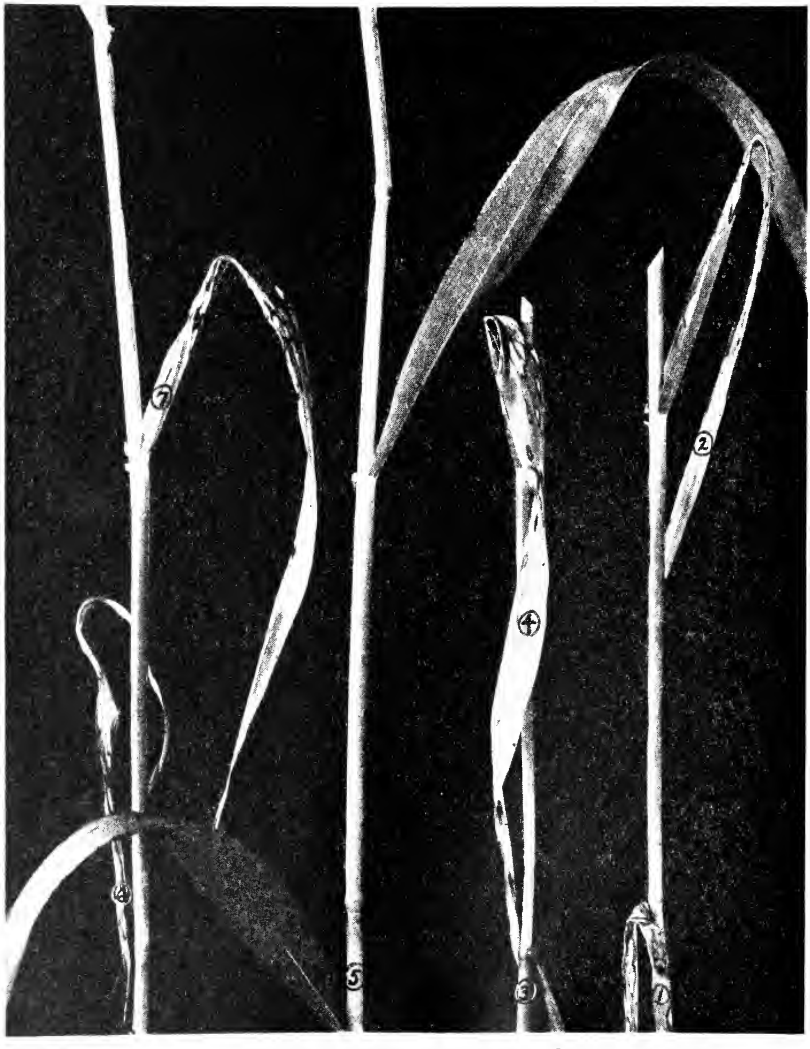

Fig. 10.—Leaf pruning of wheat through scald attack: nos. 1, 2, 3, 4, 6, and 7 show scald; no. 5 is a scald-free plant. (From Bul. 511.)

that attack barley. In both, the kernel is changed into a mass of dark-brown, dusty smut spores and entirely ruined. In the case of covered smut, caused by *Ustilago hordei*, the affected grains are fairly solid and covered at first with a thin grayish membrane. Infection in this disease

takes place in the young seedling, usually from spores (fig. 12) that were sticking to the surface of the seed. The smut fungus grows up in the form of invisible threads inside the barley plant and produces smut again in the new grain.

Fig. 11.—Barley smuts: covered smut on left, loose smut on right.

In loose smut, caused by *U. nuda*, some of the young kernels are converted into black, loose masses of smutty powder which shake off, and leave the stalks bare. The spores which compose this powder blow about in the air and some of them lodge in the healthy flowers. Here the fungus grows into the very young kernels. Such kernels develop into normal-looking grains. If they are planted the next season, however, the smut fungus which is inside starts to grow as the seed germinates and spreads upward in the plant through the stem and into the new flower and seed parts. Such flowers then produce masses of smut spores again instead of

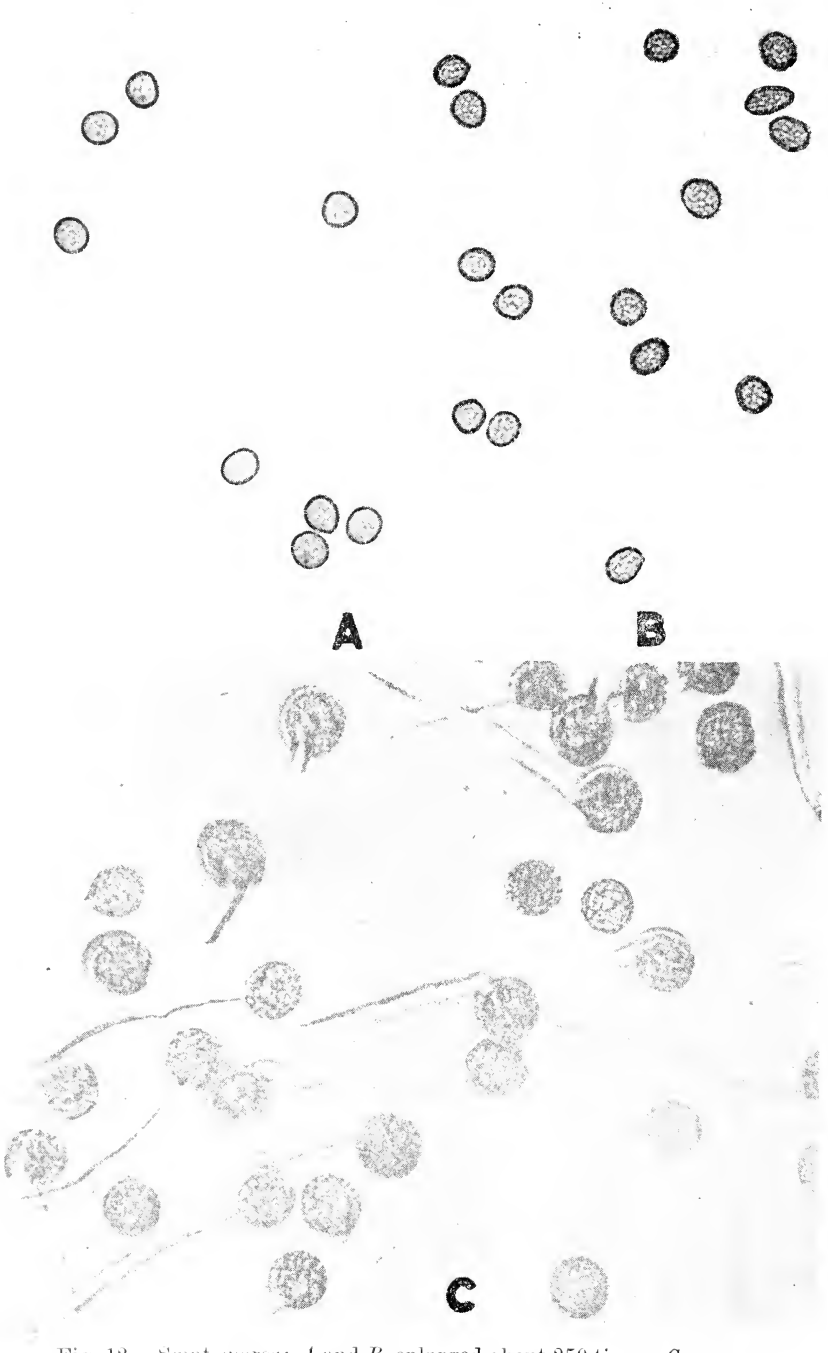

Fig. 12.—Smut spores: *A* and *B*, enlarged about 250 times; *C*, spores germinating. (From Bul. 511.)

normal grain. In loose smut of barley there is also some infection of young seedlings by spores on the surface of the seed.

Since loose smut is rarely found in California, seed treatment is unnecessary. Covered smut, on the other hand, is likely to cause severe losses when untreated seed is used. Careful and continuous use of copper carbonate or New Improved Ceresan will control both covered smut and stripe disease. See page 21 for details of barley seed treatment.

Fig. 13.—Spot, or late, blotch of barley on the dorsal and ventral sides of barley leaves: *A*, large form of blotch; *B*, small form of blotch. (From Bul. 511.)

Spot Blotch.—Large, dark-brown spots (fig. 13) appear on the leaves late in the growing season, and sometimes kill the leaves or cause the grain to shrivel. The same fungus, *Helminthosporium sativum*, attacks wheat.

Seed treatment (p. 21) gives partial control. The varieties Velvet, Comfort, Glabron, and Vaughn are reported to be resistant.

Stripe.—Long, dark-brown stripes develop on the leaves (fig. 14) and destroy the tissue so that the leaf separates into ragged strips. This fungus disease, caused by *Helminthosporium gramineum*, produces considerable loss in barley, the plants attacked seldom produce grain.

Demonstrations by the Agricultural Extension Service and the Division of Agronomy have shown that stripe can be effectively controlled by regular treatment of seed barley every year with copper carbonate. Even better control can be obtained, especially with badly infested seed,

Fig. 14.—Stripe disease of barley.
(From Bul. 511.)

by the use of New Improved Ceresan. See the following paragraphs for details.

Seed Treatment for Barley Diseases.—Several different methods are available for the treatment of seed barley to control some of the diseases described above.

Covered smut, loose smut, and stripe may best be controlled by New Improved Ceresan, a proprietary mercury dust compound (p. 74). The seed, before planting, should be thoroughly mixed and coated with the

dust at the rate of 1 ounce per 100 pounds of seed. This should be applied with a rotary barrel machine or commercial machine built especially for treating seed. Long and improper storage after treatment, especially with wheat, may injure the seed. Copper carbonate (p. 73), when used year after year at the rate of 4 ounces per 100 pounds of seed, will have a cumulative effect in reducing the amount of these diseases, but is not so effective as New Improved Ceresan.

The hot-water treatment formerly recommended for loose smut is cumbersome and is not needed in California.

BEAN[7]

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

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

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

Cottony Rot.—In cottony rot, the stems, and sometimes the leaves and pods, are affected by a soft rot covered with a fluffy, white mold containing small, round, black bodies called "sclerotia." This fungus, *Sclerotinia sclerotiorum,* is most apt to develop in heavy, matted vegetation where there is an abundance of moisture. See "Cottony Mold" (p. 66).

Curly Top.—Curly-top plants are stunted and leaves deformed and curled in a peculiar manner. This is the same virus disease as curly top of beets (p. 29) and is transmitted by the beet leafhopper, *Eutettix tenellus.* It is not often serious on beans in California. Some varieties are resistant. For further information, apply to the Division of Agronomy.

Downy Mildew.—A white, downy mold (*Phytophthora phaseoli*)

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

sometimes develops on the pods of lima beans, as well as in the young shoots and blossoms, and deforms and stunts them. The fungus infection is carried inside the seed.

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

Fig. 15.—Bean mosaic. (From Ext. Cir. 119.)

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

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

Good soil preparation, proper irrigation and cultivation, and crop rotation are the only control measures which can be used against diseases

of this type. Resistant varieties of different types of beans may in time be developed but none are available at present.

Mosaic.—The leaves of plants attacked by this virus disease are much

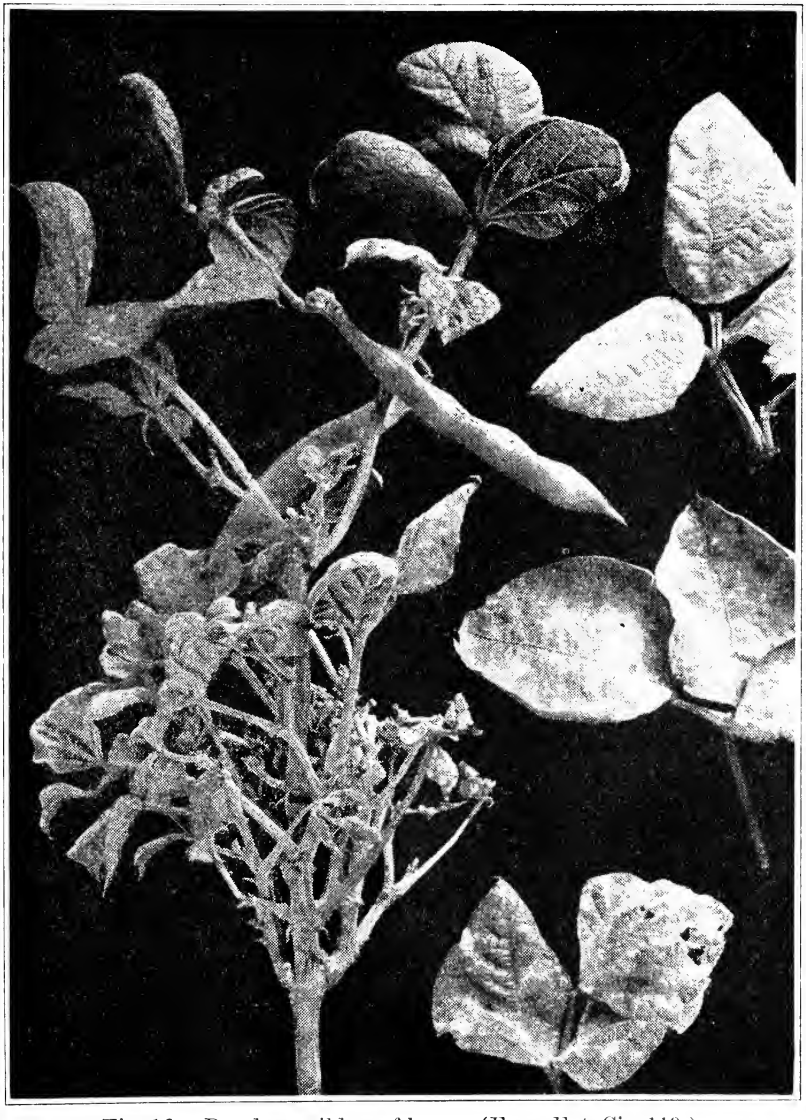

Fig. 16.—Powdery mildew of beans. (From Ext. Cir. 119.)

puckered and cupped downward at the edges. In color they are darker green than normal or mottled with green and yellow patches (fig. 15). Early-affected plants bear little seed. The infection is carried in the seed and spread by aphids.

Control measures for this disease lie in obtaining clean seed. Plantings for seed production should be made in places well isolated from other bean fields and with seed from fields which are as free from mosaic as

Fig. 17.—Rhizoctonia stem rot of bean. (From Ext. Cir. 119.)

possible. The seed field should then be carefully rogued by pulling out every plant which shows mosaic as soon as it can be detected.

Powdery Mildew.—A gray mildew, *Erysiphe polygoni,* sometimes de-

velops on the foliage of beans in cloudy weather or in the fall when humidity increases (fig. 16).

Dusting with sulfur (p. 74) is the most effective control measure if any is needed for this fungus disease.

Rhizoctonia Stem Rot, Rhizoctonia Canker.—Symptoms of this dis-

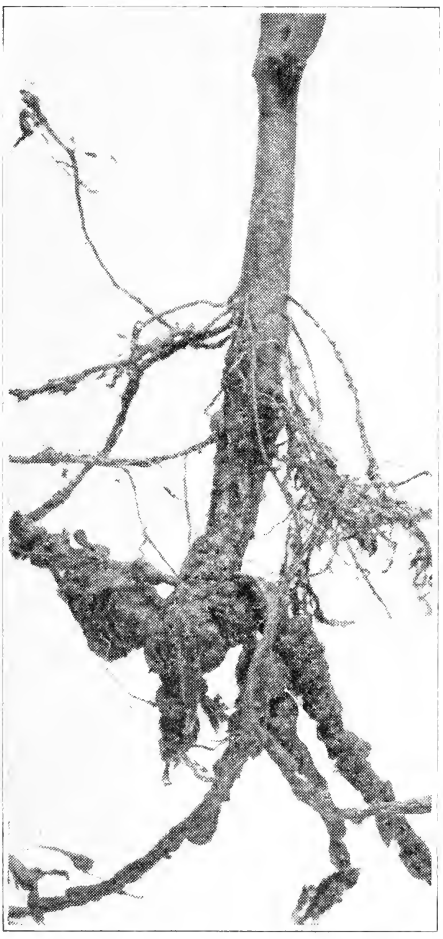

Fig. 18.—Root-knot nematode on bean roots. (From Ext. Cir. 119.)

ease are dark-red or brick-red, dead areas or cankers that develop on the lower part of the stem (fig. 17) and kill or stunt the plant. The same fungus, *Corticium vagum,* attacks potatoes and many other plants and causes damping-off of seedlings.

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

Root-Knot Nematode.—Galls or swellings, larger and of a different

appearance from the nitrogen-bearing nodules, appear on the roots (fig. 18) of plants attacked by the root-knot nematode, *Heterodera marioni*. The plants are badly stunted and killed.

Infested soil should be avoided for beans and other susceptible crops but may be used for winter cereals with clean summer fallow. See "Nematodes, Eelworms" (p. 68).

Rust.—In affected plants, red, dusty pustules of rust spores break

Fig. 19.—Sclerotial fungus that causes southern root rot. (From Ext. Cir. 118.)

out in great abundance on the leaves, mostly on the lower surface. In bad cases, the plant is greatly injured and the crop ruined. This fungus disease, caused by *Uromyces phaseoli* var. *typica*, is common in the state but causes the most serious damage on winter string beans, particularly the Kentucky Wonder variety, grown in frostless districts of southern California.

Dusting or spraying with sulfur (p. 74) at the first appearance of rust is of some value in control but has never proved entirely satisfactory. Seedsmen now offer rust-resistant strains of the Kentucky Wonder and other bean varieties. This is the most satisfactory method of control.

Southern Root Rot.—The plants attacked by this disease die prema-

turely and the roots are rotted. Small, brown sclerotia (fig. 19) resembling mustard seed are produced in the soil near the surface of the roots. These bodies keep the fungus, *Sclerotium Rolfsii,* alive in the soil. They are much less abundant on beans than on sugar beets or other hosts. In California the fungus attacks many other plants, of which the sugar beet is one of the most important.

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

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

BEET[8] (Sugar Beet, Garden Beet, Swiss Chard, Mangel-Wurzel)

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

Charcoal Rot.—The leaves of affected plants wilt, turn brown, and die. The roots show a brownish-black rot starting at the top of the beets (fig. 20) which reduces them to a mass of dry fibrous tissue, covered by a thin, dry, papery surface layer. This disease is caused by a soil fungus, *Rhizoctonia bataticola,* which also attacks corn, beans, sweet potatoes, and other crops, and which is active only at high temperatures. Consequently its principal importance is in the interior valleys, where it makes its greatest progress in midsummer when extremely hot weather prevails.

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

Crown Gall.—Beets sometimes show large, smooth galls, or swellings, on the sides of the main roots. This condition is the same as crown gall on

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

fruit trees and is caused by the same bacterial organism. *Phytomonas tumefaciens*. Somewhat similar galls of a more irregular nature are characteristic of the bacterial pocket disease, previously described, which is

Fig. 20.—Charcoal rot of sugar beet. (From Ext. Cir. 119.)

also caused by a bacterial infection. This trouble is not serious on beets and does not require control.

Curly Top.—Beet plants affected by curly top are stunted, dwarfed, and deformed in a characteristic way, the edges of the young leaves roll inward, and the veins are translucent when held toward the light. A

rough, warty condition develops on the backs of the leaves (fig. 21). The main roots show a mass of hairy secondary roots and pronounced black rings in cross section. All the various plants of the beet family, including sugar beets, table beets, and Swiss chard, are affected by curly top.

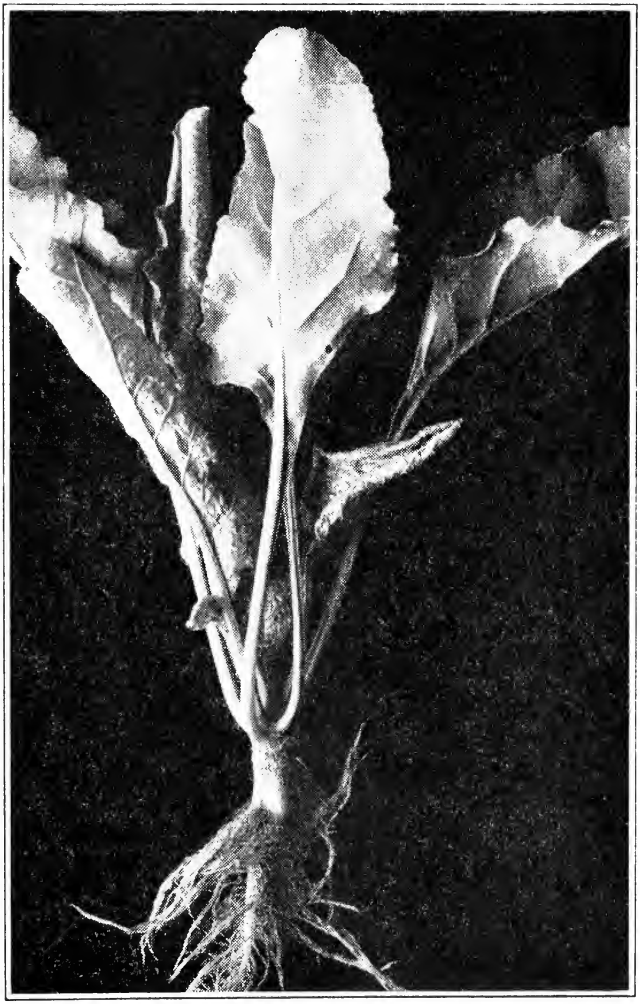

Fig. 21.—Young beet plant affected with curly top.

Many other kinds of plants are also susceptible, the most important being the tomato, in which the disease was first called "western yellow blight." For other hosts, see the general discussion of this disease (p. 68). Curly top is an extremely sporadic disease, being very abundant and destructive some years and again almost absent. The cause of the disease is a virus. As a rule it is more common in the warmer interior valleys and

less troublesome in cool, foggy districts near the coast. These facts are explained by the habits of the beet leafhopper, *Eutettix tenellus,* an insect which comes from native vegetation in the foothills and spreads curly top in feeding on the beet plants. This insect is described in California Extension Circulars 87 and 95 (see footnotes 2 and 8, p. 3 and 28).

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

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

Replanting has been the only method of overcoming this trouble. Recently the practice of treating the seed with chemical dusts for control has come into common use with excellent results. The beet-sugar companies in some cases treat the seed for their growers who request it, and several commercial operators make a business of treating seed. The grower may, if he wishes, treat his own seed by rotating it with the correct amount of the dust in a drum mounted on an axle, or in any other device that provides a thorough and uniform coating of the seed. Under most conditions, satisfactory control of damping-off (see this disease

under "Cotton," p. 41) can be secured by treating the seed with Ceresan (p. 74) at the rate of 1 or 1½ pounds for 100 pounds of seed, the larger amount being recommended only when the infestation is severe. New Improved Ceresan (at the rate of 6 ounces per 100 pounds of seed) is, in most cases, equally effective; and where *Pythium* is the chief organism responsible for the seedling infection, red copper oxide (p. 73) at the rate of 3 pounds per 100 pounds of seed will provide adequate protection.

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

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

In places where beet seed is grown and downy mildew is common, the original infected stecklings in the root bed should be watched for and destroyed. Infected stecklings should also be eliminated at the time of transplanting to fields for seed production. The young stecklings may be sprayed with bordeaux mixture 4–4–50 (p. 72) as soon as the disease appears. Early-planted sugar beets in coastal districts and portions of the interior valleys may be severely injured by downy mildew during seasons of moist weather. Later-planted fields are less affected. No direct control measures can be recommended, but some varieties are much less susceptible than others. Information regarding this can be obtained from the United States Department of Agriculture Bureau of Plant Industry, Sugar-Beet Investigations, Riverside.

Dry Rot and Leaf Spot.—This disease is often very destructive on sugar beets grown in places where there is rain in summer; it has caused

some rotting of beets in California in certain seasons but is not important in this state. The fungus, *Phoma betae,* produces light-brown, dead spots on the leaves and a dry rot of the crown of the beet. The fungus is seed-borne and is found on many European seed samples but not as yet on American-grown seed. This is one of the causes of damping-off (p. 31).

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

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

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

Root-Knot Nematode.—The roots of sugar beets are affected by two distinct species of nematodes, the root-knot nematode (*Heterodera marioni*) and the sugar-beet nematode. The latter is discussed on page 35. The former causes good-sized galls or swellings on the main or branch roots of the beet. The same parasite attacks roots of most of the common vegetables, ornamentals, trees, and weeds. It is most destructive in light, sandy soils, but is also abundant in peat soils, where it is frequently referred to as the "potato nematode."

Land badly infested with root-knot nematode should be avoided for planting sugar beets. For further information see page 68.

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

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

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

The fungus which is responsible, *Corticium vagum,* may also cause a dry-rot canker of mature beets. This usually starts at cracks or around the bases of secondary roots toward the lower part of the beet, where the

Fig. 22.—Dry rot canker of sugar beet.
(From Ext. Cir. 119.)

brown, dead, woody tissue is marked with fine, concentric, circular, surface markings (fig. 22). Beets which have been injured or weakened in some way are more likely to be affected by this disease. The same fungus attacks many other hosts.

This disease is in part the same as that described under "Damping-

off" (p. 31). Unless seed treatment is effective in preventing serious injury, not much can be done except to replant fields that have been badly attacked by the seedling form of the trouble.

Southern Root Rot.—In this disease, the roots of beets growing in the field become affected with a rot which spreads from plant to plant. The fungus, *Sclerotium Rolfsii,* develops an abundant white mold on the beets and soil and on this growth are seen a great many small, round bodies of about the size and color of mustard seed. These are the sclerotia (fig. 19, p. 27), which act as the seeds of the fungus and help to spread it. This fungus attacks many different kinds of plants and persists for years in the soil after it once gets started. It requires rather high temperature and does not develop on plants grown in the winter in California.

Land and crops infested with *Sclerotium Rolfsii* should be handled very carefully to prevent the further spread of the fungus. Bulbs, roots, or rooted plants which have grown in infested soil should not be planted in clean land. The dump screenings and trash and the wash water from sugar beets are also important means of distribution. Dump screenings should not be returned to the fields but should be piled on nonagricultural lands. Wash water should not be run onto clean land. In small areas of land that are already infested, it may be possible to eradicate the fungus by saturating the surface of such spots with Formalin (p. 74), 1 pound to 12½ gallons of water at the rate of 1 gallon or more for each square foot. Where there is too much land infested for this to be practical, nothing can be done except to use cropping methods. Badly infested soil may be kept fallow and clean of vegetation for one or more years, or may be planted to alfalfa or some nearly immune crop such as asparagus, cereals, or corn, or to winter crops such as peas, lettuce, or spinach. Carrots, beans, potatoes, and lettuce for seed are susceptible. By examining soil samples collected under the supervision of the sugar companies or the farm advisor, it is possible to estimate the population of the fungus and to predict with reasonable accuracy the amount of disease which can be expected if the field is planted to sugar beets. Nitrogenous fertilizers applied at rates approaching 100 pounds of nitrogen per acre usually provide a partial control, but are recommended only where such applications are also stimulating to the crop. For further information on this subject, consult the Division of Plant Pathology, College of Agriculture, Davis.

Sugar-Beet Nematode.—The plants are badly stunted by the attack of this parasitic worm, *Heterodera schachtii,* upon the roots. This species produces no root galls upon its host. In this case the tiny, lemon-shaped, white, female worms can be seen clinging to the roots. Some of the females die while still filled with eggs and become brown, sac-like cysts

in which the eggs may lie dormant for many years, a few hatching every year and the larvae, which resemble those shown in figure 43 (p. 69), escaping from the cyst. The attack of this species of nematode is limited to beets, spinach, Swiss chard, and related weeds, and to cultivated and

Fig. 23.—Wet root rot of sugar beet.
(From Ext. Cir. 119.)

wild species of the mustard family. They are spread by irrigation water, by particles of soil or roots mixed with seed, and by the return of dump screenings to the land.

In land infested with beet nematode, sugar beets should not be grown oftener than once in five years, with alfalfa, barley, beans, or some other nonsusceptible crop between. Weeds which might carry over the pest

should be eliminated. Dump dirt and wash water should be handled as advised in the preceding section, "Southern Root Rot."

Wet Root Rot.—Sugar beets sometimes show a soft, wet, brown rot of the main roots (fig. 23), starting at the lower end. This is caused by a fungus, *Phytophthora Dreschleri,* but usually develops only in low spots in the field where water stands for a long time or where water penetration is impeded by a compact layer of subsoil. Similar fungus diseases caused by species of *Phytophthora* attack other hosts.

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

BLACK-EYE BEAN

See "Cowpea, Black-eye Bean" (p. 43)

BROAD BEAN

See "Horse Bean, Broad Bean, Fava Bean" (p. 47)

BROOM CORN

See "Sorghum" (p. 54)

BUCKWHEAT

Powdery Mildew.—A white mildew fungus, *Erysiphe polygoni,* sometimes attacks buckwheat but is rarely seen in California.

CHICK PEA

See "Garbanzo, Chick Pea" (p. 45)

CLOVER

Leaf Spot, Sooty Spot.—The fungus *Phyllachora trifolii* occasionally forms black, thick, circular spots on the leaves of clover growing near the coast, but the trouble is not serious.

Powdery Mildew.—A white mildew, *Erysiphe polygoni,* covering the leaves, is abundant in a few places where clover is grown near the coast in California, especially in Santa Cruz County. No control is feasible.

Rust.—A true rust, *Uromyces trifolii,* covers infected leaves with dark-red, dusty spore pustules and ruins the plants for hay. It is favored by moist weather. The only feasible control is to cut and burn badly affected crops.

Stem Rot.—The plants are sometimes killed by a white, cottony mold (p. 66), *Sclerotinia sclerotiorum,* which attacks the stems, usually where the growth is thick and matted and the ground moist.

CORN, MAIZE[9]

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

Land in which this disease has occurred should not be used again for corn for several years. Seed should not be taken from an affected field. Seed corn may be disinfected with one of the proprietary organic mercury dusts like Semesan Jr. (p. 74). If this disease, which is new in California, becomes serious, one should write to the Division of Plant Pathology, College of Agriculture, Berkeley, for the latest information on control.

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

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

Boil Smut.—See "Smut" (p. 40).

Brown Spot.—Brown spot has but recently been observed in California. Reddish-brown spots and blotches appear on the leaves and stalks, which sometimes become blighted and killed. The cause of the disease is a fungus, *Physoderma zeae-maydis,* which lives in the superficial plant cells. Corn should not be planted the following year on land where this disease has been abundant.

Downy Mildew.—Affected plants are stunted and more or less deformed. The leaves show yellow stripes covered with a whitish down of spores of the fungus *Sclerospora phillipinensis* or similar species. Sorghum is also attacked. The disease occurs in the Philippine Islands and other tropical regions with high humidity. A federal quarantine requires that corn imported into the United States from such countries be treated to destroy spores of downy-mildew fungi.

[9] For further information on corn diseases see:

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

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

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

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

Ear Mold, Pink Rot.—This disease causes the ears to mold in the field, the kernels becoming crusted together with fungus growth. It ruins the corn or impairs germination the following season. It occurs especially

Fig. 24—Boil smut of corn. (Courtesy of the Illinois Agricultural Experiment Station; from Bul. 511.)

in late-maturing corn, in seasons of early rain, or in fields heavily irrigated late in the season. Any of several fungi may be responsible, especially *Diplodia zeae* and *Fusarium moniliforme.*

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

Head Smut.—See "Smut" (p. 40).

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

Smut.—Two fungus smuts attack corn. In boil smut (fig. 24) caused by *Ustilago zeae,* large, fleshy, irregular swellings appear on the stems,

Fig. 25.—Head smut on corn: *A,* smutted tassel; *B,* smutted ear. (From Bul. 511.)

ears and heads. These are at first covered with a whitish membrane which bursts at maturity and sets loose a mass of dusty, black, spore powder. In head smut (fig. 25), caused by *Sorosporium Reilianum,* the plant is stunted and the tassels and ears are transformed into masses of dusty smut spores. This disease also attacks sorghum, but on corn is not seen as frequently as boil smut.

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

COTTON[10]

Angular Leaf Spot.—This disease, caused by *Phytomonas malvacearum,* has been reported in California but, if it occurs, is very uncommon. Small, angular, water-soaked spots appear on the leaves of plants affected by this bacterial disease. These spots darken in color. If they are abundant, the leaves drop off. Larger spots develop on the bolls, work into the lint, and stain and decay it. Some of the bolls dry without maturing or drop off.

Angular leaf spot is first brought into the cotton field on the seed, and it is therefore most effectively prevented through seed treatment. The use of seed which has been delinted with concentrated sulfuric acid is said to give perfect control.

Boll Rot.—The interior tissue or immature lint and seed in the boll become discolored, moldy, and finally turn into a dark-colored mass of dusty, fungus spores. The infection takes place largely through insect injuries and may be caused by either *Aspergillus niger* or *Rhizopus nigricans.*

Crazy Top.—This name comes from the fact that the growth of affected plants takes on a peculiar abnormal form. The term is sometimes used in California to designate unusual-looking plants but it is not certain that the true disease which bears this name in other parts of the Southwest has been recognized here. The cause is unknown.

Damping-off, Seedling Rot.—Young seedlings affected by damping-off die or fail to come up. Where this trouble is serious in cotton, seed treatment with 2 per cent Ceresan or New Improved Ceresan (p. 74) is recommended.[11]

Fusarium Wilt.—Plants affected by this disease, caused by *Fusarium vasinfectum,* wilt and die, sometimes in definite spots in the field which gradually enlarge. The roots turn black, and a brown or black discoloration develops in the wood of the stem. Although it has not been reported in California, this is a very serious cotton disease in other parts of the country, and there is no good reason to expect that it will not develop here.

Land in which this trouble occurs should not be put into cotton for several years, for the fungus which causes the disease persists in the soil.

[10] For further information on cotton diseases see:

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

Neal, D. C., and W. W. Gilbert. Cotton diseases and methods of control. U. S. Dept. Agr. Farmers' Bul. 1745:1–34. 27 figs. 1935.

[11] Growers who wish to treat cottonseed on a large scale should write to the U. S. Department of Agriculture, Washington, D. C., for a copy of the following circular: Haskell, R. J., and H. D. Barker. Cottonseed treatment. U. S. Dept. Agr. Leaflet 198:1–8. 3 figs. 1940.

Cereals, alfalfa, and vegetables are safe. Resistant varieties of cotton are available but none are of a good type for planting in California.

Root-Knot Nematode.—Plants infested by root-knot nematode, *Heterodera marioni,* are dwarfed and stunted, and the roots are covered with irregular galls or swellings. Cotton is very susceptible to this pest and, since the worm also attacks melons, sweet potatoes, tomatoes, sugar beets, peaches, almonds, grapes, potatoes, and figs, cotton land is very likely to become infested.

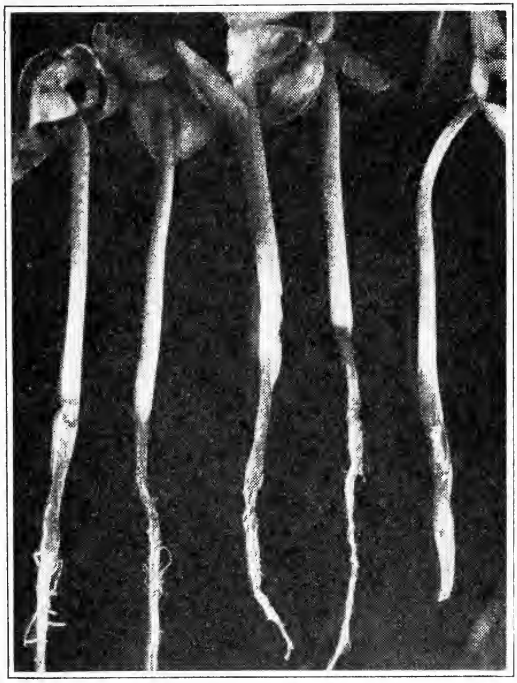

Fig. 26.—Sore shin of cotton seedlings. (Courtesy of the Arizona Agricultural Experiment Station.)

Clean fallow or summer fallow with winter cereals usually reduces this pest rapidly in California soils. (See p. 68.)

Sore Shin.—On the stems of young plants attacked by sore shin, dark, reddish-brown, sunken cankers develop at or just below the ground surface (fig. 26). These cankers may girdle the stem or penetrate so deep that the plants fall over and die. Some may partially recover but make inferior plants. The fungus causing this disease, *Corticum vagum,* also causes jelly end and rhizoctonia disease of potatoes, damping-off of seedlings, and many other diseases. Sore shin is most likely to develop when temperatures are low and the surface soil full of moisture. On this ac-

count, the disease is most common in early-planted cotton. It is closely related to damping-off and seedling rot (p. 41).

Delinting the seed with sulfuric acid and chemical seed disinfection may help to prevent this trouble if it is serious. See "Damping-off, Seedling Root Rot" (p. 41).

Texas Root Rot, Ozonium Root Rot.—The disease is responsible for more or less circular areas of dead plants in the field. These spots gradually enlarge by the growth of the fungus, *Phymatotrichum omnivorum,* in the soil. Diseased plants first wilt, then die. On the surface of the roots, the slender, light-brown, stringlike strands of the fungus can be seen. This is one of the most dreaded plant diseases in the Southwest but in California has occurred only in a few scattered instances on alfalfa in the extreme southeastern part of the state. See "Cotton Root Rot, Texas Root Rot, Ozonium Disease," under "Alfalfa" (p. 9).

Cotton, alfalfa, or other susceptible summer crops should not be grown on affected land for several years. Grains, cantaloupes, winter lettuce, asparagus, and onions may safely be planted. Any suspected cases of this disease should be reported to the County Agricultural Commissioner.

Thrips Effect.—In some young seedlings, the leaves are thickened and have a gray, rough surface, with patches of the normal texture and green color. This condition is frequently taken for a disease, but no cause except attacks of an insect, which is the common bean thrips, *Hercothrips fasciatus,* has been found. Extension Circular 87 (see footnote 2, p. 3) recommends dusting with dry sulfur for thrips control.

Verticillium Wilt, Verticilliosis.—The leaves of affected plants develop pale, yellowish areas between the veins. These finally die and turn brown and the leaves fall, so that the plants become defoliated except for a few small leaves at the tips. The bolls ripen prematurely and produce lint that is shorter than that from healthy plants. This disease is caused by the same soil fungus, *Verticillium albo-atrum,* that causes similar troubles in other plants. See general discussion on page 71.

If land becomes badly infested with this disease, it is advisable to rotate with alfalfa or grain crops. Efforts are being made in coöperation with the United States Cotton Field Station at Shafter, California, to develop resistant strains of cotton.

COWPEA, BLACK-EYE BEAN

Charcoal Stem Rot.—This fungus disease, which also attacks bean ("Stem Blight, Charcoal Rot," p. 28), corn ("Dry Rot, Stem Rot," p. 39), and sugar beet ("Charcoal Rot," p. 28), has been reported on cowpeas but is not serious except on seedlings. It is caused by *Rhizoctonia bataticola.*

Mosaic.—The leaves of mosaic cowpeas are mottled and somewhat distorted and stunted in a manner typical of similar diseases on other hosts. The disease, caused by a virus, is not serious on cowpea.

Powdery Mildew.—A white mildew fungus, *Erysiphe polygoni,* sometimes attacks the foliage of cowpeas, but the trouble is not so important as on beans.

Root-Knot Nematode.—Stunted plants and galls or swellings on the roots are characteristic of the effects of the root-knot nematode, *Heterodera marioni.* These galls are distinct from the nitrogen nodules which are also present on the roots of legumes. The soils in which cowpeas are commonly grown are very likely to have become infested with nematode by previous crops of melons, tomatoes, or sweet potatoes.

Some varieties of cowpeas are highly resistant to nematode. Types have been produced by breeding which are resistant to both nematode and the wilt disease and likewise well adapted to California conditions and requirements. For latest information, address Division of Agronomy, College of Agriculture, Davis, or see the county farm advisor.

Rust.—The leaves show dusty spore pustules of a typical red rust. In bad cases the leaflets may shrivel and fall. No control method is known for this disease, caused by the fungus *Uromyces vignae,* but it is not often serious.

Stem Canker—Symptoms of this disease on cowpeas are the same as on beans ("Rhizoctonia, Stem Rot, Rhizoctonia Canker," p. 26). The disease, caused by *Corticium vagum,* is not serious on this crop.

Wilt.—Plants affected by this disease are stunted, turn yellow, wilt, and die. The woody part of the stem and main root becomes discolored and finally the root rots off. Large areas of soil in affected districts become so thoroughly infested with the fungus, *Fusarium bulbigenum* var. *tracheiphilum* that susceptible varieties of this crop can no longer be grown. As stated under "Root-Knot Nematode," good types of cowpeas are now available which grow well in soil infested by wilt.

EGYPTIAN CORN

See "Sorghum" (p. 54).

FAVA BEAN

See "Horse Bean, Broad Bean, Fava Bean" (p. 47)

FLAX

Flax is attacked by several serious diseases in various countries of the world and in other parts of the United States. Up to now, however, very little specific trouble has been experienced in California with this com-

paratively new crop. The diseases listed here are, except the first, those most important in other flax-growing regions. For general control measures, see "Control of Flax Diseases," below.

Botrytis Blight.—During the winter of 1940, several plantings of flax were ruined by the common gray-mold fungus, *Botrytis cinerea.* This happened during a protracted rainy period in February and March, when the blossoms of the flax plants became covered with the fungus growth. Fallen moldy petals spread the infection to leaves and stems, and the plants were thus killed. Such an occurrence as this is the result of weather conditions unusually favorable to the fungus and cannot be prevented by any known method.

Pasmo.—This fungus disease, caused by *Phlyctaena linicola,* shows up in certain areas in the field. The leaves show definite, dark-brown spots and finally wither and fall. Dark spots appear also on the stems.

Rust.—A true rust on leaves and stems, with pustules of yellow or dark-brown fungus spores (*Melampsora lini*), is sometimes very destructive.

Verticillium Wilt, Verticilliosis.—Flax plants infected with *Verticillium albo-atrum* wither and die as in similar diseases of many other crops. (See general discussion on p. 71). No serious case of this trouble on flax has been observed in California, but all the better-known varieties, including Punjab and Abyssinian, are susceptible. Rotation of flax with cotton has been suggested, but the latter is also attacked by verticilliosis (p. 43).

Wilt.—Plants affected with this disease wilt, turn yellow, wither, and die at any stage during their growth. The soil becomes so infested with the fungus (*Fusarium lini*) that susceptible varieties of flax can no longer be grown in it.

Control of Flax Diseases.—The only possibilities of controlling any of these diseases lie in crop rotation and the development of resistant varieties of flax. The latter has already been done in other states in the case of rust and wilt. Seed treatment is of value with some of the diseases. In bringing flax seed into California, great care is advisable not to introduce diseases.

GARBANZO, CHICK PEA

Root Rot.—Plants attacked by the common soil fungus *Corticium vagum* turn yellow and slowly wither and die. The roots and underground stem show dark-colored lateral lesions and finally rot off.

This plant prefers high temperatures and a rather dry, light soil. Cool, moist weather and heavy wet soil are very favorable to the disease. Garbanzos should not be planted where such conditions prevail.

GRAIN

See individual hosts, as "Barley," "Oats," "Wheat"

GUAYULE, *Parthenium argentium*

Root Rot.—Guayule, which has been planted in California for the production of rubber, is rather susceptible to excess soil moisture and often succumbs to a rotting of the roots when the soil becomes too wet. The specific cause of the rotting is unknown.

GYP CORN

See "Sorghum" (p. 54)

HOP

Crown Gall.—Plants affected by crown gall are stunted and fail to make proper growth. Large, fleshy galls or swellings are found at the

Fig. 27.—Hop downy mildew.

crown of the plant, just below the surface of the ground. This is the same bacterial disease as crown gall of fruit trees; both are caused by *Phytomonas tumefaciens.*

Serious cases of this disease in hops usually result from planting infected roots or from using soil in which fruit trees, raspberries, blackberries, or other crops affected with this disease have previously grown. Both of these conditions should be avoided.

Downy Mildew.—Stunted shoots or "spikes" sometimes come up from the roots in spring. The leaves of these shoots are small and brittle, silvery on the upper side and violet-black with spores of the fungus *Pseudoperonospora humuli*, on the lower surface. Later in the season some of the lateral shoots may be similarly affected, and numerous angular, brown spots appear on the leaves, with spores on the lower surface (fig. 27). This disease is favored by moist weather and at such times may cause defoliation, poor growth, and reduction in quantity and quality of the cones. In California it has been present for only a few years and has seldom caused serious damage.

Wild hopvines in the vicinity of commercial yards should be eradicated and their reëstablishment prevented. This will eliminate serious sources of infection. All diseased spikes which show in spring should be cut off and burned. In most seasons this will be enough to hold downy mildew in check. If it should flare up in an occasional wet spring, the vines may be sprayed at the first appearance of the disease with 2–2–50 bordeaux mixture (p. 72), in which a spreader (p. 75) should be used. For control of aphids, 1 pint of 40 per cent nicotine sulfate (Black Leaf 40) may be added to 100 gallons of the spray mixture.

Powdery Mildew.—Affected leaves and young cones become covered with a white mildew which may ruin the crop in moist weather. This fungus disease, which is not known to occur in California, is caused by *Sphaerotheca humuli* and is entirely different from downy mildew, previously described. Dusting with dry sulfur is the standard treatment for this disease.

HORSE BEAN, BROAD BEAN, FAVA BEAN

Leaf Spot.—Affected leaves show definite, roundish spots with a light center and dark-brown margin. The cause is unknown, but the disease is not often serious.

Mosaic.—Horse beans are susceptible to several of the mosaic diseases of leguminous plants caused by viruses. The two diseases described in following sections as "scab" and "yellows" may be of this nature. This plant is also a host of curly top (p. 68).

Rust.—The leaves occasionally show pustules of reddish spores of a rust fungus, *Uromyces fabae*, but this disease is not usually serious.

Scab.—The pods of affected plants are rough and deformed and disfigured with corky protuberances that are dark within (fig. 28). The leaves are crinkled and mottled and many of the flower buds or young

pods blacken and wither. No parasite has been found in connection with this disease, which has many of the features of a virus trouble. It is abundant only in occasional years. No method of control is known.

Yellows.—In this disease the leaves turn bright yellow, the stems blacken, and the plants die. Sometimes single plants here and there are

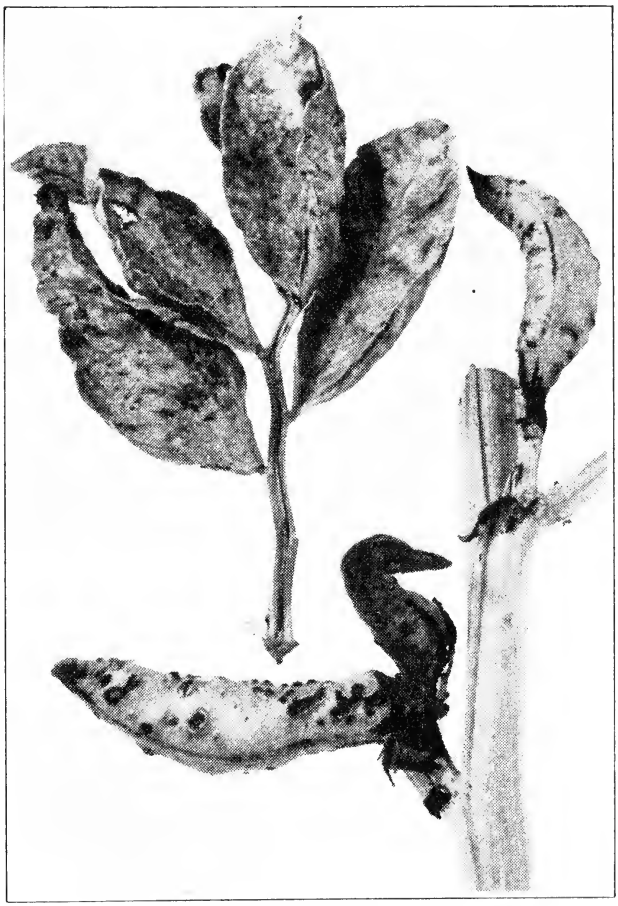

Fig. 28.—Scab disease of horse bean.

affected, and again the disease seems to become established or spread in certain spots in the field like a fusarium wilt, which this trouble resembles in some respects. Considerable work has failed, however, to isolate any fungus from plants showing this disease, which is the commonest one attacking horse beans in California.

No specific control for yellows can be suggested, but crop rotation is advisable for horse beans as a precaution against diseases and pests in general.

KAFIR

See "Sorghum" (p. 54)

MAIZE

See "Corn, Maize" (p. 38)

MANGEL-WURZEL

See "Beet" (p. 28)

MILO

See "Sorghum" (p. 54)

MUSTARD

Cottony Rot.—Affected plants rot at the base of the stem or wherever dense masses of vegetation cover the ground. The pure-white mold growth of the fungus, *Sclerotinia sclerotiorum,* develops upon such vege-

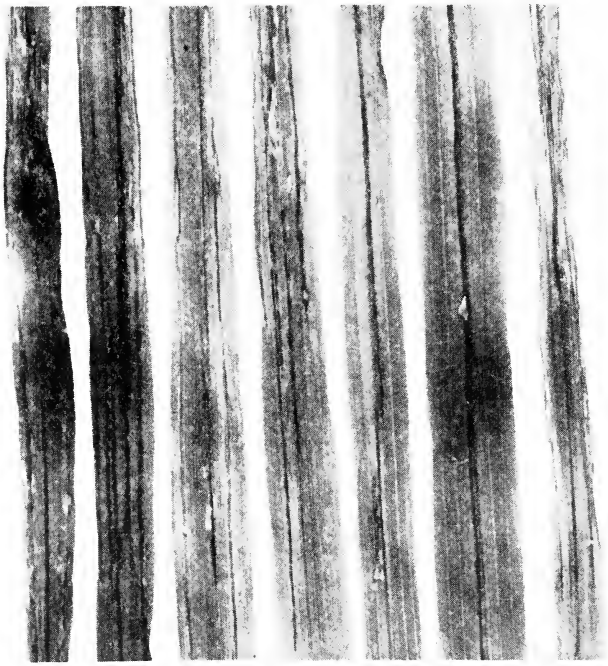

Fig. 29.—Stripe leaf blight of oats. (Courtesy of Elliott, United States Department of Agriculture; from Bul. 511.)

tation. Sclerotia and spores (see "Cottony Mold," p. 66) are often produced abundantly from this host, which is frequenty used as an orchard covercrop and also grows wild in great abundance.

OATS[12]

Bacterial Stripe, Stripe Blight.—Long, water-soaked stripes with narrow, yellow margins sometimes appear on the leaves (fig. 29). These are caused by *Phytomonas striafaciens*. When the leaves are moist, a yellowish, sticky, bacterial exudate oozes from them. This dries in thin white scales on the surface. The Kanota variety is very resistant to this disease.

Blast.—In this disease, part or all of the branches of the stem die prematurely in a blanched, stunted condition. The cause of this has not been

Fig. 30.—Halo blight of oats. (From Bul. 511.)

discovered, but no insect or fungus or other parasite seems to be concerned. The Kanota oat, one of the best California varieties, is very free from this trouble.

Covered Smut.—See "Smut" (p. 52).

Crown Rust.—See "Rust" (p. 51).

Halo Blight.—Large, oval, dead spots develop on affected leaves, these spots being brown and dry in the center and surrounded with a pale,

[12] For further information on diseases of oats see:

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

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

yellowish-green margin (fig. 30). The leaves die prematurely and the yield and weight of the grain is affected. The cause of this disease is a bacterial organism, *Phytomonas coronafaciens*. No practical method of control for this disease is known and no resistant varieties are available.

Loose Smut.—See "Smut" (p. 52).

Fig. 31.—*A*, Kanota K 5179, very susceptible to stem rust, but resistant to leaf rust; *B*, Richland 320*a*, immune to stem rust in California. (From Bul. 511.)

Nematode.—The plants attacked are stunted with twisted, deformed leaves, numerous stems, and swollen leaf bases near the ground. This condition is due to one of two nematodes—*Ditylenchus dipsaci* or *Anguillulina tritici*. The worms (fig. 36, p. 60), of microscopic size, are found in the diseased tissues. The disease has been seen only rarely in California. Infested soil should not be planted to oats for two or three years.

Rust.—Two types of rust—stem rust and crown rust—attack oats.

The small, light-red, pustules of crown, or leaf, rust, *Puccinia coronata*, which attacks only oats among the cereals, are found mainly on the leaves. They are slow to open and covered with a thin membrane of the plant epidermis. This fungus disease is less destructive than stem rust. In the latter disease, long, dark-red or black pustules of rust spores, *P.*

Fig. 32.—Leaf-blotch disease of rice.

graminis var. *avenae* (fig. 38, p. 62), break out on the leaves and on the leaf sheaths which enclose the stem (fig. 31). The thin epidermis of the plant curls back from these pustules in ragged margins. The plants may be badly injured and die without forming grain.

No tried varieties resistant to rust can be recommended at present for California. Consult the Division of Agronomy, College of Agriculture, Davis, for further information.

Smut.—Two types of smut—covered and loose—attack oats. In cov-

ered smut, caused by *Ustilago levis,* affected grain is transformed into a mass of black smut spores covered with a thin, whitish membrane. In loose smut, caused by *U. avenae,* the affected kernels shatter away into black spore dust before the grain is mature. In both types of disease, spores (fig. 12, p. 19) become attached to the surface of the seed grain, germinate with it, and infect the young seedlings, and the fungus grows up through the plants to appear again as smut in the new crop of grain.

New Improved Ceresan treatment as described for barley (p. 21), when practiced every year, effectively controls both of these diseases.

Stem Rust.—See "Rust."

RICE

Rice is attacked by many different parasitic fungi and other disease types in various countries of the world and in other parts of the United States. Descriptions of many of these will be found in Bulletin 511.[13] Up to now, however, scarcely any specific disease has been observed on this crop in California.

The disease called "stem rot," caused by the fungus *Leptosphaeria Salvinii,* has been reported from one locality in California, where it apparently was introduced on seed from Arkansas.

The condition shown in figure 32, which is sometimes known as "blotch," has been seen here occasionally but never in a serious form, and no definite cause has been found for this. It may be due to a light infection by a fungus species of the *Helminthosporium* type.

RYE[14]

Ergot.—In this disease, some of the florets of the head develop into long, horny, cylindrical, black bodies several times the length of the normal grains (fig. 33). In California this fungus disease, caused by *Claviceps purpurea,* has been found only on certain wild grasses and not on cultivated cereals.

Nematode Disease.—This disease, which is more common on wheat, sometimes attacks rye. For description see page 58.

Root Rot.—See this disease under "Wheat" (p. 59).

Rust.—There are three principal rust fungi of rye, none of which is of importance in California. Leaf rust (*Puccinia dispersa*) closely resembles leaf rust of wheat, in having small, roundish, orange-red pustules of rust spores on the leaves. In the fall these turn black. Stem rust (*P. graminis* var. *secalis*) produces longish pustules, mainly on the stems

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

[14] For further information on diseases of rye, see: Mackie, W. W. Diseases of grain and their control. California Agr. Exp. Sta. Bul. 511:1–87. 46 figs. 1931. (Out of print.)

(fig. 31). Stripe rust (*P. glumarum*) attacks wheat also and produces long, yellow lines of spore pustules on the leaves.

Smut.—Rye is attacked by three smuts. Two of these, stinking smut (*Tilletia tritici*) and loose smut (*Ustilago tritici*) are caused by the same fungi that attack wheat and are controllable by the same methods. Neither, however, is important on rye in this state.

Stem smut (*Urocystis occulata*) produces long, dark-colored streaks

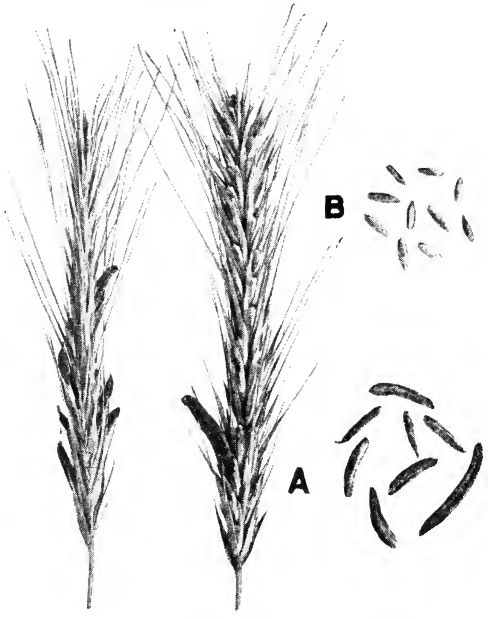

Fig. 33.—Ergot of rye: *A*, the ergots, or sclerotia, three to four times the size of the rye kernel; *B*, kernels of rye. (Courtesy of the United States Department of Agriculture Cereal Disease Investigations; from Bul. 511.)

or lines of smut spores on the stems and leaves. The plants are stunted. Seed treatment with copper carbonate or New Improved Ceresan and crop rotation prevent serious damage from this disease. See page 21.

SORGHUM (Broom Corn, Egyptian Corn, Gyp Corn, Kafir Corn, Milo)[15]

Root Rot.[16]—Affected plants die from a rotting of the roots. The fun-

[15] For further information see:

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

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

[16] Kendrick, James B., and Fred N. Briggs. Pythium root rot of milo and the development of resistant varieties. California Agr. Exp. Sa. Bul. 629:1–18. 7 figs. 1939.

gus *Pythium arrhenomanes,* increases, spreads, and persists in the soil so that susceptible plants can no longer be grown. The disease is confined mainly to milo.

Resistant strains of milo have been developed for planting on soil infested with this disease. Information regarding seed may be obtained

Fig. 34.—*A,* Loose smut of sorghum; *B,* kernel smut of sorghum. (From Bul. 511.)

from the Division of Agronomy, College of Agriculture, Davis. Susceptible varieties should not be planted on soil where root rot is present.

Rust.—A true rust, *Puccinia purpurea,* causes purple spots on the leaves, with small, dark-brown, spore pustules of the fungus. The sweet sorghums are much more susceptible than the milo varieties. There are no methods of control for this disease.

Smut.—In closed-kernel smut, caused by *Sphacelotheca sorghi* (fig.

34, *B*), the individual grains are composed of a dark-brown to black powder or fungus spores covered with a thin, whitish membrane. In loose smut, caused by *S. cruenta* (fig. 34, *A*) the spores scatter away freely in a dusty powder. In head smut, caused by *Sorosporium Reilianum* (shown on corn in fig. 25, p. 40), the whole head is stunted and destroyed by the disease, which is of the loose-smut type.

Copper carbonate treatment (p. 21) easily controls kernel smut and should reduce infection with head smut if combined with crop rotation. There is a great difference in the susceptibility of different types and varieties of sorghum to smuts. For detailed information about old and new varieties, consult the Division of Agronomy, College of Agriculture, Davis.

SOYBEAN

Wilt.—The wilt-infected plants turn yellow, wither, and die. Soybeans are not extensively grown in California but are now being tried in various places. The causal fungus closely resembles *Fusarium bulbigenum* var. *tracheiphilum*, which causes wilt of cowpeas, but if soybeans are planted on cowpea-wilt-infested land, they do not develop this disease. Crop rotation affords the best method of control.

SUDAN GRASS[17]

Rust.—This disease, which also attacks sorghum and Johnson grass, causes purple spots on the leaves with small, irregular pustules of the dark-brown fungus spores of *Puccinia purpurea*. The damage is not serious.

Smut.—Two smuts of sorghum (p. 55) also attack Sudan grass. In kernel smut caused by *Sphacelotheca sorghi*, the grains are swollen to two or three times the normal size and composed of a rather firm mass of black fungus spores covered with a white membrane (fig. 34, *A*). In loose, or head, smut, caused by *Sorosporium Reilianum* (fig. 25), they break down into a black, dusty powder.

These smuts are not very important on Sudan grass. Kernel smut may be controlled by seed treatment with copper carbonate or New Improved Ceresan (p. 21).

SUGAR BEET

See "Beet," (p. 28)

SUNFLOWER

Powdery Mildew.—The leaves sometimes become covered with a coating of white mildew, caused by the fungus, *Erysiphe cichoracearum*.

[17] For further information see: Mackie, W. W. Diseases of grain and their control. California Agr. Exp. Sta. Bul. 511:1–87. 46 figs. 1931. (Out of print.)

Dusting with powdered sulfur would probably help to control this fungus, but such treatment is seldom necessary.

Rust.—Affected leaves show numerous pustules of dark-colored fungus spores of *Puccinia helianthi,* mostly on the undersides. As with the previous disease, dusting with powdered sulfur would probably be beneficial if treatment seems called for.

Wilt, Stem Rot.—The plants infected with wilt die from a rotting at the base of the stem. A white mold, *Sclerotinia sclerotiorum,* is visible at this point, and on this and in the stem cavity are found the black sclerotia (see "Cottony Mold," p. 66) of this fungus. Affected plants should be pulled and burned to check the spread of this disease, which attacks a great variety of plants.

SWEET CLOVER, MEDICAGO

Leaf Spot.—The leaves sometimes show dead spots caused by the fungus *Cercospora zebrina.* No feasible control method is available.

VETCH

Cottony Rot.—A vigorous, pure-white mold often grows abundantly during wet weather in thick, matted growth of vetch planted in orchards for covercrop. This kills the plants. The fungus, *Sclerotinia sclerotiorum,* produces sclerotia and spores on the surface of the ground (see "Cottony Mold," p. 66); this, or similar growth on other covercrop plants (see p. 49 under "Mustard") or weeds, often forms the principal source of spores for infections of other plants aboveground.

WHEAT[18]

Bunt, Covered Smut.—See "Smut" (p. 62).

Downy Mildew.—Affected plants show excessive tillering and a peculiar twisted and swollen distortion of stems, leaves, and heads. This disease, like many other downy mildews, has never become serious in California. It is caused by the fungus *Sclerospora macrospora.*

Flag Smut.—This disease has long been known in Australia, India, China, Japan, and other foreign countries and caused considerable apprehension when it first appeared in the United States about 1918. Up to

[18] For further information on diseases of wheat see:

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

Johnson, A. G., R. J. Haskell, and R. W. Leukel. Treat seed grain. U. S. Dept. Agr. Misc. Publ. **219**:1–7. 4 figs. Revised 1937.

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

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

Sprague, Roderick. Controlling seed-borne stinking smut of wheat by disinfectants. Oregon Agr. Exp. Sta. Bul. **363**:1–33. 1939.

date, it has not proved at all serious, but the recent discovery of the disease in the Pacific Northwest has attracted renewed attention to it. The greatest losses from flag smut have occurred in Australia, under climatic conditions similar to those of California. Elongated spore pustules of the fungus, *Urocystis tritici,* develop along the parallel leaf veins and cause the foliage to fray into strips. Usually no heads or grain is produced.

There is a federal quarantine against bringing wheat into the United States from certain foreign countries, unless it has been treated to destroy spores of this fungus.

Flag smut is reduced by the same seed treatment that is applied to wheat for stinking smut, coupled with crop rotation. Some wheat varieties are resistant.

Foot Rot.—See "Root Rot, Pink Root, Foot Rot, Fusarium Blight, Seedling Blight" (p. 59) ; "Take-All, Foot Rot" (p. 65).

Leaf Rust.—Small, oval pustules of bright, brick-red fungus spores break out on affected leaves, which droop and shrivel if badly attacked. Leaf rust of wheat, caused by *Puccinia rubigo-vera* var. *tritici,* is not often very severe in this state. Stem rust may be present on the same plant, but appears later.

Loose Smut.—See "Smut" (p. 62).

Mold.—In the more humid districts toward the coast of California, the leaves and heads of wheat sometimes become covered with a dense growth of dark-colored mold (*Cladosporium herbarum*) which may cause considerable damage to the yield and quality of grain. This condition is sometimes called "rust," but it has no relation to true wheat rust.

Mosaic, Rosette.—Many of the seedlings affected with this disease fail to send up normal stalks but remain in a low, compact, "rosette" form (fig. 35). The leaves of affected plants show a mosaic, or green and yellow mottled appearance. Badly diseased plants die or make little or no seed. Infection occurs only in the seedling stage and comes from the soil. The cause of the disease is a virus (p. 4).

Comparatively few varieties of wheat are susceptible to this disease, which is not a serious one in California.

Nematode.—When the wheat plant is attacked by the nematode *Anguillulina tritici,* the grain in the ears is transformed into hard, dark-colored galls, shorter and thicker than the normal kernels. These galls closely resemble the fungus-filled kernels in stinking smut. Inside them may be seen with a microscope numerous slender worms (fig. 36) which are able to live almost indefinitely in the dry grain. When the seed is sown, the worms escape into the soil and attack the young seedlings, where they live around the growing points and leaf sheaths. The leaves

of such seedlings are curled, twisted, and dwarfed. When the plant blooms, the worms penetrate the young flower parts and cause the formation of galls instead of normal kernels. This disease has been reported in California in one or two instances, but is not known to exist here at present.

Nematode galls may be removed from seed wheat by floating them off in a brine solution composed of 40 pounds of common salt in 25 gallons of water. Subsequent rinsing of the seed in clean water is recommended.

Fig. 35.—Mosaic of wheat showing dwarfed and rosetted plants. (Courtesy of the United States Department of Agriculture; from Bul. 511.)

Powdery Mildew.—In this disease, the leaves are covered with a dirty-white growth of a surface fungus, *Erysiphe graminis*. Barley, oats, and other cereals and grasses are also attacked.

Resistant varieties offer the only feasible means of control. For information consult the Division of Agronomy, College of Agriculture, Davis.

Root Rot, Pink Root, Foot Rot, Fusarium Blight, Seedling Blight.—Diseases of the type indicated by these names often attack wheat, barley, and other grains in California and elsewhere, and for practical purposes may be grouped together in this manner. Affected plants are attacked by a rotting of the roots which causes them to die prematurely; or they are stunted, the yield is reduced, and the quality of the grain impaired. This condition is caused by several different soil fungi of which *Gibberella Saubinettii, Fusarium culmorum, F. avenaceum, F. niveum,*

and species of *Helminthosporium* and *Pythium* have been identified in this state. Grain that is not growing well on account of unfavorable soil conditions is most likely to be affected. In more humid climates, several of these fungi cause blighting or mold of the heads and kernels, but this

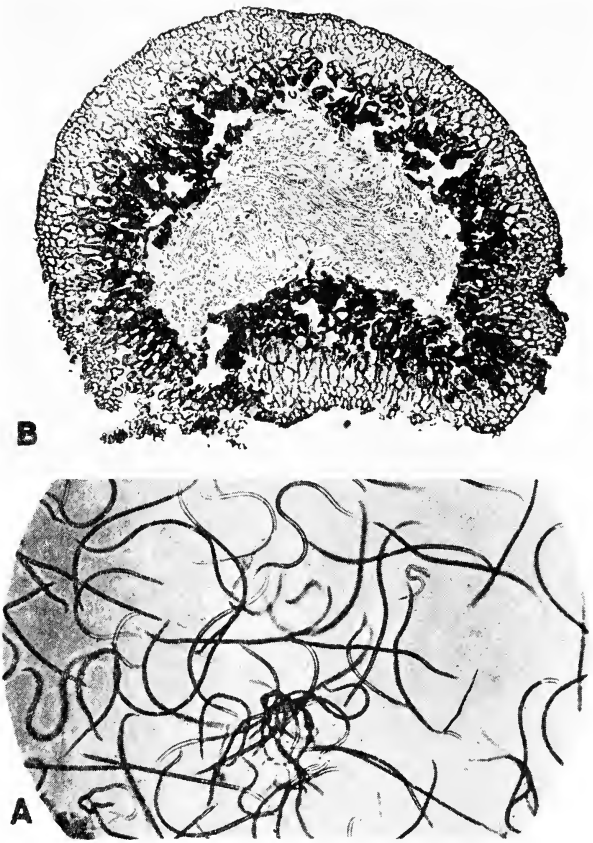

Fig. 36.—*A*, Nematode of wheat; *B*, wheat kernel showing mass of nematodes. (Courtesy of the United States Department of Agriculture Cereal Disease Investigations; from Bul. 511.)

does not occur in California. The disease called "scab" is the head-attacking phase of the fungus *G. Saubinettii* mentioned above. Another disease sometimes called "foot rot" is also known as "take-all" (p. 65).

Crop rotation with noncereal crops and good soil preparation are the best remedies for diseases of this type, which are partly responsible for "running out" of grain land. Seed treatment with copper carbonate dust reduces the infection from this fungus disease, but New Improved Cere-

san is still more effective (p. 74). This, however, will not prevent infection from contaminated soil. Long storage of seed treated with Ceresan is liable to reduce germination.

Fig. 37.—Loose smut of wheat: *A*, normal head of club wheat; *B*, head smutty before heading; *C*, spores beginning to blow away; *D*, spores almost blown away; *E*, spores entirely blown away. (From Bul. 511.)

Rust.—See "Leaf Rust" (p. 58), "Stem Rust" (p. 64), and "Stripe Rust" (p. 65).

Smut.—There are two types of smut in wheat—loose and covered, the latter called also "stinking smut" and "bunt."

Covered smut, or bunt, may be due to either *Tilletia tritici* or *T. levis*,

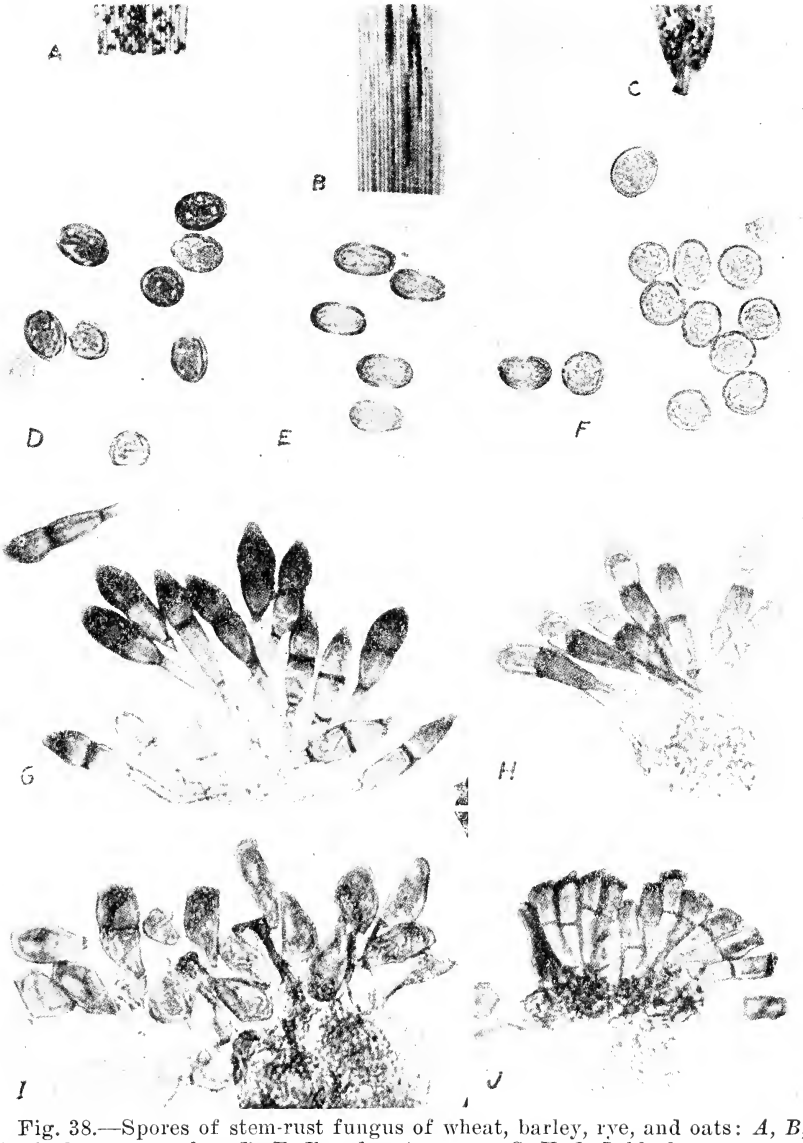

Fig. 38.—Spores of stem-rust fungus of wheat, barley, rye, and oats: *A*, *B*, *C*, black-rust pustules; *D*, *E*, *F*, red-rust spores; *G*, *H*, *I*, *J*, black-rust spores. (Enlarged about 250 times.) (Courtesy of McAlpine; from Bul. 511.)

the former being the common species on the Pacific Coast. Affected plants are usually shorter than normal ones. The head has a swollen appearance and the individual kernels push out of the husks. The inside of the ker-

nel, within the surface covering, is transformed into a mass of black smut spores which have the offensive odor of decaying fish. The infection process is the same as in covered smut of barley (p. 17).

Seed treatment for covered, or stinking, smut is the same as for barley (p. 21). Long storage of seed which has been treated with New Improved

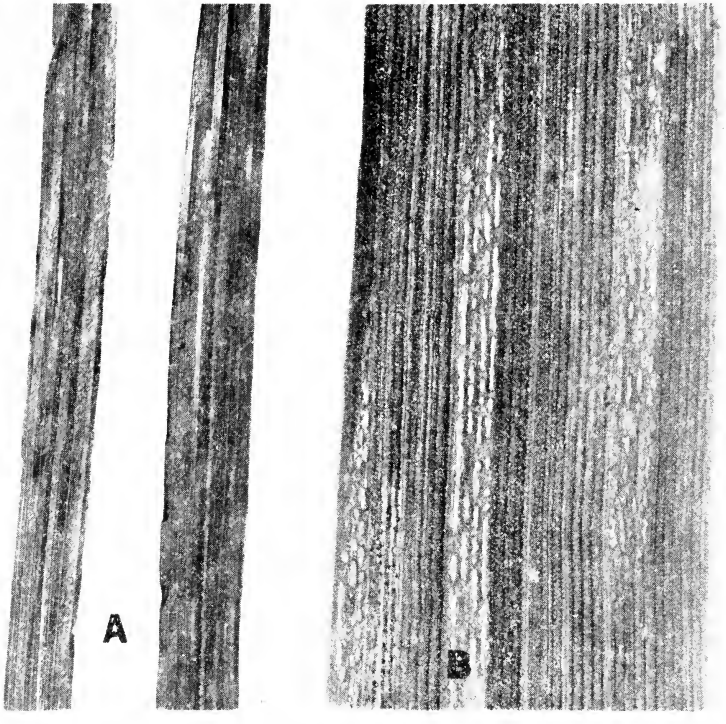

Fig. 39.—Stripe rust of wheat: *A*, red pustules (uredinia, or sori) of summer spores together with black pustules (telia) of winter spores; *B*, normal stripe of rust confined between parallel ribs. (From Bul. 511.)

Ceresan is liable to reduce germination, especially with wheat. Some varieties of wheat are more resistant to covered smut than others. The Division of Agronomy, College of Agriculture, Davis, is carrying on breeding work to develop disease-resistant cereal varieties and should be addressed for latest information.

Loose smut of wheat, caused by *Ustilago tritici* (fig. 37), is similar to the disease of barley of the same name, infection taking place in the flowers so that the fungus is inside the seed when planted. Loose smut of wheat is not serious enough in California to need treatment.

Speckled Leaf Blotch.—This disease is characterized by light spots about the size of pinheads appearing on the leaves. These develop into

black spore pustules of the fungus *Septoria tritici.* The leaves become blighted, the plants weakened, the grain shriveled, and the yield reduced. The fungus flourishes in cool, moist weather on early-sown wheat. No control method is known. Crop rotation is beneficial.

Stem Rust.—This rust appears about the time of heading and attacks both the leaves and the leaf sheaths, which enclose the stem (fig. 31, p. 51). The pustules are long and dark red at first, and their edges turn back in ragged margins; later the pustules turn black. This color change

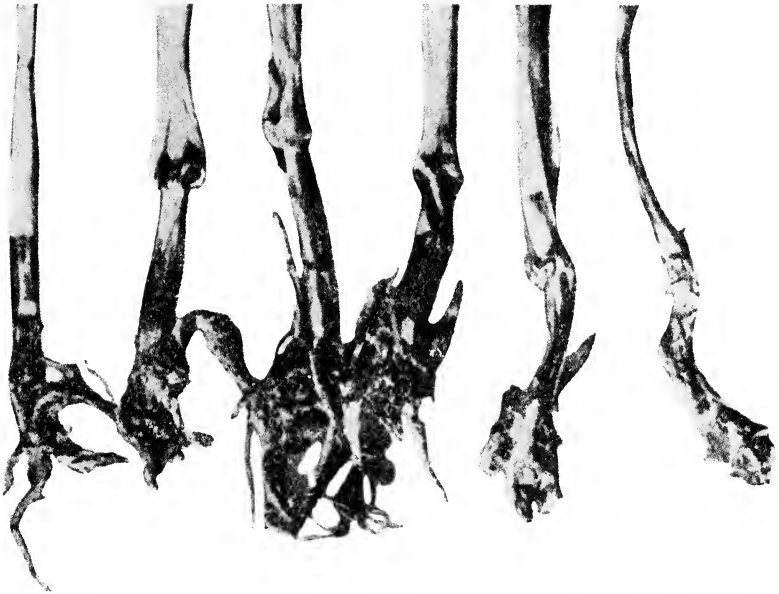

Fig. 40.—Take-all, or foot rot, on wheat. (Courtesy of the New South Wales Department of Agriculture; from Bul. 511.)

is due to the fact that two different types of spores are produced (fig. 38). The plants may be badly injured and killed. In most places this rust fungus, *Puccinia graminis,* passes one stage of its development on the common barberry, and the eradication of such bushes helps to control wheat rust. In California, this host is not attacked, and the rust lives the year round on wheat, barley, and certain grasses.

No method of field treatment for wheat rust has been known until recently, when dusting the fields with sulfur by means of airplane has shown some promise; but even this does not appear economically feasible. The first applications of sulfur should be made just as soon as pustules of rust appear and must be repeated at 7- to 10-day intervals, using 15 to 20 pounds of dusting sulfur per acre for each application. Seed treatment has no effect on rusts.

Much successful work has been done in many parts of the world in developing varieties of wheat resistant to rust. So many variable factors exist in this situation, however, that specific information cannot be given within the limits of this publication. Recently two varieties of stem-rust-resistant wheat have been perfected by the Division of Agronomy, College of Agriculture, Davis, where information can be obtained.

Stinking Smut.—See "Smut."

Stripe Rust.—On affected leaves, the spore pustules of the stripe-rust fungus, *Puccinia glumarum,* are small and elongated in form and of a bright-orange color. They are usually confined between the parallel veins of the leaf and united end-to-end to form long, yellow stripes (fig. 39). In Europe and in parts of Mexico, stripe rust often causes immense damage to wheat crops, but in California no appreciable injury has been noted.

Take-All, Foot Rot.—This disease is caused by the soil fungus, *Ophiobolus graminis,* which kills young seedlings or more often shows its effects after the plants have headed. Such plants mature too early and show a characteristic blanching of the head and very shriveled grain or none at all. Just above the ground the stalk shows a black, shiny surface (fig. 40). Take-all is an important disease of wheat in Australia and parts of Europe. It occurs in the United States and has been reported in California.

Crop rotation is advisable if this disease occurs. Oats are not susceptible and the same is true of all noncereal crops.

Another disease sometimes called "foot rot" is discussed under "Root Rot, Pink Root, Foot Rot, Fusarium Blight, Seedling Blight" (p. 59).

DISEASES AFFECTING MANY CROPS

ALKALI, BORON, SALT[19]

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

In the case of symptoms like the above which cannot be explained in any other manner, samples of soil and irrigation water for analysis should be sent to the Division of Plant Nutrition, University of California, Berkeley. It would be well first to write a letter describing the case and asking for instructions about taking samples. Faulty soils can be corrected to a certain extent by chemical treatment, washing with fairly pure water, and drainage. Harmful irrigation water cannot be improved by any known method.

COTTONY MOLD

The fungus *Sclerotinia sclerotiorum* is referred to several times in this circular as the cause of diseases of various plants. In such cases it causes a rotting of stems, roots, leaves, or other fleshy parts, with an abundant growth of pure-white, cottony, fluffy mold upon the affected tissue (fig. 41). 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, toadstool-like bodies with hollow, disk-shaped tops about ⅛ to ¼ inch in diameter on the surface of the ground (fig. 42). These are called "apothecia," and the spores of the fungus are developed in them.

[19] 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. 1935.

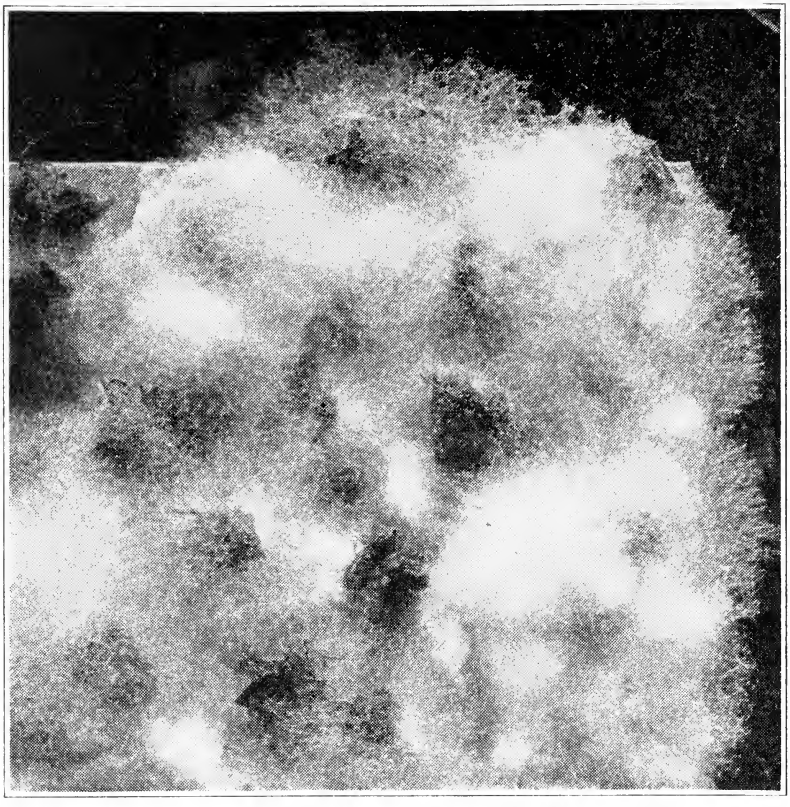

Fig. 41.—Cottony-mold fungus. (From Ext. Cir. 118.)

Plants that have a thick mass of vegetation near the ground, or the stems or roots of plants, may become infected with cottony rot by direct contact with the cottony-mold growth; parts entirely aboveground,

Fig. 42.—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.)

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 persist long enough to attack other plants growing later in the same places.

CURLY TOP

This disease, which is best known in connection with the sugar beet (p. 29) and tomato, sometimes attacks a variety of other plants under especially favorable circumstances. Beans, cantaloupes, celery, cucumbers, geraniums (*Pelargonium*), mangels, nasturtiums, pansies, peppers, squash, and zinnias are examples of this. This is a virus disease which is spread from plant to plant by a small insect, the beet leafhopper, *Eutettix tenellus*. (See Extension Circular 87, footnote 2, p. 3). These insects overwinter on native plants in the foothills in the more arid portions of the state, whence they migrate in spring to beet fields and other vegetation in the valleys and introduce the disease. In the vicinity of a badly affected beet field, when the beets are ploughed out, swarms of infective leafhoppers spread to all neighboring vegetation, and various kinds of plants may show disease symptoms. These are usually of the nature of stunting, mottling, and deforming of the leaves.

NEMATODES, EELWORMS

Nematodes (fig. 36, p. 60; fig. 43) that 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 parts affected or causes the development of galls, swellings, and other abnormal growths and eventually weakens or even kills the host plant. These effects are similar to those which often are produced by fungi and bacteria and, since the causative organism is almost 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. These again attack plants when favorable conditions and hosts are available.

The common root-knot nematode, *Heterodera marioni*,[20] causes swellings or galls on the roots of a great many different kinds of plants (fig. 18, p. 26) including most annual crops, fruit trees, ornamentals, and

[20] For further information see: Tyler, Jocelyn. The root-knot nematode. California Agr. Exp. Sta. Cir. 330:1–34. 5 figs. 1933.

many weeds. The worms are embedded in these galls, the largest form being the adult female which has a white, pearl-shaped, pinhead-sized body.

The sugar-beet nematode *Heterodera schactii,* (p. 35) is very similar to the garden nematode; leaf, bulb, and stem-attacking nematodes of a number of species occur commonly, especially on alfalfa, oats, and wheat, among the field crops. Stem nematode *Ditylenchus dipsaci,* on alfalfa, is discussed on page 13.

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, the only practical method which has thus far been found is to starve out the

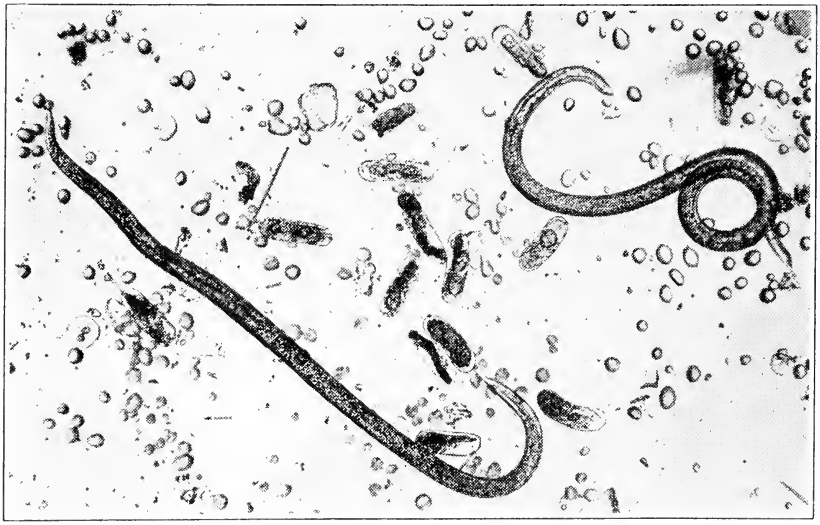

Fig. 43.—The narcissus stem nematode, with young worms and eggs. Enlarged nearly 150 times.) (From Ext. Cir. 118.)

worms by growing some unsusceptible crop or keeping the land clear of all vegetation for one or more years. Drying the soil tends to kill out the worms. Of the crops commonly grown in California, the various grains, including sorghum, milo, and Kafir, as well as wheat, barley, oats, and rye are highly resistant and 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 resistant crops which may be grown are certain varieties of cowpea (consult Division of Agronomy, College of Agriculture, Davis, regarding names and seed), velvet bean, sweet clover (*Medicago*), and peanuts. *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[21] 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, of prohibitive cost. Miss Tyler (see footnote 20, p. 68) 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 possible value, but effective and practical methods of application have not yet been developed.

The bulb, or stem, nematode, *Ditylenchus dipsaci,* lives in the tissues of affected plants of many different species, like strawberries, alfalfa, oats, garlic, narcissus, and phlox. In this case, however, many of the host-plant species have distinct strains or races of the parasite, so that the worms from alfalfa, for instance, may 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.

SOIL DEFICIENCIES

It is a well-known fact that plants require for their normal development the presence of certain chemical elements, as well as water, in the soil. Until rather recently, these essential elements were supposed to be nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulfur. It is now known that at least four others—namely, boron, manganese, copper, and zinc—must be added to this list, and there may still be others. One usually thinks of three elements—nitrogen, potash and phosphorus—as being most likely to benefit plants when added to the soil. Of these, nitrogen is the one most commonly lacking in California. Ordinary effects of nitrogen deficiency, where fertilization of plants with this element results in increased growth or vigor, are not usually considered as diseases. Cases are not unknown of plant failure from lack of one of the other two elements. Certain obscure troubles of plants seem to be due to deficiencies of some of the less common elements, or at least they are corrected by supplying them. Chlorosis due to lack of available iron is an example. Symptoms caused by excess of certain substances (see "Alkali, Boron, Salt," p. 66), may not be unlike those due to deficiencies.

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

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 determine the lack of a single element by experimenting on a small scale with single substances like sodium nitrate, potassium sulfate, copper sulfate, iron sulfate, zinc sulfate, superphosphate, or sulfur. The common belief that deficiencies of substances necessary for plant growth can be detected by chemical analysis of the soil unfortunately is seldom true.[22]

VERTICILLIUM WILT, VERTICILLIOSIS[23]

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

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

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

[23] For more complete information see: Rudolph, B. A. Verticillium hadromycosis. Hilgardia 5(9):197–361. 9 figs. 4 plates. 1931.

FUNGICIDES[24]

COPPER

Bordeaux Mixture.—The following formula, known as the 5–5–50 mixture, is one of those 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 the 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 "processed lime," which is pulverized quicklime.

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

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

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

Commercial Bordeaux Mixtures.—Several commercial brands of bordeaux mixture in a powdered or paste form are on the market. These are more convenient to use than the homemade preparation and usually give satisfactory results, although they are admittedly inferior in sticking

[24] This discussion is limited to the fungicides that are referred to in this circular. A more extended list will be found in the other circulars mentioned in footnote 2, p. 3.

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 made with quicklime. 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 appreciably.

Copper-Lime Dust.—For the control of certain fungus diseases, the practice of dusting plants with a dry powdered material containing copper finds considerable use. This is prepared by thoroughly mixing together finely pulverized copper sulfate 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. Results will be better if this dust 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.

Copper Oxide.—Finely pulverized, red oxide of copper (cuprous oxide) has in recent years come into extensive use for seed treatment as a dry powder (see p. 32) and is also showing promise as a spray material, suspended in water. Commercial brands are available. To be of value, the red oxide must not have deteriorated to the black (cupric) oxide. Superiority is claimed for a yellow, more finely divided form 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.

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 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 (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.

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

SULFUR

Dusting Sulfur.—The essential feature of a dusting sulfur for control of powdery mildews and other diseases is extreme fineness. A good brand should be fine enough so that most of the particles pass through a screen of 325 meshes to the inch. Some types of sulfur are much finer than this. There are 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 particle size.

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

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

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

Make a smooth paste of the calcium caseinate and 1 quart of water, mix with the sulfur, and add the rest of the water. Glue—⅜ ounce dissolved in 3 quarts of water—may be substituted for the calcium caseinate paste.

ZINC

Zinc Oxide.—This is a white powder sometimes used for seed treatment and control of damping-off. Commercial brands are available.

SPREADERS AND STICKERS

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

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. Appli-

cations 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, the use of airplanes for spraying is finding a certain amount of value. 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 and are also dusting crops by airplane 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.

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[25] The Plant Disease Reporter. (Mimeo.) Issued by the United States Bureau of Plant Industry, Division of Mycology and Disease Survey, Washington, D. C.

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