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DISEASES OF STRAWBERRY

A GUIDE FOR THE COMMERCIAL GROWER

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DISEASES OF

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This Circular Tells About

ROOT AND CROWN DISEASES

VIRUS DISEASES

FOLIAGE DISEASES

FRUIT DISEASES

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STRAWBERRY

By Stephen Wilhelm

Unlike most fruit, the strawberry fruit represents not the end product of the ripened ovary, but an enlarged and fleshy stem on which the flower parts were borne. The real fruit in the botanical sense is the seeds.

Of value only when ripe, and then extremely perishable, the strawberry fruit must be used quickly after picking. Storage beyond a few days may result in losses. Wet weather and the ever-present diseases it favors constitute the greatest hazard to the fruit.

The control of strawberry diseases is particularly important in California where annually more than one third of the nation's total strawberry crop is produced on 12,000 to 15,000 acres, and where high berry quality sustains the favorable market.

Strawberry diseases have a great variety of causes, and present control measures are based largely on prevention of infection rather than on cure of diseased plants. This means that it is of utmost importance to know what diseases the strawberry is susceptible to, when and where they are likely to occur, and what measures must be taken to prevent them. Furthermore, many of the fungus parasites of strawberry also cause diseases in other crops or are harbored by other crops and, therefore, to know something about the diseases of other crops is also necessary.

This circular is designed to help the grower recognize the important diseases of strawberry in California. Where control measures are known and can be recommended, they are outlined in detail at the end of each discussion.

ROOT AND CROWN DISEASES

Root and crown diseases which are typically soil-borne are among the most important diseases affecting strawberry in California. They cannot be properly understood without some knowledge of the healthy strawberry root system.

The supporting structural roots. The root system of a healthy strawberry plant is composed of structural or supporting roots and feeder rootlets. The structural roots are hard, woody, and frequently rather dark-colored. They penetrate deep into the soil where possible, have a rather thick, distinct bark, and are capable of long life. They support the feeder rootlet system which is made up of delicate, white, rather short-lived rootlets.

The function of feeder rootlets. Feeder rootlets not only absorb water and minerals needed for plant growth; they also manufacture essential foodstuffs required for plant growth and fruiting. They are very important to the plant but, being out of sight, their importance is frequently overlooked. Large yields and good fruit size are not possible except on plants supported by extensively developed, glistening white feeder rootlets.

Feeder rootlets, in addition to being short-lived, are typically produced in successive crops. At least two crops of feeder rootlets per year are produced in California. This means that after a rather specific period of function a given feeder rootlet dies and is replaced by a new one.

The most active period of feeder rootlet growth, at least in the central coastal strawberry district where it has been studied most, is in the fall and winter when the plant is making little or no growth of top. This growth of rootlets in winter is probably due to the fact that roots use plant foods made by the leaves and can obtain large quantities of such foods only when demands by flower and fruit are lowest. High spring yields of fruit are possible only on plants which have produced an extensive healthy feeder rootlet system during the winter. A winter soil environment favorable to strawberry rootlet growth—good drainage must be provided because roots need air—is a primary factor in determining yield and fruit size.

Feeder rootlets formed in the winter soil environment usually begin to die in midsummer and are replaced by new ones. The death and replacement of rootlets may be gradual or sudden, depending upon soil and plant factors. Usually a distinct summer slump in plant vigor and production attends the period of rootlet change.

Healthy strawberry rootlets are glistening white, free from fungus and nematode invasion, and are clothed with root hairs over much of their surfaces. They have been produced consistently, even on plants grown in old strawberry fields, by fumigation of the soil prior to planting. Chloropicrin is the chemical fumigant which to date has proved most effective in ridding the soil of injurious root-infecting organisms and thus providing for healthy growth of the roots (fig. 1). The grower is urged to read the part on soil fumigation which appears at the end of the section on Verticillium wilt.

Strawberry root infecting nematodes, namely the root knot (*Meloidogne hapla*) and root lesion types (*Pratylenchus spp.*), are not specifically discussed in this circular. Root knot appears to be of rather infrequent occurrence in the

Fig. 1. Strawberry plant with extensively developed root system was grown in chloropicrin-fumigated soil; stunted plant in field soil. Both plants are 18 months old, the same variety, set at the same time.

major strawberry-growing areas and the role of root lesion nematode in causing root degeneration is still uncertain. Soil fumigation as recommended for the control of Verticillium wilt also controls these nematodes.

Verticillium Wilt

Verticillium wilt is caused by a widely distributed soil-borne fungus, Verticillium albo-atrum. *This fungus is particularly prevalent in land with tomato, potato, pepper, or cotton crop history, or in land infested with the nightshade weed. Control by soil fumigation with chloropicrin is effective.*

Verticillium wilt is one of the most widespread and destructive diseases of strawberry. Known early to growers in California as "brown blight," it has been reported from many areas of the world since it was first described in 1932. The disease occurs in all of the commercial strawberry-growing areas of California.

Symptoms. Verticillium wilt causes a collapse of strawberry plants during the peak of the first year's growth. Outer leaves of plants may become wilted in late spring and begin to dry at the edges and between the veins (plate 1).* Growth of new leaves is retarded, resulting in a stunted, flattened plant. As the season progresses, more outer leaves collapse and the stunting becomes more pronounced until finally the plant is worthless. Side crowns may continue feeble growth after the center crown has collapsed, but in the Lassen and Shasta varieties such attempts at growth usually do not result in any significant recovery.

Petioles of affected plants often show brownish-black streaks or blotches along the upper grooved side. This is frequently one of the first symptoms to appear. There is usually no vascular discoloration visible in the crown when it is cut nor any rotting of roots attributable to Verticillium wilt. The main veins of the petioles may show a slight vascular browning.

Climatic conditions and plant nutrition greatly influence symptom expression in Verticillium wilt. A lush vegetative plant grown rapidly with high nitrogen is more severely affected than one grown slowly and hard. Cool overcast weather in spring interspersed with warm bright days favors symptom expression, especially if the infected plant is bearing fruit. Late-planted (May or later) plants may escape serious injury during the first year, but will often succumb in the second.

Previous crops key to Verticillium losses. The amount of Verticillium wilt appearing in a strawberry planting usually reflects the past history of the land in terms of Verticillium-susceptible crops such as tomato and cotton or the nightshade weed. Tomatoes greatly favor both the introduction (in transplants, not by seed) into fields and increase of the Verticillium fungus in the soil. Tomatoes are commonly infected by Verticillium anywhere in California and by the end of the growing season the fungus has completely pervaded their woody tissues. During the winter, Verticillium produces small, dark, resting bodies (microsclerotia) in the decaying plant, and these may persist for years in the soil. Experimental soil indexing for Verticillium has shown that it readily persists in soil through eight to ten years of presumably nonsusceptible vegetable (bean, lettuce, sweet corn), grain, or pasture crops. In one instance, Verticillium was detected in soil that had not been in tomatoes for twenty-five years. Heavy losses from wilt, i.e., greater than 50 per cent, have occurred in lands out of tomatoes only five years or less.

Other crops, especially potatoes, cotton, chrysanthemum, pepper, and the weed, hairy or Brazilian nightshade, *Solanum sarachoides* Sendt. (fig. 2) are much the same as tomato in perpetuating and building up Verticillium. Nightshade is a symptomless carrier of Verticillium.

* The plates for this circular are shown in the color section at the end.

Fig. 2. *Solanum sarachoides,* **a symptomless weed carrier of a strain of Verticillium which is severely pathogenic to strawberry.**

Nightshade grows abundantly in orchards and particularly among such irrigated crops as lettuce, carrots, and beans. It is rather infrequently found in grain or pasture lands. Because of the common occurrence of nightshade, much old orchard land can no longer be considered free from Verticillium. The only way that Verticillium can be identified in the weed is by laboratory culture.

Verticillium fungus is hard to kill. Although too small to be seen with the unaided eye, the microsclerotia or resting bodies of Verticillium are capable of withstanding environments adverse to many living organisms. The resting bodies may tolerate drying at 100° F for many months; they are resistant to the action of many of the commoner soil fumigants, such as methyl bromide, ethylene dibromide, carbon disulfide, and the dichloropropane-dichloropropene mixture sold as D-D. Few soil organisms appear to prey upon them.

The occurrence and severity of Verticillium wilt are not greatly affected by soil pH or soil type. Severe outbreaks in strawberry have been noted on soils ranging in pH from 4.8 to 8.5, on sandy loams, clay loams, and peat soils. There is, however, a noticeable tendency for the Verticillium fungus to persist longer in soils along the coast, which tend to be heavy in texture, than in soils of the San Joaquin Valley, which tend to be sandy.

Control Measures

Control through resistance is possible. Genetic resistance is present in strawberry but not as yet in varieties as high yielding as Shasta and Lassen.

Resistance to Verticillium wilt in strawberries is quantitative, i.e., is expressed in varying degrees of tolerance to symptom expression. Shasta has a little more tolerance than Lassen, for instance, and Marshall has more than Shasta. Blakemore and Sierra are highly resistant. Sierra may be grown without losses from wilt on heavily infested land, such as land that has been repeatedly planted to tomatoes.

Highly resistant plants have been selected from certain crosses in greenhouse inoculation studies. Complicating the selection of plants resistant to Verticillium wilt is strain specificity of the wilt fungus. Two distinct strains of Verticillium pathogenic to strawberry are now known. These are strains which produce the Verticillium disease in tomato and strains parasitic to the nightshade weed. More undoubtedly exist. Strawberries selected for resistance to the tomato strain of Verticillium may succumb to the nightshade strain.

Chloropicrin soil fumigation gives outstanding control. Because the most desirable varieties grown at present are not resistant to Verticillium wilt, and because much of the land suitable for strawberries is infested, control by fumigation is recommended.

In many tests, and in extensive commercial practice, effective control of Verticillium wilt has been achieved by fumigating land with chloropicrin prior to planting. A minimal dosage for heavy soils being fumigated at low temperatures (45 to 50° F) is 3 milliliters injected 6 inches deep into each square foot of land, or the uniform chisel application of 480 pounds (34.5 gallons) to the acre. Less chloropicrin may be required for sandy soils being fumigated at higher temperatures (70 to 75° F).

If soil is covered with polyethylene sheeting immediately after fumigation and left covered for 20 hours or more, 320 pounds of chloropicrin per acre are as effective in controlling Verticillium as 480 pounds not covered. If a mixture of chloropicrin 2 parts and methyl bromide 1 part is used, and is followed by tarping, 320 pounds of the mixture are effective.

Effective control by fumigation is possible only in deeply tilled soil moist to the surface. In southern California where late summer planting is practiced it usually is necessary either to irrigate or to sprinkle the land prior to fumigation. No single requirements in soil fumigation are as important as seed bed tilth and moisture. The moisture must extend up to the soil surface.

In our experience, land may be repeatedly fumigated with chloropicrin—that is, year after year—without the danger of building up injurious or toxic conditions. Once land has received the high dosage of chloropicrin, and has been rid of Verticillium, however, the dosage may be reduced considerably in subsequent fumigation without jeopardizing disease control.

A fumigation schedule for chloropicrin:

1) Plow, disk, or preferably rotovate the soil to at least 9 inches as soon after rain or irrigation as the land can be worked. This will insure an adequate moisture level at the surface of the soil. Break up all clods. Should the surface soil dry out before the fumigant is applied, either rotovate the soil again just before fumigating to bring moist soil to the surface or sprinkle the land (fig. 3).

2) Secure the services of a skilled commercial operator for the actual application of the fumigant.

3) Chain-drag the soil after injection of the chemical, or smooth it in a similar way and roll it. If water is available a light sprinkling will provide an excellent seal. If water for sprinkling is not available, and it usually is not, and if the soil was moist to the surface when fumigated, the initial dragging and rolling will suffice.

4) Do not plant the land until two weeks after fumigation.

The amount of disease control obtained by fumigation is dependent not only upon the properties of the chemical but upon the condition and tilth of the soil. *Dry, cloddy, shallowly worked soil should not be fumigated.* A poor job of fumigation or application of too low a dosage may actually cause Verticillium wilt to increase.

*Chloropicrin mixtures for Verticillium wilt and weed control.** The 2:1 chloropicrin-methyl bromide mixture has given excellent control of Verticillium wilt (and of many weeds as well) in many

* Not recommended yet. Data not yet available on uptake of bromide by strawberry.

Fig. 3. Rotovation just prior to injection of chloropicrin improves soil tilth and brings moist soil to the surface.

soil types at dosages as low as 320 pounds (214 pounds of chloropicrin, 106 of methyl bromide) per acre. Skill and speed in applying chloropicrin-methyl bromide mixtures are essential because of the highly volatile nature of methyl bromide (fig. 4). Immediately after injection of the fumigant, cover the area with polyethylene sheeting. The sheeting must remain a minimum of 12 to 20 hours or longer at lower soil temperatures. Two-mil sheeting is satisfactory.

Here, as in the use of chloropicrin alone, strict attention is paid to soil moisture and tilth. Good results are possible only on land with a seed-bed level of soil moisture to the surface and deep tilth. When tarping is done, the area to be fumigated must first be carefully divided into strips the width of which is a direct multiple of the width minus 2 feet (for burying the edges) of the polyethylene sheeting being used. It is strongly recommended, because of problems of handling, that the width of polyethylene sheeting not exceed 20 feet. Lengths up to 1,400 feet have been used satisfactorily (fig. 5).

Prior to the actual injection of the fumigant one edge of the polyethylene sheeting should be secured by burying it in a furrow made the length of the field. In making the furrow the soil should be plowed out, away from the strip being treated. The furrow should be as straight-sided as possible and at least 6 inches deep (fig. 6). After the sheeting edge is anchored and buried, the fumigant can be applied.

Each chisel must be checked to deliver the required amount of material at the previously determined tractor speed. The tractor should also be equipped with a

Fig. 4. Injection equipment consists of chisels mounted 12 inches apart on tractor draw bar, a manifold take-off for polyethylene tubing which connects to each chisel; a system of applying constant and uniform pressure to the fumigant cylinder and ring roller to smooth and compact the injected soil.

Fig. 5. In addition to injecting and rolling the soil a furrowing shovel opens a 6–8-inch deep straight-sided furrow into which the tarpaulin edge is buried.

Fig. 6. The tarpaulin—polyethylene sheeting—is tacked in place and the furrow is plowed shut.

chain drag or spike tooth harrow and light roller to smooth and compact the soil. As the tractor passes, the tarpaulin is immediately pulled over the treated strip of soil. Along the other edge of the treated area a second furrow is made. In this furrow the loose edge of the polyethylene sheet is anchored by burial under soil. Any rips in the polyethylene must be patched immediately (fig. 7).

The next day, as fumigation proceeds, the sheeting is simply turned over to cover the newly fumigated area.

WARNING

Chloropicrin fumes are irritating and disquieting to persons and the liquid should always be handled with care. Chloropicrin will not burn the skin if it is promptly washed off with paint thinner, kerosene, or soap and water.

Chloropicrin fumes are exceedingly toxic to aerial parts of plants. If it is spilled carelessly or allowed to drip onto roadways from chisels during a machine application, sufficient fumes may settle over nearby areas to scorch the vegetation.

The covering of fumigated soil has distinct advantages:

1) It reduces the hazard of fumes that may escape into residential areas.

Fig. 7. All rips in the polyethylene, even minute rips, must be patched, and if strong winds are a threat the covered areas must be patrolled for blowouts.

2) It limits the amount of chloropicrin applied on any one day.

3) It insures a control of Verticillium in the surface soil.

4) It gives a greatly improved control of weeds, especially if methyl bromide is added.

5) The recommended dosage of 320 pounds of chloropicrin per acre with tarping costs less than 480 pounds without tarping.

Red Stele

Red stele is a destructive root disease of mature strawberry plants in poorly drained areas. Outbreaks have not been generally widespread in California, but the causal fungus, Phytophthora fragariae, *may be widely distributed. Adequate drainage is important.*

Sudden outbreaks of red stele may appear almost anywhere in poorly drained areas following wet winters. The causal fungus is adapted to living and growing in water and prefers low rather than high temperatures and acid rather than alkaline soils. It is also adapted to long survival in soil and produces abundant thick-walled resting spores (oöspores).

A principal source of the disease may be infected planting stock. The plant producer should make an effort to avoid any land with a red stele history, and caution should be exercised by the purchaser in accepting diseased stocks.

Disease restricted in distribution. At present the disease is restricted to the central coastal berry-growing areas of California, primarily to Santa Clara, Santa Cruz, and Monterey counties, and to certain northern counties.

Symptoms. The disease causes a general collapse of strawberry plants in the spring typically when in their second growing year. Only rarely are plants affected in the first year. The plant collapse is the result of root destruction at a rate faster than replacement, and most often coincides with the period of earliest fruiting, when root regeneration is slow because of food demands for fruit initiation and production.

Infected plants after passing their first winter may resume normal growth in the spring, but may collapse later as warm weather sets in. Typically, entire beds or areas of considerable size are affected (plate 2). One of the first evidences of the disease is temporary wilting of affected plants during the warm part of the day, the youngest as well as the outermost leaves becoming flaccid. Plants also cease to grow, the foliage loses its shiny green luster, and the older leaves become tinged with yellow and red. Dry areas may appear in these leaves. An examination of the roots usually reveals the older ones to be entirely dead and the new crown roots to be dying from the tips back (plate 3). The dying from the tips of the new crown roots gives rise to the symptom called "rat-tail." Cutting these rat-tail-like roots lengthwise above the dead tips usually discloses the red interior (stele) of the root (plate 4). This is the symptom upon which diagnosis is primarily based.

Zoöspores (swimming spores) of this fungus invade roots at the tips, and growth of the fungus with accompanying internal rot of the roots proceeds upward. Later, the outer root tissues also collapse. This infection process is in contrast to black root rot in which outer root tissues are affected considerably ahead of the central cylinder or stele.

As the season progresses into summer some recovery of affected plants may be apparent, but rarely is recovery complete.

In some instances, red stele may be somewhat difficult to differentiate from Verticillium wilt, but generally strawberries affected with red stele collapse early in the season or during the months of February through May. The central immature leaves as well as the outer ones collapse at once. In Verticillium wilt, on the other hand, plant collapse usually occurs in summer and fall, during the months of June through October, and involves chiefly the outer leaves. Also, in Verticillium wilt first-year plants primarily are affected, whereas in red stele, second-year plants are affected. In red stele, roots are rotted; in Verticillium wilt they are not. In Verticillium wilt, distribution in the field may be erratic and spotty; in red stele, entire areas or beds are usually affected.

California varieties susceptible. The varieties presently grown in California—mostly Shasta and Lassen—are readily susceptible to red stele, Shasta perhaps a little more so than Lassen. Lassen has a root system capable of more vigorous growth and regeneration than Shasta, and may be able to recover from red stele more readily if environmental and soil conditions permit. Red stele resistant strawberry varieties, such as Aberdeen, Temple, Pathfinder, Sparkle, Fairland, Climax, and Siletz, developed elsewhere, unfortunately are not productive in California.

Poor drainage favors disease outbreaks. Though infected nursery stock may constitute a principal source of infected plants, poor drainage—standing water—and low temperatures during the winter are the primary factors responsible for severe outbreaks of red stele. Outbreaks generally are restricted to low areas or to areas underlain with hardpan or clay or otherwise impervious to water penetration.

Control Measures

Adequate drainage to carry away all excess water during the winter should help to decrease the severity of red stele. Exceptionally heavy soils in the central coastal berry district should be avoided.

One report suggested that Nabam may be of value in preventing red stele infections if applied at the onset of flowering at a dosage around 1.5 per cent in 2,000 gallons of water per acre, that is 30 gallons of actual Nabam per acre. Nabam, however, will not effect a cure of obviously diseased or infected plants. In our tests, Nabam applied in irrigation water up to rates as high as 60 gallons per acre was ineffective in curing diseased plants or in preventing symptom development in infected plants.

Black Root Rot

This is a disease complex—no one specific causal agent has been identified, but several acting singly or in combination appear to be involved. Control is uncertain because of the many causal factors.

Symptoms. Black root rot is a rather nondescript disease characterized by feeder rootlet killing, deterioration and blackening of the main root system, and decline in vigor and productivity of the plants.

Feeder rootlets are killed. One of the first effects of the disease is the killing of feeder rootlets. This divests the perennial supporting roots of their absorptive function, and reduces plant vigor. Later the outer tissues of the perennial roots darken and deteriorate. The woody central portion continues to live on after death of the outer tissues, remaining white and apparently still able to conduct some water. Significant decline in vigor of affected plants is often not apparent until the second growing year and even then it may not set in severely until after the main spring crop of fruit. This suggests that the preceding winter with wet, cold soil and a reduced growth of the plants, may provide the favorable conditions for onset of the disease.

Care must be taken in the diagnosis of black root rot because as the main roots grow older the young, outer white tissues normally are replaced by a dark outer protective layer, the polyderm, which may vary in color from light to dark brown. Also, feeder rootlets are not perennial, but are rather short-lived; consequently, some dead ones can always be found, even on healthy plants.

Many different fungi attack strawberry roots. Roots of strawberries are subject to attack by many different fungi and by certain nematodes. The role of any one of these in causing root degeneration and loss of plant vigor is imperfectly known.

Idriella

Idriella lunata, a recently described fungus, has been shown to penetrate strawberry roots and to produce distinct black lesions and root killing such as is ascribed to the black root disease (fig. 8). It can attack and kill small feeder rootlets and from these may grow into the larger supporting roots, girdling them, or it may attack larger roots directly. Idriella, after killing outer tissues, may grow into the water-conducting elements and plug them. Idriella is a slow-growing fungus, favored by relatively low soil temperatures, which produces its injurious effect on plants by a slow, steady killing of roots.

Pythium

Pythium ultimum, a water mold widely distributed in soils, is also a primary fac-

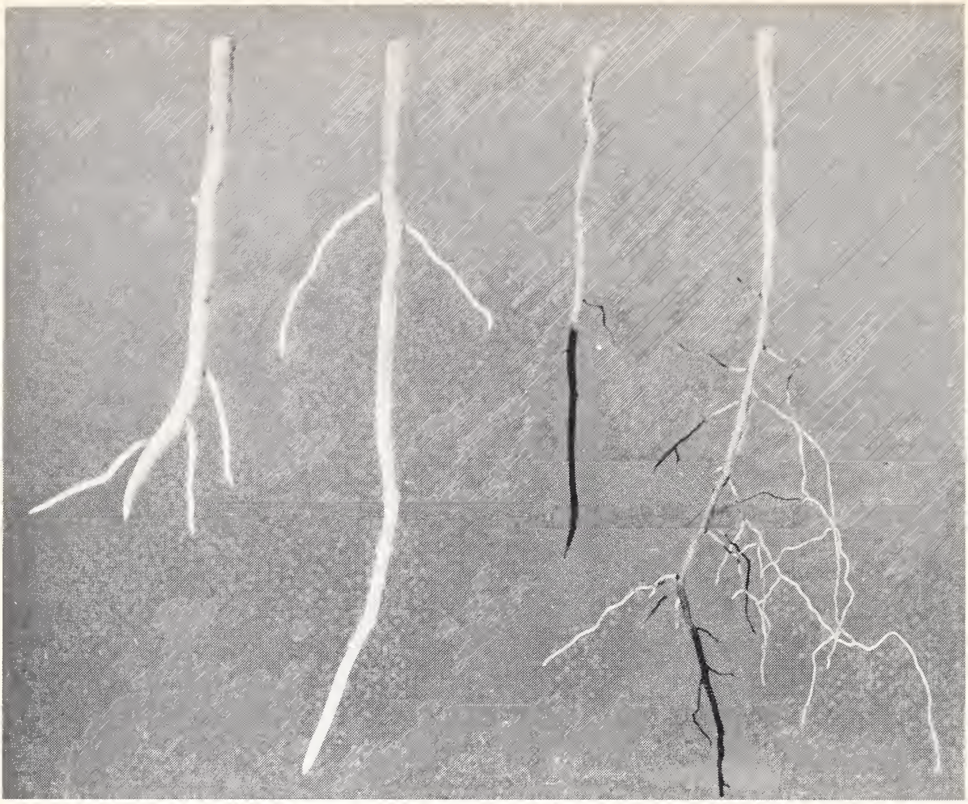

Fig. 8. Severe root killing and blackening caused by *Idriella lunata*. Infections begin at or near root tips.

tor in causing decline in plant vigor in plantings two years old and older. Its primary role in plant decline appears to be the killing of feeder rootlets. Evidence of loss in vigor and productivity usually is not apparent until the second year, and wet soil during the first winter may predispose a planting to Pythium injury. Evidence of injury is the general absence of live feeder rootlets by midsummer of the second year, and although the main roots may attempt to replace them, they are killed as rapidly as they emerge. In this way the main supporting roots become progressively denuded of absorptive rootlets and the plant slowly declines in vigor. Saprophytic soil fungi which colonize the dead feeder rootlets or root surfaces before death, such as the ubiquitous *Cylindrocarpon radicicola*, may gain access into the wood of the main supporting roots through the dead rootlets, and may contribute to their premature death.

Rhizoctonia

Rhizoctonia solani, a fungus widespread in the soil, commonly attacks strawberry roots. The large perennial roots are penetrated only slightly and are apparently not seriously affected, but the delicate feeder rootlets may be destroyed. Low soil temperatures and wet conditions also favor this fungus and the period of greatest root susceptibility appears to be the winter months (plate 5). Rhizoctonia mycelium may be so abundant in the winter as to literally clothe the rootlets with its growth. This growth may be mistaken for root hairs. *Rhizoctonia solani* and *Pythium ultimum* frequently are found together and in the author's opinion these two fungi constitute primary factors responsible for the rootlet killing and degeneration known as black root rot.

Rhizophagus

Rhizophagus, a Phycomycetous fungus, may contribute to the death of feeder rootlets. Though generally assumed to be mycorrhizal in nature, and thus possibly beneficial to the strawberry, indirect evidence has accumulated which suggests that this fungus is an injurious root parasite. Strawberry rootlets frequently are pervaded by this fungus to such an extent that nearly every root cell is in contact with the large, internal fungus mycelium and the innermost cortical cells are pierced and nearly filled by specialized sucking organs of the fungus—the haustoria. Large spherical vesicles also form on the fungus mycelium and these may actually rupture feeder rootlets, leading to their premature death.

Studies have shown that Rhizophagus fungus attacks the roots of many different plants, but inoculation studies have not yet established its real role in causing root degeneration. According to experiments by the author, rootlets of strawberry free from Rhizophagus, such as may be found in some fumigated soils, are whiter, straighter, and possess more root hairs than do rootlets infected with Rhizophagus. It is also the opinion of the author that rootlets infected with Rhizophagus are more susceptible to the attack of other fungi than noninfected rootlets.

Root lesion nematodes

Root lesion nematodes and others may penetrate the rootlets of strawberry and, if sufficiently abundant, may cause plant degeneration. According to recent studies, 5,000 lesion nematodes per pint of soil are a level at which significant root injury may be expected. The fact that a nematode or any other organism is able to penetrate a root is alone not sufficient ground for attributing to them an injurious role, and results of recent studies have not convincingly shown that lesion nematodes alone can cause root degeneration. However, in combination with other organisms such as fungus pathogens root lesion nematodes may have a significant role.

Control Measures

Control may be uncertain because of a multiplicity of causal factors. Preplant soil fumigation with ethylene dibromide and a dichloropropane-dichloropropene mixture according to commercial recommendations may benefit the plant temporarily, but these usually do not control black root rot for long. Chloropicrin fumigation as recommended for the control of Verticillium wilt gives an excellent control of black root rot, but conditions during the first or second winter after fumigation may favor the reintroduction and build-up of rapidly growing fungi such as *Pythium ultimum* and *Rhizoctonia solani.*

If these fungi are reintroduced at a time of year favoring their rapid growth, such as during wet weather, extensive rootlet killing may result. Rhizophagus, which may be present in planting stock, appears likewise to spread greatly in previously fumigated soils.

Armillaria Root and Crown Rot

The root and crown rot caused by the oak root fungus Armillaria mellea, *occurs primarily on land cleared of orchard or native trees harboring the fungus in their roots.*

Apricot, peach, plum, almond and, to a limited extent, apple are the more common fruit trees attacked; oak is the commonest native tree. The Armillaria fungus may persist for many years within dead tree roots deep in the soil, but it dies rather quickly in surface soil which has been permitted to dry out thoroughly, or from which tree roots have been removed.

Symptoms. Strawberry plants are usually affected in rather specific circular areas which correspond to the locations where diseased trees stood previously. Affected plants turn reddish brown, collapse, and die. Just beneath the bark of the larger roots and crowns white plaques of the fungus parasite form. These are called mycelial fans. On rare occasions the mushrooms of the fungus grow up from the bases of diseased plants. Mushrooms, however, are to be seen only during the rainy season in spring.

Control Measures

There is no cure for affected plants, and rarely are losses serious enough to warrant prior fumigation of the entire field.

If specific areas are known to be infested with Armillaria, fumigation of these with carbon disulfide may be warranted. Prior to fumigation, while the land is being prepared for planting, as many of the old tree roots as possible should be removed and burned. A day or two prior to fumigation the areas should be sprinkled with enough water to wet the surface down 2 to 3 inches. This makes the application of carbon disulfide much easier, reduces the fire hazard—carbon disulfide being flammable—and provides a partial seal for the vapors. Carbon disulfide should be injected into the soil 6 inches deep on 18-inch staggered centers at the rate of 2 fluid ounces per injection. Fumigated land may be planted in one to two months without danger to the strawberry plants.

Dematophora Root and Crown Rot

This severe disease of strawberry is caused by the fungus Rosellinia (Dematophora) necatrix. *The disease is yet limited in distribution.*

The fungus *Rosellinia (Dematophora) necatrix* is a destructive pathogen better known on apple and pear trees, but capable of killing many kinds of plants, shrubs, and trees. In the United States it is apparently present only in California.

Symptoms. Dematophora fungus pervades cortex, cambial zone, and wood of the roots and crown bases, forming indefinite plaques of white tissue in the cambial zone. If sufficient moisture is present, cottony growth often penetrates the soil surrounding the roots (plate 6). Though the disease is exceedingly destructive to those plants which it attacks, losses noted thus far from Dematophora have not been great.

Dematophora-infected strawberry plants collapse and die from a complete loss of the root system. Plants thus infected have a tendency to occur in rather distinct areas where diseased trees have stood previously (plate 7). Old invaded tree roots left in the soil serve as food bases from which the fungus grows through the soil and penetrates the strawberry roots. Only limited spread has been noted in strawberry in a four-year-old planting, but some losses can be expected wherever the fungus is present.

Control Measures

No control of the disease nor means of eradicating the fungus are known. The disease is similar to that caused by the oak root fungus, *Armillaria mellea,* but is not controlled by carbon disulfide fumigation, unless very high dosages are used and the soil is covered with polyethylene sheeting. The fungus is exceedingly resistant to drying and to the common soil fungicides available now.

Bud and Crown Rots

Bud and crown rots are serious only during prolonged wet periods. Several different causal fungi may be involved.

Rhizoctonia

The primary cause of bud rot is the semi-ubiquitous soil and plant-borne parasitic fungus, *Rhizoctonia solani,* which requires low temperatures and abundant moisture for optimum development. The disease is prevalent particularly in the central and southern coastal berry-growing areas of California.

Symptoms. Rhizoctonia kills unfolding buds (plate 8). It may cause heavy losses in localized areas of fields in years which favor the fungus. Active primarily in winter and spring during rainy periods, Rhizoctonia present in senescent tissues around leaf bases enters and kills the unfolding flower and vegetative buds of the strawberry. The large terminal buds are usually the first to be killed. With loss of these, latent or small lateral buds lower on the crown begin to grow. If wet weather continues, these may likewise be killed (fig. 9). Plants set deep, particularly in heavy soils, are particularly prone to attack.

Crowns suffering from repeated killing of buds become greatly weakened, display disfigured side growth but only rarely are killed. Side growth is spindly, petioles are distinctly elongated and reddish in color, and leaflets frequently deeply notched and otherwise disfigured. By the continuous production of side growth, the crown may become so abundantly multiplied that the plant resembles a wild strawberry more than a cultivated variety. Such plants rarely fruit.

The Rhizoctonia bud disease may resemble somewhat injury caused by the foliage-infecting nematode, *Aphlenchoides fragariae,* or injury resulting from methyl bromide fumigation, such as is used for the control of cyclamen mite. In California, however, injury from this nematode is extremely rare.

Fungus attacks wide range of plants. The causal fungus, *Rhizoctonia solani,* causes diseases of many different kinds of plants, but only certain strains of the fungus cause bud rot in strawberry. On culture media these are, almost without

Fig. 9. Recently set plants attacked by Rhizoctonia. Top, terminal bud containing flower buds is killed. Spindly growth from lateral buds is appearing. Bottom, distorted leaflets. Leaflets were injured while still in the bud.

exception, fast-growing aerial types such as commonly attack plants at or slightly below the ground line. These produce abundant dark-brown sclerotial mats. Rhizoctonia isolates of this type obtained from other plants, such as tomato, may cause the bud rot in strawberry. In experiments, bud-rotting types of Rhizoctonia do not commonly attack strawberry roots to any significant degree if the roots are established in the soil and vice versa, root-rotting types of Rhizoctonia have only rarely been found to cause bud rot. Roots emerging through old crowns, however, may be infected and killed before they make contact with the soil.

Recovered plants may harbor the fungus. Plants only slightly affected by Rhizoctonia such as stock set late in the spring, or plants which have apparently recovered from the disease, may harbor the fungus throughout the year in the old crown tissues and leaf bases. This illustrates the important fact that for survival and limited growth, the Rhizoctonia fungus needs no specialized conditions, but for disease production protracted periods of high moisture and low temperatures are necessary.

No resistant varieties. Though the disease has been more prevalent in Shasta than in Lassen, both varieties are susceptible. No varieties are known to be resistant and plants of all ages are susceptible.

Nursery stocks may harbor the fungus. The Rhizoctonia fungus may be carried in nursery stocks and may cause bud-killing in newly set plants. Because plants set early generally are subjected to lower temperatures and more rain than plants set late, early set plants are more prone to Rhizoctonia attack. Furthermore, plants which may have been dug in the nursery either before being fully dormant or after beginning growth in the spring are more prone to Rhizoctonia attack than fully dormant plants. Plants not fully dormant when set in the field make slower, weaker growth in the spring than fully dormant plants and thus are more readily overtaken by Rhizoctonia.

When introduced with planting stock, the carrier plants commonly form focal points of ever-widening circles of affected plants. Plants set deep particularly in heavy soils are also very prone to attack.

Control Measures

There are no known cures for the diseased plants. In many instances rapid recovery follows environmental conditions which favor the growth of the strawberry more than growth of the fungus parasite. For bud rot caused by Rhizoctonia these conditions most typically are dry weather and air temperatures above 70°F.

Botrytis

Under prolonged wet conditions the common gray mold, *Botrytis cinerea*, may attack strawberry buds and other crown tissues, petiole bases, and of course the fruit. The activity of this fungus usually subsides quickly with the coming of dry weather.

Sclerotinia

The common soil-borne fungus, *Sclerotinia sclerotiorum*, may kill strawberry buds and crowns particularly on plants growing in low areas of fields which are flooded during irrigation. Frequently this fungus produces its large, distinct, black resting bodies, the sclerotia, in the dead crown tissues.

Macrophomina

The common soil-borne fungus, *Macrophomina phaseoli*, may kill strawberry crowns under the special conditions of high moisture and soil temperature of 80° F and higher. This fungus is widespread and at soil temperatures such as generally prevail along the coast it is an unimportant root parasite of many plants. Injury to strawberry has been noted only in the central warm val'eys of California, and in the Sacramento Valley nursery areas.

VIRUS DISEASES

Virus diseases cause serious losses in strawberry plant vigor and productiveness. Not only may the viruses be carried perpetually in planting stocks, but they may also be spread from diseased to healthy plants by insects, foremost of which is the strawberry aphid.

Yellows (Xanthosis) or Yellow Edge

Early emphasis in California strawberry-disease research was to locate resistance to the virus, or viruses, causing yellows, and to incorporate it into desirable fruiting varieties. This was accomplished in the release of the Shasta and Lassen varieties. Though not immune to these viruses, Lassen and Shasta possess a high level of tolerance, and have proved successful in many areas of California where the older varieties failed because of yellows.

Symptoms. Under the favorable, generally cool conditions of the central coastal berry-growing areas, Lassen and Shasta may occasionally manifest symptoms of yellows, and decline in plant vigor and productiveness. In addition to the general loss in plant vigor the immature central leaflets may frequently show the distinct yellow margins characteristic of the disease and may grow at an unequal rate. Affected leaflets cup upward in Lassen (plate 9), and downward in Shasta. These leaflet symptoms may be apparent only during the cool seasons, as early spring and late fall.

Planting stock may carry infections. In fields showing serious effects of yellows in their first or second year one can frequently trace the infestation to a particular source of planting stock which was carrying one or more of the viruses at the time of purchase. All daughter plants produced from a diseased mother are diseased. This fact makes evident the lack of wisdom in stripping old strawberry fields to obtain planting stocks.

Virus combinations produce yellows. The combined effects of at least two and possibly three distinct viruses are responsible for the yellows disease. Singly, in Lassen or Shasta, these viruses produce no readily detectable symptom, though they undoubtedly undermine the vigor of the plant. Symptoms produced by the single viruses can be detected only in the wildwood strawberry, *Fragaria vesca.*

Cool weather favors yellows. Cool weather is favorable for the expression of yellows symptoms in strawberry. It also favors the rapid increase of the strawberry aphid, the principal vector, and promotes the retention of the viruses within the bodies of the aphids. These factors increase the chances for successful dissemination of the viruses in the main central coastal strawberry areas.

Crinkle

In contrast to yellows, the crinkle virus disease has been rather unimportant in California. Like yellows, it is caused by the interactions of a complex of at least two viruses. One virus, commonly called the "mottle component" which may itself be composed of many strains, is common to both diseases. The strawberry aphid is the primary vector.

Symptoms. The principal symptoms are crinkling and chlorosis of the foliage; irregularly spaced flecking caused by small yellow spots in the leaves; and occasional yellow streaking along the main veins.

Aster Yellows

Aster yellows is a leafhopper-transmitted virus disease of many plants (weed and cultivated), so named because it was first described in aster. The Lassen strawberry may occasionally be affected. Shasta thus far appears to have escaped infection.

Symptoms. Leaves of affected Lassen may become small, appear under-developed, and may cup upward. Any of the flower parts such as anthers and pistils may become green and leaf-like. Greening of flower parts is not a certain symptom of aster yellows in strawberry, because occasionally other factors may bring it on. Severely affected aster yellows plants usually die from a collapse of the root system. Prior to their death, leaves may become distinctly reddened.

Aster yellows in strawberry may be related to or similar to a serious midsummer black root and plant collapse prevalent in some other states.

Control Measures

Certification of planting stocks in nursery, and grower coöperation. The control of virus diseases must begin with the nursery. The present nurserymen-supported, state-operated certification program is the best means available for producing virus-free planting stocks. "California Certified Strawberry Plants" are descendants of mother plants which have passed certain rigid tests which indicate freedom from viruses. These mother plants have been maintained as clonal units in registry beds far removed from any known agriculture. Fields planted to such stocks generally have shown increased vigor and productiveness when compared with virus-carrying stocks. Certified stocks are practically valueless, however, if planted near old diseased plantings. Aphids may quickly spread the viruses to them, particularly if old plantings are on the windward side of new ones. Wind is the primary factor in determining the direction of aphid migration. Districts noted for high production may become poor producing districts if congested with strawberry plantings to the extent that isolation no longer is possible. This is especially true of coastal areas where virus dissemination and aphid increase are favored. Some suggestions for maintaining districts in a high state of production are given below.

Isolation of strawberry plantings essential in checking virus. The following suggestions will aid in checking virus spread. They apply only to fairly isolated districts, and must be adhered to by all of the growers.

1) The district must first have been free from all strawberries for a time sufficient for all of the strawberry aphids to die. Since the strawberry aphid lives almost exclusively on strawberry, it is expected that a sufficient time is one to three months.

2) New plantings must all be made with certified stocks or comparable stocks at the time the area is first planted.

3) New plantings should never be located on the lee side of old plantings. In the central coastal berry-growing area with the prevailing winds off the ocean, this consideration should not be difficult to comply with. In other terms, it means that at the time the district is first planted, the new plantings must all be as far from the ocean as possible. Subsequent plantings the following year would be made closer to the ocean so that all new plantings would be on the windward side of the old. This would apply also in the year following. When all suitable land between the first planted fields and the ocean (or direction from which the prevailing wind blows) has been planted, new planting in the district must stop until all the old fields have been eliminated.

In addition, fields should be separated from each other in a lateral direction, i.e., in the direction at right angles to that of the prevailing winds, by a distance sufficient to greatly reduce the chance of aphid invasion. Perhaps one-half mile is sufficient. Natural barriers such as hills or rows of trees may also help to protect a field from wind-blown aphids.

There would also have to be a general agreement among growers of the district that any field which became infested with virus as evidenced by such symptoms as lack of vigor and productiveness would be eliminated voluntarily. It may also be desirable to set a limit of three years on the life of any field.

A certain measure of aphid control may also be required especially in the youngest, i.e., first- and second-year fields. These, being on the windward side of the older fields, still may constitute a virus hazard if infested with aphids.

FOLIAGE DISEASES

In general the foliage diseases of strawberry, leaf blight, leaf spot, scorch, and crimp are relatively unimportant in California. The fungus and nematode pathogens responsible for them are present and even wide-spread, but they are kept from causing serious outbreaks of disease by the generally semi-arid climate which restricts their development. California growers are thus spared costly spray programs.

Leaf spot, blotch, and scorch

The causal fungi are spread by water-splashed spores, and require high humidity for penetration of leaves.

Leaf spot is a disease caused by the fungus, *Ramularia* (*Mycosphaerella*) *fragariae,* characterized by small white spots with distinct reddish-brown borders (plate 10). Common in nurseries where overhead irrigation is practiced, the leaf spot fungus rarely persists for more than one year in fields under the common system of furrow irrigation. Three factors appear to keep the disease in check: 1) the general lack of summer rain which prevents dissemination of spores of the fungus; 2) the general relatively low humidity prevalent during the long spring and summer growing seasons which prevents infection of the leaves by any spores present; and 3) the practice of topping plants about a month or more before spring growth begins, and removing the leaves from the field.

The causal fungus of the disease, leaf blotch, *Zythia fragariae* (perfect stage *Gnomonia fructicola*) has been found in California but not associated with typical leaf blotch symptoms. Only occasionally are first leaves on newly set plants attacked. For the most part the fungus is restricted to unimportant infections at the crown of the plant.

The fungus, *Diplocarpon earliana,* is the cause of the disease leaf scorch. It may be found occasionally on wild strawberries but is unimportant on the cultivated strawberries.

June, Transient or Blakemore Yellows

This is a noninfectious heritable disease of the chlorophyll-producing mechanism of the plant.

June, transient or Blakemore yellows, also known as yellow plant, suspected mosaic, leaf variegation, leaf chlorosis, sudden yellows, or gold plant, was first described from the eastern United States in the Blakemore strawberry. It is a ruinous disease brought on by what is called genetic instability latent in the variety. Some varieties that have remained free of this condition for years have suddenly displayed it, and once the genetic instability has been triggered, an ever-increasing number of the individuals of the variety may show the condition. Within a few years varieties have become worthless. The California variety Cupertino has succumbed to this genetic fate as has also the outstanding English variety Auchincruve Climax, and several older ones.

Lassen to date appears to have remained entirely free of this condition, but Shasta plants suggesting this condition occasionally have been found. The condition in Shasta approximates more nearly what has been termed "stripe," a genetic abnormality less serious than Blakemore yellows.

Symptoms. Plants of the varieties exhibiting this condition show irregularly shaped yellow areas or distinct yellow segments in the leaves (plate 11). Each year the symptoms of affected plants increase in severity, lowering the yield and shortening the productive life of the strawberry plant.

Tip Burn

This is a noninfectious debilitating disease induced by unfavorable environment. There is a greater tendency for tip burn to develop in Southern California than in Central Coastal California, and the Shasta variety is more prone to it than the Lassen. Recovery is almost always a certainty.

High temperatures may induce tip burn. Though its cause is unknown, tip burn frequently develops after rather sudden marked fluctuations in air temperature and light intensity. High temperatures in the spring or early summer, particularly if they suddenly interrupt a rather steady cool period, appear to induce the disease. High temperatures during summer and fall may or may not induce the disease, depending apparently upon the physiological status (hardness) of the plant.

Flower tissues appear to be somewhat less susceptible to tip burn than young leaf tissues, but severe outbreaks may result in extensive flower deformity and a corresponding lessening of production.

Symptoms. Frequently during late spring and early summer in the central and southern coastal berry-growing areas, terminal growing tissues of young unfolding leaves and flowers are killed. When full grown, such leaves are irregularly shaped and puckered, appearing to be burned back from their tips to about half the normal size. Plants of all ages over wide areas may be affected, suggesting that the disease does not bear any direct relationship to soil types, cultural conditions, or micro-element nutrition. The disease typically appears rather suddenly and may simply be the result of the reaction of the strawberry plant to unfavorable environmental conditions to which it cannot adapt without sustaining injury. Vigorously growing succulent plants usually suffer greater injury than plants grown more slowly (fig. 10).

Recovery is a certainty. Though affected leaves are permanently disfigured, tip burn is not a lethal disease. Recovery is almost always a certainty, but the rate is influenced by the vigor and adaptiveness of the strawberry plant and by climatic factors.

Fig. 10. Severe tip burn in Lassen.

Powdery Mildew

This is the vegetative growth of the fungus, Sphaerotheca humuli, *feeding within, but growing on the leaf surface. Sulfur dust, wettable sulfur, and Karathane have been used successfully as control measures.*

Spread by air-borne spores, powdery mildew occurs wherever strawberries are grown, and is particularly serious during periods of cool, foggy weather such as that occurring commonly along the coast. Powdery mildew is rarely serious in the interior valleys, where high temperatures and bright light appear to inhibit its development.

Symptoms. All aboveground plant parts are susceptible. Leaves, calyces of flowers and fruit, particularly seeds of the fruit, support growth of the mildew. Infected leaves cup upward, become reddish on the underside and, in severe instances, develop badly burned areas at the margins (plate 12). Infected fruit is delayed in developing the red color and in severe instances shows a white powdery film.

Severe or prolonged mildew infestation may reduce the general vitality and productiveness of a field and may also impair fruit quality. Lassen and Shasta are both very susceptible to mildew.

Occasionally late in the year, and usually only following severe mildew infestations, perithecia of the mildew, the sexual fruiting stage, develop. The perithecia appear as small round black spots scattered through the cottony white mycelium. These are barely visible to the unaided eye.

Control Measures

Sulfur dusts are effective in controlling mildew, but must be used with great caution because of the extreme sensitivity of the strawberry plant to sulfur. At temperatures of 80° F or higher, sulfur may be unsafe to use (plate 13). There is little danger of sulfur burn at low temperatures but with low temperatures the effectiveness of sulfur in controlling mildew is also reduced.

Dusting should begin when mildew first appears and be repeated at 7- to 14-day intervals as long as the disease threatens. In Southern California wettable sulfur is commonly used. There is much less danger of leaf burn from wettable sulfur than from the dusting type.

Karathane (dinitro (1-methyl heptyl) phenyl crotonate) has given good control of powdery mildew. Use ½ pound of the 25 per cent wettable powder in 100 gallons of water and apply 100 to 300 gallons per acre. Begin when mildew first appears, as with sulfur, and repeat at 7- to 14-day intervals if necessary.

WARNING

Do not apply later than 21 days before harvest or residues will make the berries unfit for consumption. The tolerance for Karathane on strawberries is zero.

FRUIT DISEASES

Cat face, the most widespread type of fruit deformity, can cause great financial loss. The disease is traceable to incomplete pollination. Another disease, gray mold, is the most serious strawberry fruit rot in California. Other fruit rots are present in the state but are relatively rare.

Fruit deformity (cat face)

Symptoms. The most prevalent type of fruit deformity is cat face, a term designating a deeply furrowed, gnarled, or otherwise twisted, unsightly berry. The tendency for cat face to appear most severely in the early part of the harvest season when the market is most favorable may make it a source of great financial loss.

Lassen tends toward cat face. The Lassen variety is more prone to cat face than Shasta, particularly if it is grown solidly in large blocks, and if bee activity is light. Lassen may benefit from the pollen of another variety growing nearby. Occasionally the spring crop of Shasta may be affected, but Lassen may be affected at any season of the year (plate 14).

Seed-set determines fruit shape. Plant physiologists have shown that the development of the strawberry fruit is dependent upon development of many viable seeds which must be spaced uniformly around the fruit. To produce a viable seed, both pollination, the transference of pollen from the stamens to the stigmas, and fertilization, the union of male and female sex cells in the ovule, must take place. Any factors which may contribute to incomplete pollination, or cause injury to developing flowers or fruit, may bring on cat facing. Lygus bug injury to fruit, for instance, is a serious factor in some areas.

Pollination determines seed-set. Some factors which may contribute to incomplete pollination are: 1) lack of sound, viable pollen at certain seasons of the year; 2) insufficient distribution of pollen by wind or insects; 3) fungus barriers to pollination; 4) frost injury to blossom parts; and 5) other environmental factors such as high temperatures which may render pollen inviable or stigmas unreceptive. About this last-mentioned point little appears to be known.

Under the common summer conditions of low night temperatures and high humidity which prevail in the central coastal berry-growing areas, the anthers in Lassen flowers frequently not only fail to dehisce and release their pollen but also fail to develop pollen. Insufficient pollination which may result can bring on cat facing.

A fungus may parasitize stigmatic surfaces. The above-mentioned conditions of low temperatures and high humidity, in addition to hampering anther dehiscence, may favor a fungus parasite of the stigmatic surfaces. A newly discovered fungus parasite has been shown to produce such a luxuriant growth of mycelium on the stigmatic surfaces as to present a barrier to pollination. Stigmatic surfaces when attacked become white and cottony in appearance. Experiments have shown that if the fungus has grown for as long as two days on the stigmatic surfaces, sufficient mycelium may be present to trap pollen grains and prevent their actual contact with the stigmatic surface. They remain thus suspended above the stigmas in the cottony wefts of mycelium and cannot germinate to effect fertilization.

Control Measures

Warm weather is best control for stigma fungus. No chemical control for this fungus is known. In limited tests, sulfur, Karathane, and Zineb dusts have given no control. However, the fungus is exceedingly sensitive to dryness and high air temperatures so that a few days of continuous bright, warm weather quickly reduce it to insignificance. To date the fungus has not been found in any warm interior area of California.

Gray mold rot

Gray mold rot is the most serious strawberry fruit rot in California (plate 15). It is caused by the ubiquitous fungus, *Botrytis cinerea*, which is favored by wet conditions and low temperatures. Its spores, which are produced in great quantities, are wind-borne and in wet weather most any senescent dead or delicate plant tissue can be attacked. Botrytis is able to penetrate the unbroken skin of the berry.

One affected fruit may contaminate many. An affected strawberry fruit first shows soft, dull-colored spots. In severe instances the fungus coats the fruit with its gray growth. During picking, sound fruit may be readily contaminated with spores from moldy fruit. In the basket or tray, rotting may continue in transit, or in the markets, and any factors which tend to injure the fruit such as bruising during picking or handling favor the disease. Most, perhaps all, of the gray mold that occurs in transit originates in the field.

Control Measures

Refrigeration checks gray mold. Gray mold rot is checked by refrigeration at 40 to 50°F or lower—fruit keeps best at 32°F—and by prompt movement of the fruit to market. Fruit should be picked preferably early in the day when cool, and should be shaded until loaded for transit.

Chemicals check gray mold. Recent studies have indicated that fruit washed immediately after picking in approximately 1 per cent DHA-S, which is the sodium salt of dehydroacetic acid, remains free from gray mold considerably longer than nonwashed fruit. DHA-S is still an experimental material but offers great promise of reducing losses from gray mold after picking and during transit.

Though fungicides such as Captan and Thiram at rates of 2 pounds per 100 gallons of water have shown effectiveness in controlling gray mold, spraying is of questionable value and also nearly impossible to perform during prolonged wet seasons.

Polyethylene sheeting checks gray mold. In southern California, the use of polyethylene sheeting over the strawberry beds helps to keep fruit clean during scattered showers and may reduce gray mold.

Other fruit rots

Other fruit rots are present in California but are relatively rare. Of these, hard rot caused by *Rhizoctonia solani* and leak caused by *Rhizopus nigricans* are the most common. Leak is favored by high temperatures and high humidity or rain—a combination of conditions rather uncommon in California. Hard rot arises as a soil infection, that is, the Rhizoctonia fungus grows directly from the soil into the fruit. Leather rot caused by *Phytophthora cactorum* is also quite uncommon. The two fungi, *Sclerotinia sclerotiorum* and *Sclerotium rolfsii* may also occasionally attack strawberry fruit.

In terms of monetary losses, fruit rots are the most serious diseases of the strawberry. Their occurrence, however, is always associated with wet weather during harvest. Under prolonged wet weather little can be done to check the ravages of rot, and the strawberry fruit when mature is readily susceptible to attack.

For COLOR PLATES, see following pages.

DISEASES OF STRAWBERRY

A GUIDE FOR THE COMMERCIAL GROWER

1 Left. Dry outer leaves, flattened, and stunted central growth are the most conspicuous symptoms of strawberry affected with Verticillium wilt.

2 Below. Entire strawberry beds are usually killed by red stele.

3 Above. Roots with red stele show extensive rotting which begins at the tips and progresses upward.

4 Right. The central cylinder of affected roots up beyond the rotted portions is reddish brown.

5 Winter root injury due to Rhizoctonia solani. Feeder rootlets turn brown and die; infection moves into the supporting roots killing their external tissues.

6 White, cottony growth of the Dematophora fungus may frequently be seen on roots and crown after a heavy irrigation.

7 Left. An area of plants collapsing from Dematophora attack. A diseased apple tree stood here previously.

8 Left, below. Severe Rhizoctonia bud-killing following a wet winter. All the main flower buds have been killed.

9 Right, below. Lassen severely affected with yellows shows small upwardly cupped yellow leaves.

10 Right. The leaf spot fungus caused the dead, red bordered spots on this Shasta strawberry leaf.

11 Right, center. Yellow and white streaks in the leaves of strawberry are the outstanding symptom of Blakemore yellows.

12 Above. Severe mildew causes extensive leaf reddening.

13 Right. Sulfur burn resulted when air temperatures exceeded 80°F.

14 Cat-faced fruit of the Lassen strawberry is a source of great loss.

15 Fruit affected by Botrytis or contaminated by its spores rapidly becomes worthless.

For Color Plates PULL OUT

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PLANT PATHOLOGY TODAY

The University of California Departments of Plant Pathology on the Berkeley, Davis, and Riverside campuses offer exceptional opportunities to the student entering this field. Instruction and research on the three campuses are closely integrated, yet are as distinctly different as the campuses in their geographical settings and agricultural surroundings.

Thus, with some 200 different crops grown in California and with disease expression different in the different climatic zones, the University of California provides unparalleled opportunity for the study of plant pathology. During the graduate years the student may elect to spend time on each campus, as may also the research and teaching staff of the departments.

Plant pathology is the science of plant disease and its control. It is a subject that offers solid rewards in the professional careers of research, teaching, and industry. Gains in research are often turned into valuable applied results which provide the agriculturist, specifically, and mankind, in general, with great benefits. To quote a well-known plant pathologist, "How well plant diseases are controlled determines how well we eat, what we wear, and our ability to provide shelter."

Without plant pathology few strawberries would be grown in California; there would be no extensive citrus, stone fruit, or grape industries; and little or no cultivation of beans, potato, tomato, cotton, sugar beets, asparagus, wheat or barley. The solution of the major disease problems of these crops is the result of the highest level of scientific research, training, and service.