Four Diseases of Garden Roses

L. M. Massey

Of the numerous diseases of roses, four are of chief importance in plantings in North America: Black spot, powdery mildew, rust, and the brown canker.

Because of its wide occurrence and destructiveness, black spot is the worst disease of roses in this country. It causes unsightly spots on the leaves. Yellowing and premature dropping generally follow.

Black spot is confined to the rose. Probably all classes of roses are affected but not equally so. The hybrid perpetuals, introduced in 1843; the hybrid teas, introduced in 1867; and the Pernetianas, which appeared in 1890, were more susceptible than their wild or almost wild forerunners. Most of the present-day popular varieties are sufficiently susceptible to black spot to require protection by fungicides.

But more attention is now being given to the development of resistant or immune varieties through the use of such parents as *Rosa wichuraiana*, *R. multiflora*, *R. cinnamomea*, and *R. pendulina*, which tests have shown to be resistant or immune. A start has been made, and progress is sure to be made. Some varieties—Radiance, for example—while possessing no true resistance regularly have but little black spot because the foliage is not easily wetted and therefore escapes infection.

No one knows when or where black spot started, but by the time the early botanists knew something of diseases and began to collect and identify fungi, they found the roses affected with the disease. Early reports of it came from Sweden in 1815, France in 1822, Germany in 1833, England in 1840, and Holland in 1844. The disease was noted in North America in 1831 and has now been reported in practically all States and Canada and South America. It probably occurs throughout the temperate and tropical regions of the world wherever roses are grown. The disease is most serious in areas of heavy rainfall during the growing season.

All aerial parts of the plant may be affected. The spots on the leaves are conspicuous and often are half an inch or more across. They are black and have margins marked by rays and tiny fibrils. A number of spots may merge to form larger ones and cover nearly the whole leaf. The spots may be on either surface—usually the upper.

The leaf tissue next to the black spots becomes yellowish. Sometimes the entire leaf becomes yellow before defoliation occurs. The leaflets may turn yellow in spots, or the yellow area may be limited to a band outside the black spot.

Premature loss of leaves is one of the most pronounced characteristics of the disease. Plants affected by black spot generally show naked stems except for a few young leaves at the tips. Defoliated plants are less vigorous than healthy ones and produce fewer and less desirable blossoms. Also, defoliated plants often send out a late, second crop of leaves; in doing so they fail to mature and develop normal resistance to low temperatures.

The sizes and shapes of the black spots and the rapidity and extent of yellowing and defoliation vary with the varieties as well as the conditions under which the plants are growing.

Spots on the canes look much like those on the leaves. Spots on the petioles and stipules are relatively inconspicuous, as are those on the flower receptacles, sepals, and petals. Dis-

coloration and distortion of the flower may occur.

Black spot of the rose is caused by the fungus *Diplocarpon rosae*.

In sections where the rose loses its leaves in the autumn and becomes dormant, the fungus hibernates in the old leaves on the ground and in the lesions on the stems. If the rose is in leaf throughout the year, as in greenhouses and in the warmer areas, the fungus lives the year around in the infected leaves on the plants. In any event, spores will be produced in the spring to initiate infections on the season's new leaves. The spores will be either ascospores or conidia if they are produced in the old leaves on the ground. They will be conidia if they are produced in the spots on the stems. The ascospores are forcibly discharged from the asci (little sacs), which are produced in fruit bodies, called apothecia. The ascospores are disseminated by wind. The conidia are liberated only if water is present. They are disseminated by splashing and dripping water. Spores—conidia—produced in the spots on the overwintered stems probably are the most important in initiating the infection in the garden following dormancy.

The spores must have water for germination and infection. They will germinate in a humid atmosphere if they have been previously wet. It takes about 9 hours for germination to occur. Infection will be assured if favorable temperatures and humidities continue for at least 6 or 7 hours. Penetration takes place through the cuticle. The black spots become visible in 3 to 10 days, depending on temperature and moisture. Within a day or two after the appearance of the spots on the leaves, mature fruiting bodies (acervuli) are present within the spots. The conidia will be found in these fruiting bodies, which are barely visible to the unaided eye. The spores can be liberated only in the presence of water and are disseminated by splashing rain, by wind-borne rain, by dew, and by water from the hose.

The spores of *D. rosae* can germinate and produce infection immediately after dissemination. The increase in the amount of black spot in the garden depends on the frequency of rains, which favor dissemination and germination, and in the greenhouse on the frequency of syringing. The development of the disease is favored by temperatures around 70° F. and by wet foliage, or at least a saturated atmosphere.

Black spot is controlled through the use of sprays and dusts applied at the proper times to the foliage to protect it against infection.

Wettable-sulfur sprays have replaced lime-sulfur. The "fixed" coppers, such as tribasic copper sulfate, copper oxychloride, and copper oxychloride-sulfate have largely replaced bordeaux mixture. A number of the newer fungicides, including several salts of dithiocarbamic acid gave promising results in tests in 1953.

Fungicides in dust form are as effective as those applied as sprays, and the method has advantages in ease and speed of application. A sulfur dust of at least 325-mesh fineness is often used with success. A dust mixture of 90 percent 325-mesh sulfur and 10 percent fixed copper has been found to be especially effective in Texas.

As sulfur in any form will cause injury to the foliage when the temperatures get into the 90's and above, many gardeners find advantage in turning to the use of a fixed copper, as spray or dust, during periods of high temperature. Copper fungicides are more injurious during cool, wet weather.

Ferbam, an organic sulfur, is effective against black spot and less injurious than ordinary inorganic sulfur during hot weather. It is also effective against rust but not against powdery mildew. It can be used as a spray at the rate of 2 level tablespoonfuls in a gallon, or ½ cupful for 5 gallons of water. As a dust it is used at 10 percent concentration.

Because most gardeners need a fungicide effective against both black

spot and mildew, mixtures of sulfur and ferbam are commonly used. Combinations tested and found satisfactory are: For spraying, 2 level teaspoonfuls of ferbam and 2 level tablespoonfuls of wettable sulfur per gallon; for dusting, 10 percent ferbam and 90 percent dusting sulfur. If the problem of high temperatures during the summer (with resulting burn) must be met, a straight ferbam spray, or a 10 percent ferbam and 90 percent pyrophyllite (talc) dust may be substituted for the ferbam-sulfur mixtures. Insecticides may be added to the mixtures as needed.

Roses must be protected against infection by the black spot fungus—not cured after infection takes place. Practically, then, the fungicide must be on the plant in advance of the rainy weather. The gardener should keep in mind that whenever the leaf is wet continuously for 6 hours or longer, conditions are favorable for infection and that the fungicide must be on the plant and operating throughout the period. That is the key to adequate protection.

Many gardeners proceed on a schedule of weekly applications, or at least a fixed schedule. This program may prove satisfactory under ordinary conditions, but frequently such schedules may be inadequate. During the spring when rains are frequent and growth is rapid, it may be necessary to spray or dust twice a week to protect the new growth. During the summer, when rains are less frequent and growth is less rapid, it may be feasible to go 2 or 3 weeks between applications.

With either spray or dust, coverage of both surfaces must be thorough. Sprays must include a wetting and spreading agent, as otherwise they will fail to wet and spread over the surface and adhere to the waxy covering of the leaf. Adequate pressures and nozzles with discs with small holes to break the spray into a fine mist are essential for effective coverage.

Dusting has the advantage of being easier and faster than spraying—the plants can be covered quickly, on short notice of approaching rain, between the showers, or, indeed, during the rain. Dusting is best done in the early morning or evening when the air is quiet and the plants are dry.

POWDERY MILDEW is a common disease of the rose. It is rarely absent from plantings in the garden and the greenhouse. It may make plants unsightly. It may cause severe injury.

The seasonal and regional prevalence of powdery mildew has focused attention on the relation of temperature and humidity to its occurrence.

Powdery mildew of roses does not attack plants outside the genus *Rosa*. Although we have many reports on the susceptibility of varieties to the disease, we have little information based on reliable experimentation. The climbers and ramblers frequently are mentioned as being highly susceptible; the evidence supporting that contention for such varieties as Crimson Rambler, Dorothy Perkins, and others, is impressive. Certain hybrid teas, for example Rome Glory, are known to be more regularly mildewed than others. Varieties having *R. wichuraiana* as a parent, many of which have thick, glossy leaves, are said to have some resistance. Many species of *Rosa* are reported as being susceptible. Few of the reportedly resistant roses escape in seasons favorable to the disease.

The powdery mildew of roses was probably known before its causal organism was described in 1819. It has been reported in most European countries and Asia, Australia, North America, and South America. In the United States it has been reported in almost all States and Alaska.

All above-ground parts of the rose may be affected by powdery mildew. The leaves and the young shoots are most seriously attacked.

The first symptoms are raised, blisterlike areas on the young leaves, which may become covered with a white, powdery, fungus growth. The

powdery appearance of the lesions is due to spores of the fungus, which are produced in great abundance. Older leaves may be affected, usually with little distortion, but growing leaves become twisted and misshapen. Some discoloration of the leaves may occur with an early reddening and eventual yellowing. Dark spots somewhat resembling black spot may be produced as the cells are killed. Young growing tips are commonly completely covered by the mildew; the result is dwarfing and curling of leaves, stems, and buds. The tips of severely infected canes may be killed. Often infected buds do not open. Petals, sepals, and receptacles of the flower buds are subject to attack. The petals may become discolored and dwarfed and finally die.

Powdery mildew on roses is caused by the fungus *Sphaerotheca pannosa* var. *rosae*.

Some question exists as to whether the powdery mildew on peach (*S. pannosa* var. *persicae*) is the same as the one on the rose. The evidence we have indicates that they are different. Some workers have thought that the hop mildew, *S. humuli*, is to be found on roses in the United States, but more research is needed on that point. The conclusion is favored that there is but one powdery mildew fungus on roses, namely, *S. pannosa* var. *rosae*. It is probable that pathogenic races of the fungus on roses will be found.

The white patches on the leaves and stems are seen under the microscope to consist of a moldlike growth (mycelium), composed of slender, white threads, with numerous branches that form a network over the surface. Many upright branches bearing chains of egg-shaped summer spores (conidia) arise from this network of fungus threads. At many points these threads are attached to the surface of the host by means of minute specialized branches or feeding organs—the haustoria—formed in the outer cells. The fungus gets its food supply through the haustoria. The cells into which the haustoria are sent may be stimulated at first but are killed sooner or later.

The conidia are colorless and are about one-thousandth inch long. They are easily detached. Air currents carry them away. They are thin-walled and sensitive to environmental influences after they have been separated from the stalks on which they are borne. They serve to disseminate the fungus over short distances.

Like many fungi, powdery mildew has a spore stage that helps tide it over cold spells. Globose fruit bodies, at first brown, finally black, may appear near the end of the growing season. They can be seen with the unaided eye. They are more or less buried in the mycelial cushions on canes, thorns, and leaves. Although the winter fruit bodies, the perithecia, have been observed more frequently on stems, especially around thorns, than on the mildewed leaves, they do occur on leaves, particularly on the under sides close to the midrib, and on the petiole.

Within each perithecium may be found a small sac, or spore case, the ascus. Within each ascus may be found eight spores, the ascospores. These winter spores are about the size of the summer spores.

In greenhouses, sheltered locations, and areas with warm winters where there are living leaves on the plants the year around, the fungus may be able to hibernate in the summer stages (mycelium and conidia) on the canes and leaves. Mycelium and conidia exposed to freezing temperatures will be killed. Under such circumstances, the fungus may still overwinter in the leaf buds, where it is protected somewhat by the scales.

The hibernation of *Sphaerotheca pannosa* var. *rosae*, however, is left less to chance than it would be by the overwintering of persistent mycelium in the buds. As I mentioned, the fungus produces a winter spore stage that lives in the coldest climate. The spores (ascospores) are mature and ready for dissemination in the spring; thus they bridge the periods of low temperatures, which kill exposed mycelium and co-

nidia. These perithecia are probably more generally prevalent than some reports would lead one to believe.

The perithecia absorb water and crack open in warm, moist weather. The single large ascus in each perithecium protrudes its tip and discharges the eight mature ascospores, which the wind carries away.

In the case of overwintering mycelium in the buds, the mildew is said to renew growth and rapidly cover the newly formed leaves when the rose resumes growth in the spring. Formation of stalks producing conidia follows, the spores being carried to other leaves by even slight air currents or splashing water. There is evidence that the conidia are actually shot away when mature. The conidia and the ascospores behave similarly with respect to germination and infection and lead to the formation of identical structures.

The spores germinate at once on reaching a new, favorable location on the leaf or stem. They germinate best in a relative humidity of 97 to 99 percent and at temperatures between 64° and 75° F. Free water is unnecessary for germination; submergence in water lessens germination. After being separated from the stalks on which they are borne, the conidia die quickly when exposed to adverse conditions, such as low relative humidities and high or low temperatures.

Under favorable conditions of temperature and humidity, the conidium puts out a germ tube quickly and thus penetrates the cuticle and epidermal cell of the rose leaf, resulting in the formation of a haustorium within the cell. The germ tube and its haustorium are formed within 24 hours. On completion of the haustorium, the apex of the germ tube resumes its growth. From the same conidium one to three secondary germ tubes may grow out directly into hyphae (mycelial threads), thus initiating the felty mass on the surface of the leaf or stem.

The haustorium serves as the food- and water-absorbing organ for the mycelium, which otherwise is entirely on the surface. Many such haustoria are formed by the mycelium as it spreads over the leaf surface. Within 48 hours after germination of the conidium, young spore stalks are present. Soon a new crop of spores—conidia—is being produced on the stalks. The conidia fall off or are shot away.

With the coming of the cool weather of autumn, conidia production ceases, and perithecia may be formed. They carry the fungus through the winter, as does the mycelium formed within the buds, thus completing the life history.

Both temperature and relative humidity are important in influencing the initiation and development of powdery mildew, the humidity being more important than temperature. Maximum germination of spores takes place at about 70° F.; the most rapid germination occurs between 76° and 82°. One reason is that the higher temperature hastens the processes that lead to the death of the spores as well as those that cause germination. But with the proper relative humidity infection occurs rapidly around 80°, before the loss of viability becomes a serious factor. At 76°–82° spore production is speeded up and germination increased. The fungus has a short cycle, as short as 4 days. The disease may quickly become epiphytotic.

The spores of the fungus germinate best at high relative humidities, above 95 percent. But some germination will take place at a relative humidity as low as 25–30 percent. Mycelium development is much poorer at 20 percent relative humidity than at 97 percent. Far fewer spores are produced at low humidities, and the spores are shorter lived.

Statements are to be found that high nitrogen favors powdery mildew and high potassium discourages it. The use of wood ashes, a source of potassium, as a fertilizer is sometimes recommended. The evidence seems to warrant the conclusion that soft, succulent growth as produced by high

nitrogen and low potassium is favorable to mildew. It is doubtful, however, whether any combination of fertilizing elements alone will enable the gardener to have plants free from mildew and at the same time have good roses.

Under conditions of temperature and moisture not especially favorable for powdery mildew, the disease is not particularly difficult to hold in check through the use of fungicides as dusts or sprays.

It can be eradicated from the plant through the use of fungicidal sprays that wet and kill the oily mycelial growth on leaves and stems. One can get advance protection by sprays and dusts applied before infection starts. But under conditions of favorable humidities and temperatures in the greenhouse or in the garden, and especially when the plants are making rapid, succulent growth, all fungicides and procedures seem to fail and the disease runs rampant.

Spraying and dusting with fungicides are the accepted ways to eradicate the fungus and to protect the plant against infection. It is important to start early to guard against the first infections and to make applications often enough to give season-long protection.

Because the mildew fungus occurs externally on the rose (except the haustoria which enter only the epidermal cells) it is possible to kill it by spraying with disinfectants. Fungicides used for it include lime-sulfur, potassium sulfide (liver of sulfur), wettable sulfur, oil emulsions, mineral and vegetable oils, sodium bicarbonate, bordeaux mixture, copper oxide, malachite green, and others. A newer fungicide, dinitro capryl phenyl crotonate, tested under the names of Arathane and Karathane and sold under the name of Iscothan, has given promising results at the rate of 1 level tablespoonful to 3 gallons of water, along with a suitable wetting agent. Often the wetting agent itself is reasonably toxic and somewhat effective. Dusts are less effective than sprays against the fungus.

The best garden practice is to protect the plants against infection. Fungicides that function both as eradicants and protectants have an advantage. The materials that are effective against black spot, rust, and other diseases and can be used in combination with insecticides save time and simplify the problem in plantings beset by other diseases and insect pests.

Sulfur is preferred to most of the other fungicides for powdery mildew and is generally used except when temperatures are high. Whenever the temperature gets into the 90's, and above, injury may be expected from any form of sulfur, spray or dust. The fixed coppers are probably less effective than bordeaux mixture. The salts of dithiocarbamic acid used as fungicides generally are not effective against powdery mildew. Malachite green causes discoloration of open blossoms. Sodium bicarbonate may be effective in mild infections, especially as an eradicant, but it probably would not be effective as a protectant against mildew and other fungi. The oils are not satisfactory as protectants and are not generally safe. The efficiency and safety of some of the newer fungicides such as Phygon and captan remain to be established.

Wettable sulfur should be used at the rate of about 1 pound in 25 gallons of water, or 2 level tablespoonfuls in a gallon. In using a proprietary material, the manufacturer's directions should be followed. To the suspended sulfur should be added, following dilution and just before spraying, enough wetter to assure that the spray wets the waxy surface of the leaf and also the oily patches of mildew, if the fungus is present. Detergents, such as Dreft, Orvus, Swerl, and Vel, or prepared wetters such as Vatsol, B–1956, Triton X–100, and Grasselli Spreader Sticker, may be used. A concentration of 1 part in 1,000 parts of water (for solids about one-third teaspoonful per gallon) is usually adequate. It is impor-

tant to use ample pressure and a nozzle that breaks the spray into a fine mist.

In dusting with sulfur, a dust of at least 325-mesh fineness should be used. Ordinary sulfur is too coarse. Mixtures of sulfur and arsenate of lead, ferbam, and other materials are satisfactory as long as there is 50 percent or so of sulfur in the mixture. The dust applications must be started early in the season, before infection occurs, and continued at regular intervals.

NINE SPECIES OF THE RUST genus *Phragmidium* have been reported attacking members of the genus *Rosa*. Of these nine species, only one occurs on the cultivated roses, such as the hybrid teas and hybrid perpetuals, that have large, firm leaflets. This rust fungus is *Phragmidium mucronatum*, frequently called *P. disciflorum*. The disease it causes has been called common leaf rust to distinguish it from other rust diseases.

Only members of the genus *Rosa* are attacked. Some 20 or more species have been reported to be susceptible, although it is not clear that the persons making the reports were always dealing with rust due to *P. mucronatum*. One report lists the hybrid perpetuals as the most susceptible; the polyantha and tea roses as the most resistant; and the Bourbons, hybrid teas, and Noisette groups as intermediate in susceptibility. Most of the hybrid teas and climbing hybrid teas grown in California and elsewhere in the country probably are susceptible.

Common leaf rust of roses has been known at least since 1665, when it was identified in England. The fungus was described in 1790. The disease has been reported throughout Europe and in Western Asia, South Africa, North and South America, Hawaii, Ceylon, Australia, and New Zealand.

Common leaf rust is of economic importance only along the Pacific coast in the United States and in England and parts of Australia. It has been collected many times in the United States east of the Rocky Mountains, but so far it has not flourished except along the west coast, especially in California, where it may be severe in nurseries and gardens.

As the range of the disease in epidemic severity is limited and as the fungus is shipped into Eastern States on plants from nurseries on the west coast, attention has been given to factors that determine its occurrence and severity. Like black spot and mildew of roses, common leaf rust is a good example of the manner in which temperature and moisture determine the range and importance of a disease.

The common leaf rust of cultivated roses is most conspicuous in its summer stage. It is characterized by the formation of reddish-orange pustules on the under sides of the leaves. The pustules, or sori, consist of a powdery mass of spores—the uredospores, or summer spores, of the fungus. The pustules average about one-fiftieth inch in diameter. Viewed from above, the lesions appear as angular dead spots in the tissue, up to one-sixth inch in length, and surrounded by a narrow zone of pale-green or reddish color. The summer stage reproduces itself every 10 to 14 days during the summer if conditions are favorable. It is the stage that causes serious damage. Infected leaves may wilt as early as the fifth day after the appearance of the orange spots and soon fall from the plant.

But there are two other stages of common leaf rust—the aecial, or caeoma, stage, which appears in the spring and the black, or telial, stage, which appears in the autumn. In the spring stage, affected leaves bear one to many circular spots about one twenty-fifth inch in diameter. The spots are bright orange or yellow. The spots may be surrounded by a narrow zone of pale green. The bright-orange color is due to the formation of masses of spores. Affected leaves are malformed by the lesions protruding downward to form cuplike depressions.

The "black rust," or telial, stage appears in the autumn. Large-stalked, black spores are formed in the uredo

sori with the reddish-orange summer spores, which they gradually replace, to the end that these pustules change to a black color. The black spores live over the winter and initiate a new cycle the next spring.

Common leaf rust on roses growing in areas with cold winters have those three stages. In a milder climate the reddish-orange stage is dominant and may occur throughout the year. Under such circumstances the spring and autumn stages are less important.

All four spore forms of the causal fungus, *Phragmidium mucronatum*, are borne on the rose. The fungus is confused in European reports with *P. subcorticium*. Before 1905 the two species were apparently considered as one. Probably physiological races exist within *P. mucronatum*.

In areas with winter temperatures low enough to defoliate roses and force them into dormancy, as in our Northeastern States, the fungus passes the winter as black teliospores in the sori in the leaves. When these thick-walled, black spores germinate in the spring they produce another type of spore (sporidia), which infects the newly developing leaves and stems to initiate the aecial stage of the rust.

The aeciospores in turn germinate and give rise to the summer spore (uredospores) stage—the reddish-orange sori so conspicuous on the under sides of the leaves. The uredospores germinate, infect leaves, and produce additional spots within 10 to 14 days. Finally the resistant black winter spore stage replaces the orange-colored summer spore stage and thus completes the cycle.

The relation of temperature and moisture to the occurrence and prevalence of the common leaf rust of the rose has been studied in some detail. The information thus obtained has supplied data to enable the plant pathologist to explain the prevalence and severity of the disease in California and its isolated occurrence east of the Rocky Mountains. Correlations between temperatures and humidities, determined under controlled conditions, and the weather records at Ithaca, N. Y., and San Diego, Calif., made the explanation possible.

Spore germination and infection in the summer stage (uredospore) are favored by temperatures of 64° to 70° F. At 75° both are noticeably lower. At 81° practically no infection occurs under otherwise favorable conditions. High temperatures are also unfavorable for the survival of the uredospores. At a medium humidity such spores remain living for about a year at 37°, about 7 weeks at 64°, and about 1 week at 81°.

Leaf infection will not occur unless the surface of the leaf is wet for at least 4 hours and a favorable temperature prevails. Even at very high relative humidity a leaf will not become infected unless it is actually wet. Dry weather, therefore, prevents the spread of the disease, while rain, dew, or fog aid in the further spread.

At Ithaca and in the Northeast generally, the common leaf rust has been comparatively unimportant because of unfavorable temperatures. The long, cold winter kills the summer spores, so that any new spring infections must come from the spores of the black rust stage. Assuming that a few infections were to get started in the spring, perhaps from introduced plants bearing rust, the generally high summer temperatures would prevent extensive spread of the rust. The weather would be favorable for a few weeks in the autumn, but that period is ended soon by the coming of winter and the defoliation of the rose plant.

The temperature in southern California is uniformly favorable for the rust. From October through April, rainfall also is adequate to allow for the spread of the disease; moisture from fog or dew supplements rainfall in the drier periods. Defoliation may be incomplete or not last long, so that the fungus may live through the year in the summer spore stage and cause infection when active growth starts again. One of the worst years in recent

times for rust in southern California was the fall-to-spring season of 1940–1941, when twice the normal amount of rain fell and the winter was so mild that defoliation was not complete.

Roses in the Southeast do not suffer seriously from rust. Summer temperatures there are even higher than in western New York; the long hot period may be the reason that the rust is not prevalent.

Roses with common leaf rust are known to occur in a few gardens in Midwestern and Northeastern States. Some of those plants have had the disease for several years. While injury is serious, the rust is less damaging than it is in California. Apparently the rust was brought into those gardens on plants from California. There is always a chance of a new strain of rust arising through hybridizing, or as a sport, that will have different potentialities with respect to survival under conditions of temperature and humidity in the Midwest or Northeast. Consequently the occurrence and prevalence of common leaf rust east of the Rocky Mountains are watched with interest.

A combination of clean culture and a good fungicide will hold common leaf rust in check. Care should be exercised not to bring diseased plants into the garden even in districts where the disease is not known to be important because it may become established.

Diseased leaves should be removed and burned as they appear. The garden should be given a complete clean-up in midwinter or when the plants are dormant and are being pruned. If feasible, the old leaves clinging to the stems should be removed and burned.

Spraying or dusting for protection should begin with the development of new leaves following the winter clean-up or dormancy. One should begin spraying or dusting before the periods of wet foliage, because it is during those periods that infection occurs. Thus the timing of applications depends on the frequency of rains or periods when the foliage is wet. A special effort should be made to cover the under sides of the leaves—where infections occur—with the fungicide.

Sulfur-containing fungicides are preferred to those containing copper. A mixture of sulfur and ferbam either as spray or dust is good. The concentrations given for black spot are satisfactory for rust. Thoroughness and sharp timing are of utmost importance.

BROWN CANKER OF ROSES, of the several diseases of garden roses characterized primarily by injury to the canes, is probably the most destructive in the United States. In many home plantings and nurseries the disease persists despite efforts to eradicate it.

Brown canker is restricted to members of the genus *Rosa*. It seems doubtful that any class, variety, or species is immune, although rugosa, moss, and brier roses may have some resistance. Certainly the teas, hybrid teas, and hybrid perpetuals are susceptible.

Brown canker has been known in the United States for 50 years. Its present range includes most of the United States, from Maine to California, and England. It may cause serious losses.

All parts of the plant above ground may be attacked. Greatest damage is done by the cankers on the stems. A cane lesion or canker is typically a dead area in the wood surrounded by a reddish-purple border, which gives it a striking appearance. The color of the dead area is raw umber. Over the surface of the canker can be seen tiny black dots, the fruiting structures of the fungus. The stem often is girdled by the advance of the fungus, and the part above it is killed. That type of injury is frequently called dieback.

Leaf spots due to the fungus that causes brown canker are not always distinguished readily from those caused by other pathogenic organisms. The spots are usually purple at first and later have white or cinnamon-buff central regions. Black pycnidia may be found in the centers. Leaf spots are

prevalent on certain species and varieties, such as *R. setigera*, *R. multiflora*, Blaze, and others. Lesions on petioles and stipules are similar to those on the leaf blades.

Lesions on the petals are discolored areas, often cinnamon buff in color, and usually bear the black, dotlike fruiting structures of the fungus. The fruiting bodies—pycnidia—are frequently in concentric circles. The infected blossoms may fail to open. The hips also may be affected and may bear the pycnidia.

Brown canker of rose is caused by the fungus *Cryptosporella umbrina*.

The fungus overwinters in the cankers on stems and perhaps in lesions on the leaves and other parts. As with the pathogens that cause black spot and mildew, there are two spore forms, sexual and asexual. The mycelium, having lived through the winter, renews growth with the warmer weather of spring, extends the area affected, and produces spores. The asexual, or imperfect, form, is produced in brown or black pycnidia and is called pycnidiospores. The sexual, or perfect, stage, is produced in little sacs (asci), which in turn are borne in fruit bodies called perithecia.

To what degree pycnidiospores live through the winter is not known; the point may not be important, because with favorable weather a new crop can be produced by the mycelium within a few days. The occurrence of perithecia bearing asci and ascospores is not uncommon and would be expected to carry the fungus over winter. Both fruiting forms, pycnidia and perithecia, have been found during each season.

The pycnidia and the perithecia usually soon rupture the epidermis, and the spores are exposed. Spore masses, or tendrils of spores, exuding from the mouths or pores of the fruit bodies, are often visible. Both pycnidiospores and ascospores are liberated in water and are largely spread by splashing, dripping, and wind-blown rain. The ascospores are probably shot from the asci; if so, they would be disseminated by wind.

Infection occurs from both pycnidiospores and ascospores. The resulting lesions are evident in 4 to 15 days. Spores, both pycnidiospores and ascospores, may be produced within a few days after the lesions are visible. They initiate additional infections, which may occur through wounds or directly through the uninjured epidermis.

Infections on the current season's canes result in many instances in shallow white lesions, in some of which the fungus passes the winter and renews growth in the spring to extend the boundaries of the cankers. Some of the tiny white cankers fail to enlarge the following spring; others may remain inactive for another year or two and then become active. Just what determines whether such a lesion is to become active, and when, is not yet known.

Temperature and moisture relations of the brown canker fungus have not received much critical attention. Observations on the fungus outside in early spring and in cultures in the laboratory would indicate that it is active at relatively low temperatures. The pycnidiospores survived for 4 months at 62° F. in a dried culture in the laboratory. Water is necessary for the production, dissemination, and germination of the spores.

The occurrence of brown canker in epidemic severity usually has been associated with injury to the canes. Injuries made by the careless use of the pruning shears or other tools may serve as infection points. When the disease was noted in test gardens of the Department of Agriculture in April 1927, the records indicated that the unusually severe hailstorm of the previous July had been an important factor. The cankers were predominantly located about the wounds produced by the hailstones. Brown canker flourished in gardens in California following the severe winter of 1932–33, when cold weather injured varieties such as the softwooded Golden Em-

blem, Ville de Paris, Los Angeles, Angèle Pernet, Souvenir de Claudius Pernet, and others. Reports from Georgia and other places where extremes of temperature and late spring frosts prevail indicate that injuries from freezing may increase the amount of brown canker.

The overwintering of the fungus in cankers on such roses as *R. setigera* and *R. multiflora* that may be growing in nearby hedges or plantings somewhat removed from the rose garden is often an item of importance. Such roses seem to thrive despite the disease and they usually get little attention. The mycelium in the cankers on such hedge plants may be a source of spores for the more formal planting in the garden and make eradication of the disease more difficult.

A control program for brown canker may also help combat the more prevalent but less injurious stem canker caused by *Coniothyrium fuckelli* and perhaps also brand canker caused by *C. wernsdorffiae*.

Such a program should include the following: Normally vigorous plants maintained so by attention to drainage, exposure, winter protection, and fertilization; prompt removal and destruction of all dead, dying, and weak parts of plants; systematic spraying and dusting for disease and insect control; care to avoid injury to stems, even small breaks in the epidermis; care in pruning and blossom cutting to avoid leaving stubs, crushing stems, or doing any more damage to the plant than is absolutely necessary; and careful scrutiny of any large, old plants (such as those of *R. setigera* and *R. multiflora*), which are back in the shrubbery and may be neglected.

Since wounds serve as infection courts for the canker fungi, it is desirable to handle the plants so as to prevent breaks in the epidermis. Wounds on the rose do not heal quickly. The maintenance of the plants in a vigorous condition may help in the formation of callus. Wounds heal more readily during the early growing season, so there is probably advantage in pruning just before, or just after, growth starts. Care, a pair of sharp shears, and clean cuts immediately above strong eyes will enable one to avoid leaving stubs that so frequently serve as infection courts.

Heavy pruning probably is to be preferred to light pruning insofar as brown canker is concerned. That practice will eliminate many of the initial cankers. Frequent inspection, with the prompt removal and destruction of all ailing plants and plant parts, is advisable if one has a canker problem. A single overlooked canker may supply the spores for general infection through the entire garden.

Regular spraying or dusting, as for black spot or rust control, will assist in canker control in that it will prevent many of the new infections that would otherwise occur. With proper conditions of temperature and moisture, infection can take place directly through uninjured tissue and it is such infection in particular that a fungicide will prevent. But spraying and dusting must be part of a program in which general vigilance and skillful handling are combined with practices making for a clean garden and vigorous growth.

Both copper- and sulfur-containing fungicides are effective in preventing infections by the fungus of brown canker. Maybe the new fungicides effective against black spot will also serve for brown canker. Either spraying or dusting will give protection. Application should begin in the early spring as soon as new growth starts and should be made often enough to provide protection throughout rainy periods and to keep the new growth covered. On the average, an application once a week will be needed from early spring until the plants are dormant.

Frequently the fungus is brought into the garden on infected plants from the nursery. That emphasizes the importance of patronizing reliable nurserymen and of giving new plants

a careful examination to be sure they are free from blemishes and infection before being accepted. Particular attention should be given to incipient cankers at the cut made just above the main bud in removing the top of the stock that constitutes the root. Many first-year failures result from infection at this point.

L. M. MASSEY *is professor of plant pathology, New York State College of Agriculture, Cornell University. He went to Cornell as a graduate student assistant in plant pathology in 1912 and was granted the doctor's degree in 1916. He served as head of the department of plant pathology at Cornell from 1922 to 1950. He has worked with rose diseases since 1917. Dr. Massey was president of the American Rose Society in 1940 and 1941 and was awarded the Society's Gold Medal in 1947 for invaluable research on rose diseases and distinguished service to the Society.*

In preparing his discussion, Dr. Massey drew on published articles of other authors, as well as those of his own that have appeared largely in the publications of the American Rose Society, Harrisburg, Pa. Among them are:

Anna E. Jenkins: Brown Canker of Roses Caused by Diaporthe umbrina, *Journal of Agricultural Research, volume 15, pages 593–599, 1918;* Brown Canker of the Rose, *American Rose Annual, 1927, pages 161–183;* Development of Brown Canker of Roses, *Journal of Agricultural Research, volume 42, pages 293–299, 1931.*

Vincent W. Cochrane: The Common Leaf Rust of Cultivated Roses, caused by Phragmidium mucronatum (Fr.) Schlecht, *Cornell University Agricultural Experiment Station Memoir 268, 39 pages, 1945.*

Karla Longree: The Effect of Temperature and Relative Humidity on the Powdery Mildew of Roses, *Cornell University Agricultural Experiment Station Bulletin 223, 43 pages, 1939.*

E. W. Lyle: The Blackspot Disease of Roses, and Its Control Under Greenhouse Conditions, *Cornell University Agricultural Experiment Station Bulletin 690, 31 pages, 1938.*

W. D. McClellan: Control of Powdery Mildew of Roses in the Greenhouse, *Cornell University Agricultural Experiment Station Bulletin 785, 39 pages, 1942.*

The attention of the reader is directed to the section of color pictures, in which rose black spot and some diseases of other ornamentals are illustrated.

Viruses on Roses

Philip Brierley

The rose is a leading crop in commercial floriculture. Firms that produce roses under glass usually are specialists, for those roses require well lighted and ventilated greenhouses and higher growing temperatures than many other flower crops.

Some producers propagate roses by cuttings, but most greenhouse roses are grafted or budded on Manetti, a special understock variety (*Rosa noisettiana* var. *manetti*) that is grown and propagated chiefly in the Pacific Coast States and Texas. Manetti stock for grafting is shipped from nurseries in Oregon, Washington, the Netherlands, England, and France to the producers who do their own grafting in the greenhouse with scions from their own flowering varieties. Nurserymen also bud Manetti in the field, inserting buds of varieties from a greenhouse or from their own field-grown roses.

Buds that are set early in the season may be forced into growth the same year by removing the top of the understock. Such plants are marketed in the fall as started buds. Buds set later in the season are not forced into growth, but on removal of the top of the understock at maturity in the fall may be sold as dormant buds.

The greenhouse producer replaces some of his flowering plants each year, generally using his selection of greenhouse varieties budded or grafted on Manetti. Hybrid tea roses dominate the greenhouse business, but a few