

**SUGARBEET
PEST MANAGEMENT:
Leaf Diseases**

Division of Agricultural Sciences
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The authors are A. O. Paulus, Plant Pathologist, Cooperative Extension, Riverside; F. J. Hills, Agronomist, Cooperative Extension, Davis; L. D. Leach, Professor of Plant Pathology, Emeritus, Davis; and J. S. McFarlane, Geneticist, Agricultural Research Service, USDA, Salinas.

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POWDERY MILDEW

Powdery mildew of sugarbeet has been known for many years in the Middle East, Europe, and Great Britain but was not a problem in California before 1974. In late March of that year the disease was found in the northern area of the Imperial Valley and by the end of April had become epidemic, invading practically all sugarbeet fields of the valley. The disease spread northward, reaching Kern County in late May; by mid June it was found in most of the early-planted fields of the beet-growing areas of the San Joaquin and Sacramento Valleys. In June, it was reported in fields of the coastal region from Ventura to Salinas. In addition to this south to north spread, the disease also spread from west to east until it occurred in epidemic proportions in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, Oregon, Texas, Utah, Washington and Wyoming.

The sudden and widespread occurrence of the disease is difficult to explain, but probably was due to the introduction or development of a virulent race of the pathogen in or near the Imperial Valley from where it rapidly spread by windblown spores to other areas. The continued presence of the disease in all areas in subsequent years indicates that this disease will be a continuing problem in sugarbeet production.

Powdery mildew of sugarbeet is caused by the fungus *Erysiphe polygoni* D.C. This organism is also described as *E. betae* (Vanha) Weltzien. Many crops are infected by similar appearing powdery mildews, but even though the fungus bodies and spore structures may look alike on different host species, the spores from one host usually cannot cause the disease on another. The fungus causing disease on sugar-

beet appears to be restricted to the genus *Beta* and thus will cause powdery mildew only on sugarbeet, swiss chard, table beet, and wild *Beta* species.

Disease development and crop loss

Powdery mildew disease is seldom seen in the field until 8 to 12 weeks after seedling emergence (depending on location and planting date) but in any case usually not before the foliage canopies of rapidly growing plants are about to close the area between the beet rows. In the Imperial Valley in some years the disease is not seen until early February, some 18 weeks after emergence. The first signs of the disease are small, white, powdery spots, usually on the under surface of older leaves (Fig. 1, A, B, C). The fungus body (mycelium) is external to the leaf and rapidly grows over both surfaces of the leaf blade. The fungus obtains nourishment by sending numerous infection pegs into the epidermal cells where nutrient absorbing organs called haustoria develop. Asexual spores (conidia) are produced profusely by the surface mycelium, causing the powdery appearance of the leaf. Conidia are airborne and can be carried considerable distances to start new infections. Once started in the field, the disease increases rapidly until within a month the leaf area can be nearly covered by the fungus.

Spores resulting from a sexual process (ascospores) are sometimes produced on old leaves but this stage of the fungus has not yet been found in California. Ascospores are borne in small cases called asci within a protective structure called a perithecium. Perithecia occur on older leaves within the mycelium of the fungus as small balls, from light yellow to black in color, about 0.1 mm in diameter. In California,

the sexual stage does not appear to be important to the survival of the fungus as it seems able to survive as mycelium, though scarcely active, on overwintered sugarbeets and other *Beta* species growing throughout the winter.

The disease is favored by a warm, dry climate. Growth of the fungus mycelium, conidial production, and germination are optimum at temperatures of between 68° and 80°F but are sharply retarded at 95°F. In contrast to many other fungus spores, conidia of powdery mildew are able to germinate at low relative humidities, although higher humidity improves their germination.

The failure of the disease to develop on young plants in the field appears to be due to an increased susceptibility of leaves as they grow older, rather than to a microclimate effect within the foliage canopy that might be more favorable for spore germination and growth. It is common to see abundant signs of the mildew on the stunted and open leaf canopy of nitrogen deficient plants. Nitrogen fertilization, however, cannot be relied on to reduce the effect of the disease as crop loss is as severe with high rates of fertilizer N as it is with N deficient beets. Table 1 gives an approximate indication as to when signs of powdery mildew can first be expected according to planting dates in different growing regions.

If the disease is not controlled it can cause a 20 to 35 percent loss in sugar yield. Crop loss is due to reduced root yield and often to a lower concentration of sugar in roots. Both effects apparently are due to a reduced efficiency of diseased leaves and to their premature death when roots are rapidly enlarging.

When the disease develops during rapid root growth, it is important not to delay control measures and not allow the disease to increase to high levels until after the major growth period has passed.

Sugarbeet varieties may differ in their reaction to powdery mildew. Those showing some resistance to the fungus appear to suffer less yield loss. The mildew resistant varieties tested so far do not have a combination of characteristics essential for California and, even though they show less mildew infection, suffer losses that are great enough to warrant a fungicide treatment. A variety useful in California should have resistance to the curly top virus, the beet yellowing viruses and to bolting. It appears possible to develop varieties with these characteristics that are also resistant to powdery mildew but this will take time.

Control

Sulfur, as a finely divided dust, wettable powder, or flowable liquid has been standard treatment for the control of powdery mildew on many crops and works well with the sugarbeet pathogen. The following summarizes research findings in California with respect to the use of sulfur for the control of powdery mildew.

Timing of the first chemical application. When conditions are conducive to the rapid spread of the disease, as in early summer in northern California, the timing of the first application is critical. It should go on no later than when an occasional small spot of mycelium can be seen on older leaves. A delay of as little as

TABLE 1. Growing regions, planting dates, and dates when powdery mildew is usually seen.

Growing region	Plant dates	First sign
Imperial Valley	September-October	Dec.-Late Jan.
Central Valley: Kern to Merced	December-March	May
Central Valley: Stanislaus to Tehama	January-March	Mid June
	April-May	Early July
Coastal: Santa Barbara to Monterey	December-February	June

2 weeks beyond this time can result in a considerable loss in sugar yield. An application of sulfur prior to first seeing the fungus does not improve production over waiting for signs of disease, but an application at layby (just before the leaves close the furrows), 2 weeks prior to the first sign of disease, can be as effective as a first sign application.

In the Imperial Valley where disease first develops in the winter it usually does not increase as rapidly, and up to 40 percent mature leaf area diseased may be tolerated before control measures are necessary.

Sulfur formation. With sulfur materials of the same particle size, formulation appears to make little difference in disease control. Sulfur dust and wettable sulfur, of the same particle size and applied at the same rate, have given comparable disease control. Soil sulfur, a material with much larger particle size, mostly rolls off the leaves and does not provide acceptable control. The particle size of flowable sulfur is considerably smaller than that of dust or wettable sulfur and it can be applied through small nozzles but gives only slightly better disease control than standard wettable sulfur.

Volume of sulfur spray. When spraying by hand directly over sugarbeet rows, volumes in excess of 10 gallons per acre appear to have little effect on the coverage of leaf surface and the effectiveness of control. Field observations, however, indicate that the suppression of fungal growth on the leaf surface coincides rather closely to the distribution of sulfur particles (Fig. 1) and that the effectiveness of sulfur can be improved by better leaf coverage. It is common to see fungus growth on the underside of leaves even when the top sides are protected. Schemes for more thorough leaf area coverage by sprays could appreciably improve control and could reduce the amount of sulfur needed for season-long control.

Duration of control from time of initial appli-

cation. When the disease is increasing rapidly and furrow irrigation is used, a single 10-pound application of sulfur usually is effective from 3 to 4 weeks and a 40-pound application lasts between 4 and 5 weeks. When fields are furrow irrigated it does not appear wise to use less than 10 pounds of sulfur per application.

When sugarbeets are sprinkle irrigated, most of the sulfur is washed from the leaves and sulfur applications may have to be more frequent. There are little experimental data concerning this point, but from 3 to 6 pounds of sulfur per acre as a wettable formulation applied every 2 weeks through the irrigation system at the end of the cycle may be effective and could appreciably reduce the amount of sulfur required for season-long control.

How long to maintain control. In 4 years of experiments at Davis, plants receiving no disease control treatments showed smaller increases in sugar yield in early and mid fall than did those that received three and four sulfur applications. But, in 3 of the 4 years, increases in sugar yield from mid October to mid November were about the same whether sulfur had been applied or not.

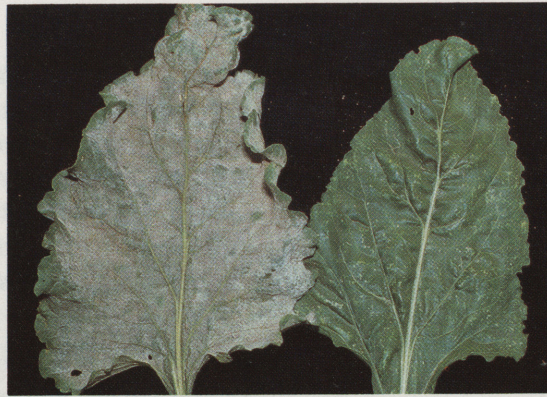
In the fall, when cooler temperatures and dews appear, the fungus growth is arrested. At this time large leaves, previously diseased, have died and younger leaves are smaller and not as severely affected by mildew. Apparently, this smaller leaf canopy is able to produce sufficient photosynthate to maintain growth and provide for sugar storage almost as well as plants with larger leaf canopies on which mildew has been controlled. There may be certain years when warmer than usual temperatures in the late fall may result in more growth potential and thus more functional leaves may be necessary.

In the Imperial Valley it seems wise to keep the disease well controlled to at least two weeks prior to the spring or summer harvest.

POWDERY MILDEW



A. Small white spots of fungus mycelium are the first sign of the disease.



B. Severely diseased leaf (left), healthy leaf (right).

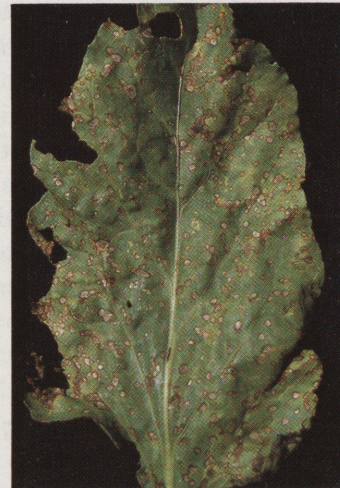


C. Development of powdery mildew in leaf area where sulfur was not deposited.

CERCOSPORA LEAF SPOT



D. Premature death of severely diseased leaves.



E. Leaf spots caused by fungus infection.

BEET RUST



G. Pustules on leaf containing spores of *Uromyces betae*.

DOWNY MILDEW



F. Sugarbeet infested with *Peronospora farinosa*.

Fig. 1. Leaf Diseases

Summary—Control With Sulfur

1. Start treatment at layby or at first sign of disease. In the Imperial Valley, start treatment no sooner than at first sign of disease and before it reaches 40 percent MLAD (mature leaf area diseased).

At layby. Ground application, 20 pounds of sulfur dust or 20 pounds of wettable or flowable sulfur in 25 gallons of water per acre. The better the coverage the better the control.

At first sign. By air, 20 to 40 pounds sulfur dust or 10 pounds wettable or flowable sulfur in at least 10 gallons of water per acre.

2. Repeat the first application at 3- to 6-week intervals if disease reappears (e.g., when mature-leaf area diseased is 20 percent).

3. Keep disease controlled (less than 30 percent MLAD) to within 2 weeks of any harvest before October 1, but not after October 1 for a late fall harvest or for overwintered beets.

Procedure for disease assessment

The rating scale which follows below makes it easy for the user to place leaves in broad categories based on the extent to which the surface area is covered by fungus. The scale is based on a commonly used statistical procedure for transforming percentage data to angles. The system is easy to learn and correlates well with crop loss; it is useful in making decisions as to when to treat or re-treat, or for comparing different methods of disease control.

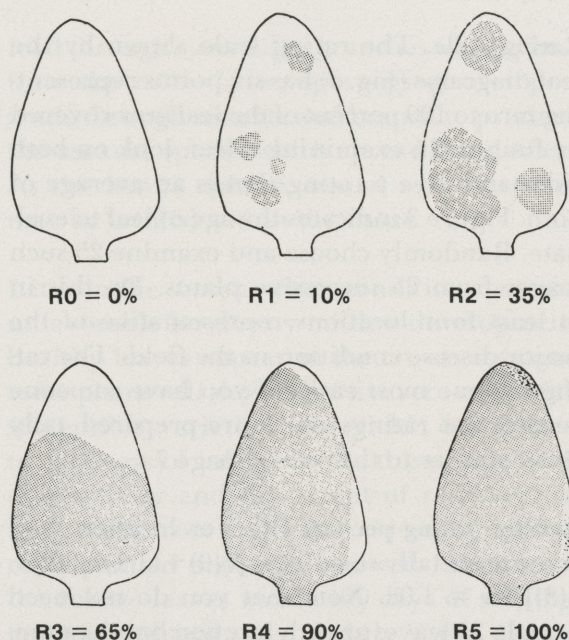


Fig. 2. Ratings (0 to 5) for powdery mildew on sugarbeet leaves. Both sides of a leaf are examined and an average rating given. See "Rating Scale" top left on page 8.



Fig. 3. For disease assay, examine a leaf which has recently attained full growth.

Sample Tally Sheet

Location	Disease ratings (R)						\bar{R}
	0 (0%)	1 (10%)	2 (35%)	3 (65%)	4 (90%)	5 (100%)	
A	++++ 111	++++ +++++ 1	++++ 1	1			1.08
B	++++ 11	++++	++++ +++++ +++++	1			1.35
C	++++ 1	++++ 1	1	++++ +++++ 1	1		1.80
D	++++ 1	++++ +++++	++++ 111	11			1.23

$$\bar{R} = 1.365$$

Rating scale. The rating scale shown by the leaf diagrams (Fig. 2) has six points representing zero to 100 percent of the leaf area covered by fungus. In examining a leaf, look on both sides and give a rating that is an average of both. Figure 3 indicates the age of leaf to evaluate. Randomly choose and examine 25 such leaves from 25 successive plants. Do this in at least four locations representative of the major disease condition in the field. The rating is done most easily if you have someone record the ratings on a pre-prepared tally sheet similar to the one on page 7.

Average rating per leaf (\bar{R}). For location A of the sample tally sheet, $\bar{R} = [8(0) + 11(1) + 6(2) + 1(3)] / 26 = 1.08$. Note that you do not need exactly 25 leaves at each location but the number should be close to 25.

Average the locations ($\bar{\bar{R}}$). For the sample tally sheet, $\bar{\bar{R}} = (1.08 + 1.35 + 1.80 + 1.23) / 4 = 1.365$.

Estimate percent mature leaf area diseased (percent MLAD). This step is a back transformation of the rating to a percentage.

$$\begin{aligned} \text{Percent MLAD} &= 100 \left\{ \text{sine} \left[\bar{\bar{R}} (18^\circ) \right] \right\}^2 \\ &= 100 \left\{ \text{sine} [1.365(18^\circ)] \right\}^2 \\ &= 100 [\text{sine}(24.57^\circ)]^2 \\ &= 100(0.4158)^2 \\ &= 17.3\% \end{aligned}$$

CERCOSPORA LEAF SPOT

Cercospora leaf spot, known since 1873, is caused by the fungus *Cercospora beticola* Sacc. The disease (Fig. 1, D) is found wherever sugarbeets are grown, but is most apt to appear in severe form in the northern part of the Sacramento Valley around Chico or in the southeastern part of the San Joaquin Valley around Tulare and Porterville. These two areas often have warm nights with high humidity in irrigated fields. In these areas the disease occurs during the late summer months about one year in five but very seldom occurs in the remainder of the Central Valley. It is

rarely found in Imperial Valley because winter-grown sugarbeets are harvested before the fungus becomes active.

Symptoms

The individual leaf spots are nearly circular and infected areas are light brown with reddish-purple borders (Fig. 1, E). Under humid conditions, the center of the spot becomes ash gray from the production of conidiophores and spores of the fungus. Infections may be so numerous that the leaf is completely riddled, taking on a shot-hole effect as the necrotic centers fall out. The older leaves shrivel, die and fall to the ground, but remain attached while new leaves develop in the center of the crown.

Disease development

Disease development is favored by temperatures in the range of 68° to 86°F and must be accompanied by high humidity or moisture on the leaves. Very little development occurs below 60°F and above 95°F.

Spores produced by the fungus are released mainly in the morning when temperature and humidity are increasing. The spores are wind-borne to susceptible leaves of sugarbeets. Germination occurs by a germ tube that enters through a stoma (breathing pore) and further development repeats the disease cycle.

Infected old beet tops are the primary source for maintaining the fungus from season to season. The fungus may also be carried on the seed. Numerous weeds have been shown to be a host of the fungus and can sustain the fungus when sugarbeets are not grown.

Control

Most sugarbeet varieties available today are susceptible to Cercospora leaf spot but moder-

ately resistant varieties have been developed by the sugar companies and are used in the upper Sacramento Valley.

Fungicides effective for the control of *Cercospora* leaf spot are maneb, mancozeb, triphenyltin hydroxide, benomyl, TBZ, and thiophanate methyl. Apply the first spray when older leaves show 10 to 20 percent of the leaf surface covered with leaf spots. Fungicides are commonly applied on a 14-day schedule during warm, humid weather.

Resistant strains of the fungus have developed where repeated applications of the benzimidazoles have been used to control leaf spot. See your farm advisor for the current recommendations for control. Fields should not be planted back to sugarbeets as the fungus may survive on debris from the previous crop.

DOWNY MILDEW

Downy mildew, caused by a fungus, *Peronospora farinosa* (Fr) Fr., is favored by moderately cool, moist growing conditions and therefore occurs most frequently in the coastal valleys of California, Oregon, and Washington or in Northern Europe. The same fungus occurs on garden beets and swiss chard and windblown inoculum may spread from market gardens or seed fields to adjacent sugarbeet fields.

Infected sugarbeets show a rosette of small, distorted and mildewed heart leaves as shown in Figure 1, F. Diseased leaves are light green, thickened and puckered with the outer edges curled downward. Asexual spores, called conidia or sporangia, are formed in large numbers in tree-like branched sporangiophores protruding from the stomata on the lower side of an infested leaf and under very moist conditions also from the upper side. Wind-carried spores germinate in a film of water and the germ tube usually penetrates the leaf through the breathing pores (stomata). The mycelium grows between the cells and absorbs

food through specialized branches which penetrate the cells. Later, sporangiophores protrude through stomata and branch to produce the asexual spores which spread the disease. As the leaves mature, sexual resting spores may be formed within the tissue.

Later in the season, when conditions become unfavorable for downy mildew development, healthy leaves appear in the crown area and some plants will show extensive recovery. With susceptible varieties, root yields are related to earliness of infection, the duration of mildew activity and the extent of recovery. In field trials, root size was reduced by half in early-planted beets that showed infection of the rosette leaves within 100 days of seeding, but was reduced only slightly if the disease appeared after 150 days.

Sugarbeet varieties used in California prior to the mid 1950's were either very susceptible to downy mildew or had only a low level of resistance. The University of California and U.S. Department of Agriculture made selections for mildew resistance and the moderately resistant US 75 variety was released in 1952. About this time two other moderately resistant varieties were released by sugar company breeders. By 1956 these three varieties had almost completely replaced the mildew susceptible varieties in the coastal valleys and losses from downy mildew became insignificant.

Later, as monogerm hybrid varieties were developed, downy mildew resistance was introduced into each of the parental lines of these hybrids. Currently, all varieties used in the coastal valleys have moderate resistance and losses from downy mildew are minor. Sufficient infection to cause economic loss has occurred in isolated fields in some years, but there is no record of wide-scale infection. Even though mildew has not been an economic problem in recent years, the potential for loss still exists. As new varieties are either developed or introduced from other areas, care must be taken that they possess downy mildew resistance. The appearance of new strains of the causal organism could also occur.

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WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in their original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits and/or vegetables ready to be picked.

Thinly spread all leftover spray material on the soil where it cannot contaminate crops or standing or underground water supplies. (Do not pour down sink or toilet.) Wrap empty containers in newspaper and put in the garbage can. **Never burn pesticide containers.**

PHYTOTOXICITY: Certain chemicals may cause plant injury if used at the wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts or the wrong formulation or from mixing incompatible materials. Inert ingredients, such as wetters, spreaders, emulsifiers, diluents, and solvents, can cause plant injury. Since formulations are often changed by manufacturers, it is possible that plant injury may occur, even though no injury was noted in previous seasons.

To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

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