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SCLEROTINIOSE OF LETTUCE IN ARIZONA

By

J. G. Brown and Karl D. Butler

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SCLEROTINIOSE OF LETTUCE IN ARIZONA

By

J. G. Brown and Karl D. Butler

Head lettuce is a major money crop in Arizona and has been such for several years. At first the crop here was subject only to one bad disease, bacterial slime (3), but later there appeared brown blight (6), and more recently sclerotiniose. The last mentioned is now the worst disease of lettuce in Arizona. It is present in three southern valleys of the state. The purpose of this bulletin on the disease is to so describe sclerotiniose that it may easily be identified and to make suggestions for its control which may help to keep it away from districts and farms which are yet clean.

THE DISEASE

Sclerotiniose of lettuce is caused by one or more of three species of fungi, *Sclerotinia sclerotiorum*, *Sclerotinia minor*, and *Sclerotinia intermedia*. Only the first species is recorded from Arizona. The sclerotiniose disease has two main types of symptoms: attack of the causal fungus on lettuce seedlings (Plate I) and on mature plants (Plate II) may result in wilting within a few hours. The sudden wilting gave rise to the name "lettuce drop." When the parasite works slower, a watery rotting of the plant occurs which does not directly affect the sap stream and thus cause wilting; this effect resulted in the name "watery soft rot" (8).

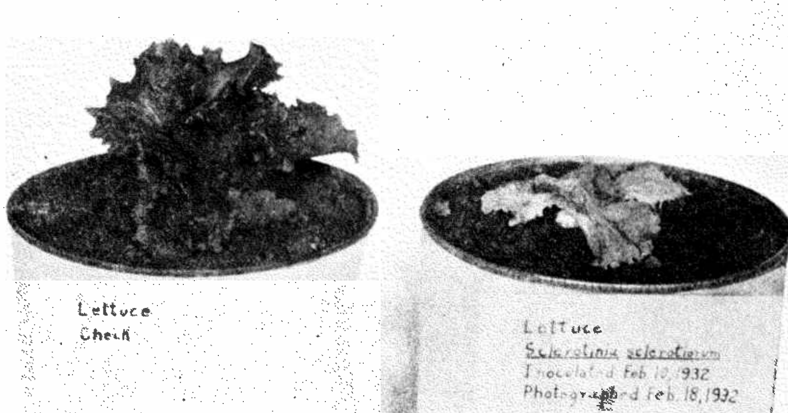

Plate I.—Lettuce drop caused by *Sclerotinia sclerotiorum*, a fungus.

Although bacterial slime of lettuce may cause equal or heavier losses, sclerotiniose is worse in several respects. The latter finds favorable conditions for its activity every winter in southern Arizona, whereas slime causes little or no loss in two to four years out of five. Sclerotiniose may ruin the usually more valuable winter crop of lettuce, but slime is worse in the spring crop. The sclerotiniose parasite can survive unfavorable conditions and reappear later in the same field in destructive form, thanks to its resting stage. On the other hand slime bacteria may disappear from a field for one or more years.

The history of sclerotiniose in Arizona began in 1925 when the disease was recorded for the first time. It was found on a small area which could have been disinfected for a few cents; the owner of the land promised to take care of the infected spot. Next the disease was observed in a 40-acre field of lettuce several miles distant from the original infection in the early winter of 1931-32. At this time a letter suggesting control measures was addressed to the proper authorities who apparently took no action. In the meantime the disease had been restricted to one valley by desert and mountain barriers, but later cull lettuce from the infected district was carried beyond the barriers into a large agricultural valley which had previously been free from sclerotiniose. There the lettuce was trimmed and sold, and the trimmings remained to infect a new area. In November, 1934, sclerotiniose appeared in the new location in a very widespread and destructive manner.

Plate II.—Lettuce drop of a mature plant caused by the fungus *Sclerotinia sclerotiorum.* The infected plant goes down in a few hours and looks like a dull green, wet, folded rag. Compare the infected plant with the crisp ones near it.

With the outbreak of sclerotiniose in the second and larger valley, there was a demand for a survey which was promptly and thoroughly made. The infection was spotted here and there throughout the valley. Although a few lettuce growers claimed

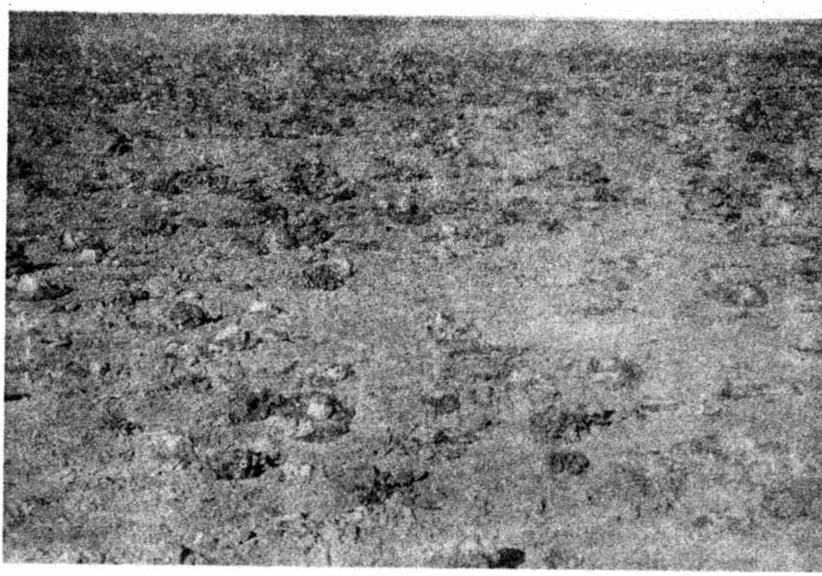

Plate III.—Part of an Arizona lettuce field attacked by drop and watery soft rot caused by *Sclerotinia sclerotiorum.*

that sclerotiniose had been present for some time, a very careful inspection of extensive cull and trimmings dumps near several large packing sheds yielded not a sign of the causal fungus. In view of the fact that refuse dumping grounds near the packing sheds in the first infected district resembled cinder yards on account of the litter of fungus sclerotia, the situation at the dumps in the second valley suggested that the infection was not present, or was light, during the previous year.

Sclerotiniose of lettuce is not a new disease. It attracted notice in Masschusetts in 1890; in 1896 it was in Florida; in 1897 in North Carolina; in 1904 in Wisconsin; at the present time it is probably in every state. In Europe De Bary (4) worked on the causal fungus in 1886.

IMPORTANCE

Actual money losses caused by any disease of lettuce vary with the acreage and the market price of the crop. The importance of the disease in the various states may be judged by data from reports of the United States Department of Agriculture (15). Thus in 1918 sclerotiniose was stated to be general on lettuce in Louisiana, with a consequent loss of 1 to 5 per cent; in New Jersey the loss was estimated at 25 per cent; in Massachusetts, at 2 per cent; in Pennsylvania, at 30 to 60 per cent; the same year Virginia reported sclerotiniose of lettuce as "serious," and Arkansas and Maryland as "considerable." In 1918 field losses in Louisiana varied from very little to 25 per cent; in New Jersey the disease was very serious with some complete failures; there was little sclerotiniose in Mississippi and North Carolina, 2 per cent in Alabama; it was general and severe in Texas and very severe in Florida.

In the years 1920 to 1935 there are fewer reports on sclerotiniose of lettuce, but California reported the disease as common and widely distributed; Ohio, that it was severe in 1927 and common in 1935; New York, that sclerotiniose was slight on lettuce in 1929 and affected 10 per cent or more in 1933; Virginia reported 3 per cent in one field in 1935. Since 1920 field reports on plant diseases apparently have been much less complete than in the preceding years, and it is probably true that sclerotiniose is fully as bad, or worse, now as during the time when more detailed reports were available. This opinion appears to be substantiated by transit and market reports.

Sclerotiniose causes losses not only in the field but also after harvest. According to Ramsey (10) species of the genus *Sclerotinia* stand near the head of the list of fungi which are important causes of vegetable diseases in transit, market, and storage. Thus in one case the infection amounted to 108 cars of lettuce out of 613 cars inspected; in 36 of the 108 cars between 75 and 100 per cent of the heads were diseased.

SYMPTOMS

Young lettuce seedlings attacked by *Sclerotinia* when the plants have only a few leaves simply wilt (Plate I) and quickly dry; larger infected plants show one or the other of two conditions: some plants wilt down so that they resemble a dull green, wet, folded rag (Plate II), or they may show at first only a few water-soaked leaves usually in contact with or near the soil, but commonly in the upper part of the head when they result from aerial spore infection. The water-soaking of the lowest leaves extends into the stem which then looks like glass or ice when cut across. This water-soaked, glassy or icelike appearance is a sign that the *Sclerotinia* fungus is growing in the tissues. The stem becomes brittle and breaks easily when the infected lettuce plant is pushed sidewise. Sometimes the infected, broken stem quickly shows a pink, blood-red, or brown discoloration. A few leaves in the outer part of the head may wilt, turn brown, and dry out; then lettuce growers sometimes mistake sclerotiniose for brown blight. Eventually the lettuce head becomes an odorless, watery, brown rotted mass (Plate IV).

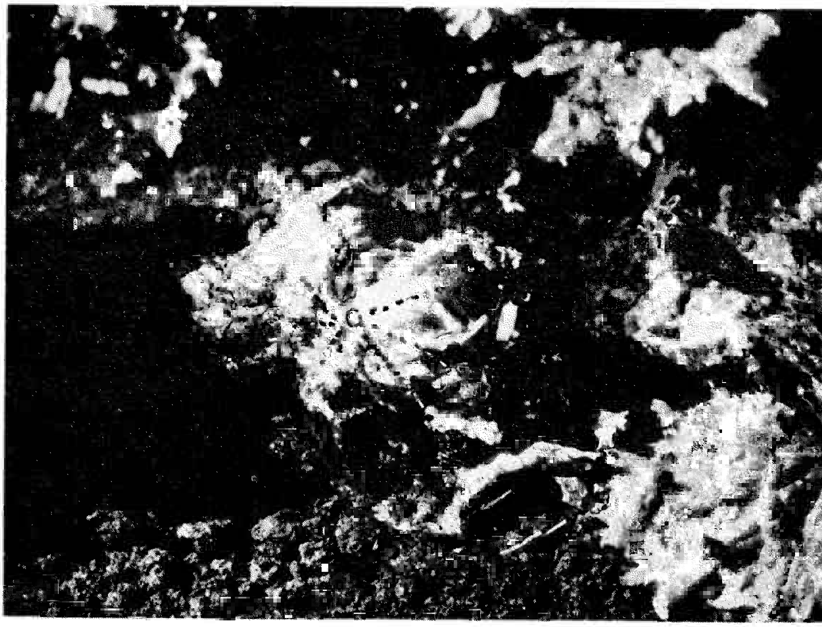

Plate IV.—Collapsed head of lettuce turned over to show the cottony white mass of fungus at *a*. In the lower mass young resting bodies (sclerotia) are forming which make the mass look lumpy.

CAUSE

Under either a wilted lettuce head or one which has been rotted by sclerotiniose may be found a white, cottony mass of fungus threads (Plate IV) on the stem and between the infected leaves, often on the ground as well; heads infected by spores from the air show the cottony threads on the upper part, under and between the decaying leaves. This mass of fungus threads is the body of the *Sclerotinia* fungus. Similar threads grow into the lettuce stem, root, and head and break up the tissues on which the fungus feeds. Penetration into the root is not extensive.

Among the threads of the cottony mass may be found soft, white lumps (plates XIII, XIV); they also develop on infected lettuce heads which are shallowly plowed under. The lumps are the so-called resting bodies of the fungus, which are known as sclerotia. Later the small, soft, white sclerotia grow larger and become hard, externally black, and even brittle. Plate V shows the sclerotia on a stalk of a sick lettuce plant and Plate XIII shows those on a decaying cabbage head. On one infected head of lettuce there may be forty or more sclerotia; a head which was left in the laboratory under a bell jar until it was completely decayed produced 212 resting bodies, and in six diseased heads of cabbage were found, by actual count, 2,221 sclerotia between January 17 and February 5, of which 1,175 were 1/5 inch or longer and some

Plate V.—Head of lettuce with watery soft rot caused by *Sclerotinia sclerotiorum*: leaf at upper right discolored; nearly mature, black resting bodies at *a*.

were 1 1/5 inches in length. The sclerotia may even be found in the seedstalk of the lettuce plant (Plate XIV). They are irregular in shape and up to an inch or more in length (Plate VI). We have some sclerotia in the laboratory which were collected about eleven years ago, of which one sclerotium out of eighteen still sprouted when cultured. Under favorably dry conditions their viability is estimated at ten or more years.

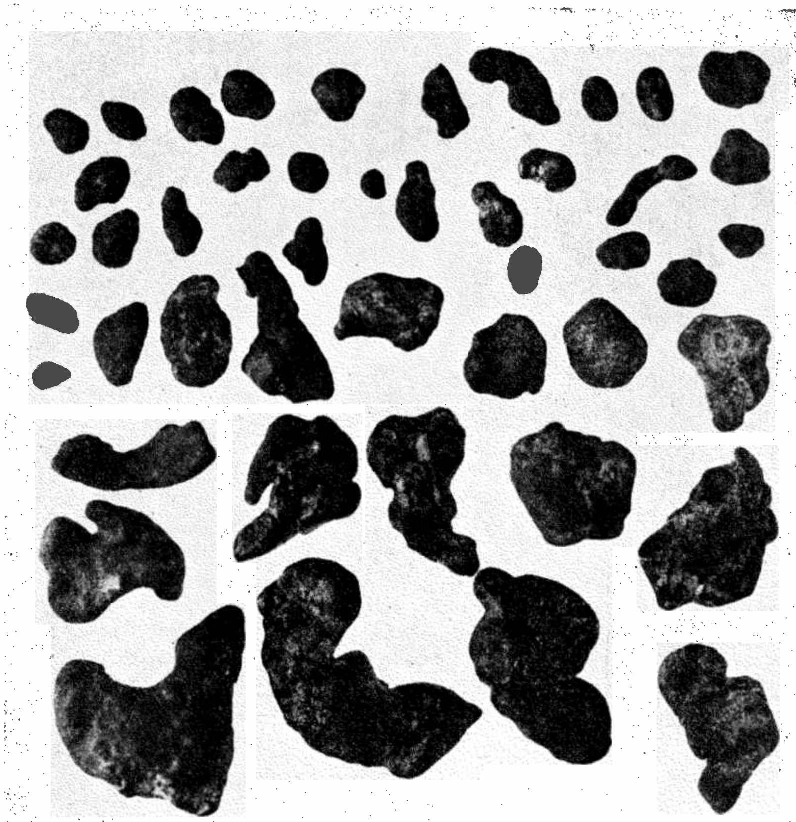

Plate VI.—Mature resting bodies or sclerotia, the largest about an inch long. One infected lettuce plant can produce about as many resting bodies as are shown in the picture, sometimes many more. The resting bodies can live for eleven years. When they germinate the resting bodies produce mushroom cups in which many spores are developed (see Plate IX).

The sclerotia sprout stalks (Plate VIII) on which small mushroom cups (Plate IX) are borne in cool moist weather. Mushroom cups may be found wherever the sclerotia are present: in the field (Plate X), on soil where lettuce trimmings and culls are dumped, in stockyards and barnyards where trimmings and culls are fed. The sclerotia vary in size (Plate VI); the largest may have a surface of 1 square inch; one sclerotium or resting body may produce as many as thirty-five cups.

Mushroom cups produced by the sclerotia contain thousands of microscopic, podlike sacks; each sack holds eight spores (Figure 1). When the spores are ripe they are expelled into the air. It is estimated that more than thirty million spores are shot from one cup. So numerous are these sack spores in the air above discharg-

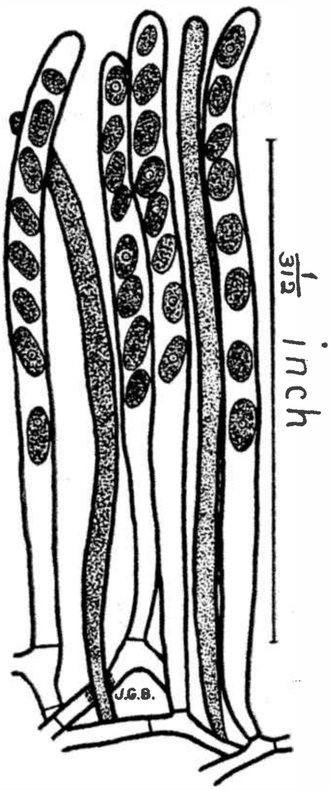

Figure 1.—Podlike sacks from a microscopic piece of the lining of a mushroom cup. Each sack is loaded with eight spores. The ripe spores are shot into the air. The four sacks drawn were produced on a strip of the cup about 1/600 inch long; under the most favorable conditions their spores might infect thirty-two lettuce plants.

ing cups that they may form a cloud which can be photographed (Plate XI). The free spores are carried in currents of air; those spores which reach a suitable host plant, in this case lettuce, sprout and make a fungus thread which starts sclerotiniose, in other words either drop or watery soft rot. Some investigators have believed that the spores must germinate in the soil and if they infect the plant do so indirectly by means of fungus threads which first develop on dead matter, but the belief is not in agreement with later experiments and observations in the field, including our own. How far the sack spores may be carried in the air and remain alive is not known. Smith (13), in his studies on the green rot of apricots, presents evidence that the spores may travel a considerable distance in the air in California and still retain the power to cause disease. There is some evidence that the sack spores have caused sclerotiniose in Arizona after traveling a distance of several miles.

Besides the sack spores from the mushroom cups of the *Sclerotinia* fungus, other spores may be formed by direct budding from the fungus threads (10); these are called conidiospores or conidia. Attempts to produce sclerotiniose in susceptible plants by means of conidiospores have failed, which suggest that the conidiospores have lost their reproductive function in nature. An alternative conclusion is that laboratory tests have failed because natural conditions were not duplicated in them. Even if the conidiospores are not considered, sclerotiniose can be spread otherwise than by sack spores, floating masses of fungus threads and pieces of infected lettuce plants in irrigation and floodwaters, and by similar diseased material on agricultural implements and the feet of men and animals. Fungus threads may grow from sclerotia, or from infected lettuce leaves and stems, directly into healthy plants with which the diseased parts come in contact. The threads

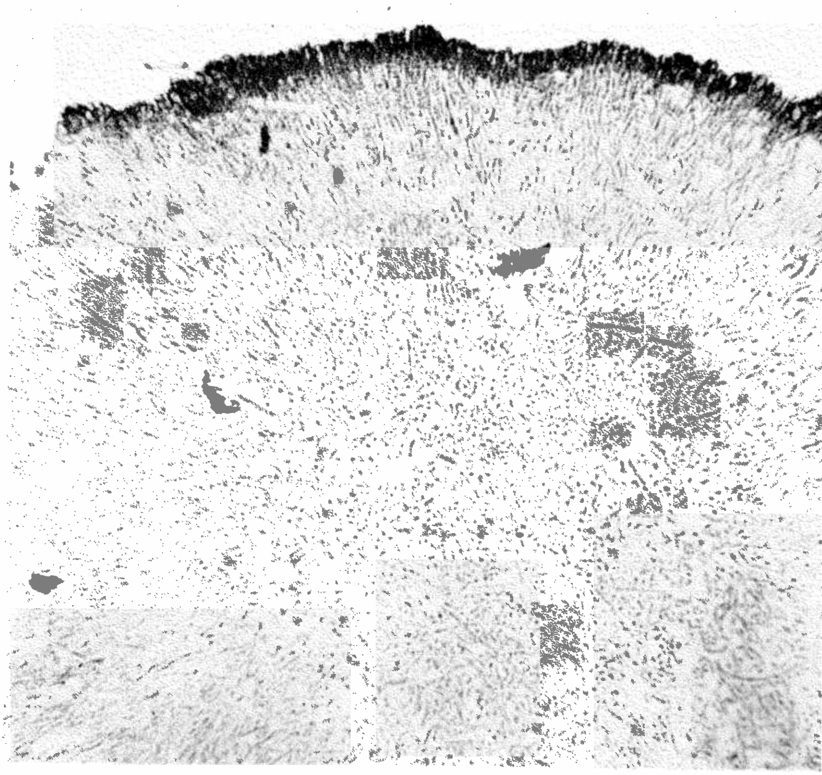

Plate VII.—The structure of the resting body explains why it can live for so many years. The above photomicrograph shows an outer protective coat which shields the inner, closely interwoven fungus threads from drying and death.

may also extend a short distance on moist soil from diseased plants to healthy ones.

Whether sclerotiniose of lettuce can be carried with, upon, or inside the seed is not satisfactorily investigated. Young and Morris (18) found two cases of *Sclerotinia* resting bodies inside seed coats of the sunflower; Bisby (2) reports that resting bodies of a *Sclerotinia,* which he believed to be *S. sclerotiorum,* were developed on alfalfa stems near Winnipeg, Canada, and became mixed with the seed in the process of threshing. Since the resting bodies freely form in the flower stalks of lettuce (Plate XIV), it appears logical to reason that they would be found mixed with lettuce seed, and that the smallest ones might occasionally escape the seed-cleaning process. However, we have searched for them without success in many samples of seed. We are not yet convinced that they are not carried into the field with seed. Many cultures of lettuce seeds—shrivelled, discolored, or healthy-appearing—have failed to show the fungus, *Sclerotinia.*

Plate VIII.—Resting body (sclerotium) beginning to sprout stalks on which the mushroom cups develop (see Plate IX).

ENVIRONMENT

The external conditions which markedly influence the development of sclerotiniose in lettuce are moisture and temperature. Moisture is always favorable for sclerotiniose where head lettuce can grow in Arizona; therefore little or nothing can be done to control the disease through the regulation of soil moisture. However, the cultivation of the soil as soon as practicable after irrigations, although it will not prevent sclerotiniose, does reduce to some extent the damage from *Sclerotinia* and from the fungus *Rhizoctonia solani* and otherwise reacts favorably on the growth of the crop. As the lettuce plants become larger and the heads form, moisture is increased in the air near the ground, which makes toward an ideal environment for the growth of the sclerotiniose fungus. The slightly dryer soil conditions resulting from elevation of the seed beds has no appreciable effect on the loss from sclerotiniose—the disease was fully as bad in elevated seed beds as in the very wet lower parts of the field which became flooded during irrigations.

Temperatures, on the other hand, are variable and greatly influence the time when sclerotiniose can appear, as well as its subsequent activity. At the time when lettuce for winter harvest is sown in southern Arizona, the month of September, maximum air temperatures frequently range from 95 to 104 degrees F. or above, and minimum air temperatures remain between 65 and 75 degrees F.; soil-surface temperatures (16) vary in daytime between 60 and 75 degrees F. Careful inspection of hundreds of acres of lettuce at this time of year and into October has failed to disclose more than a half-dozen infected plants. Again when the maximum and minimum temperatures rise in spring, the disease gradually becomes inactive and finally ceases to attack lettuce. The explanation of this increase in the activity of the parasite in the fall and its decrease in the spring depends chiefly upon the nature of the fungus.

Unlike many parasites, the fungus which causes sclerotiniose in our lettuce fields grows best at comparatively low temperatures, therefore in winter. Studies made elsewhere indicate that temperatures of 60 to 70 degrees F. are most favorable, and that the mushroom cups develop best at 65 to 71 degrees F. Summer temperatures in southern Arizona but not the coldest winter tempera-

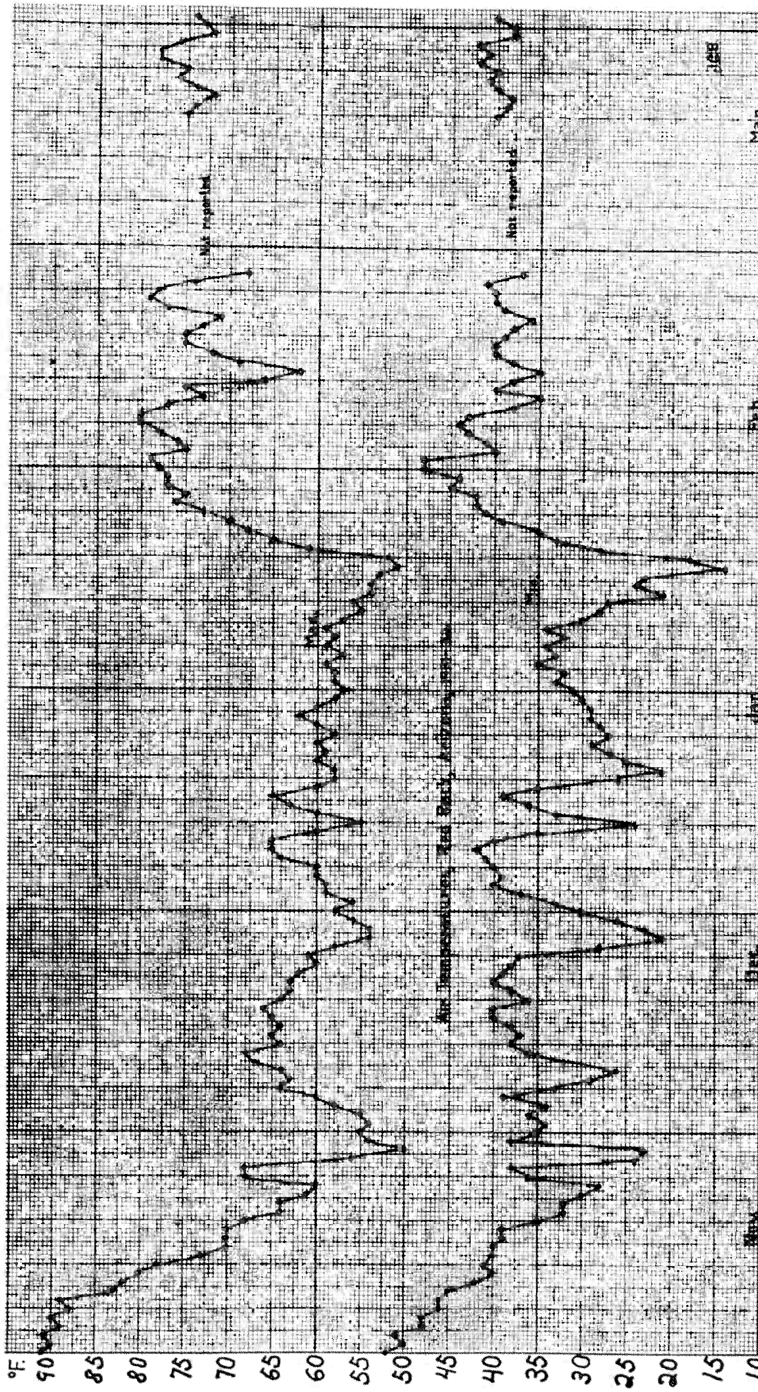

Figure 2.—Temperature curves for Red Rock, Arizona, just east of the Eloy district, for the months when sclerotiniose is present (1931-32).

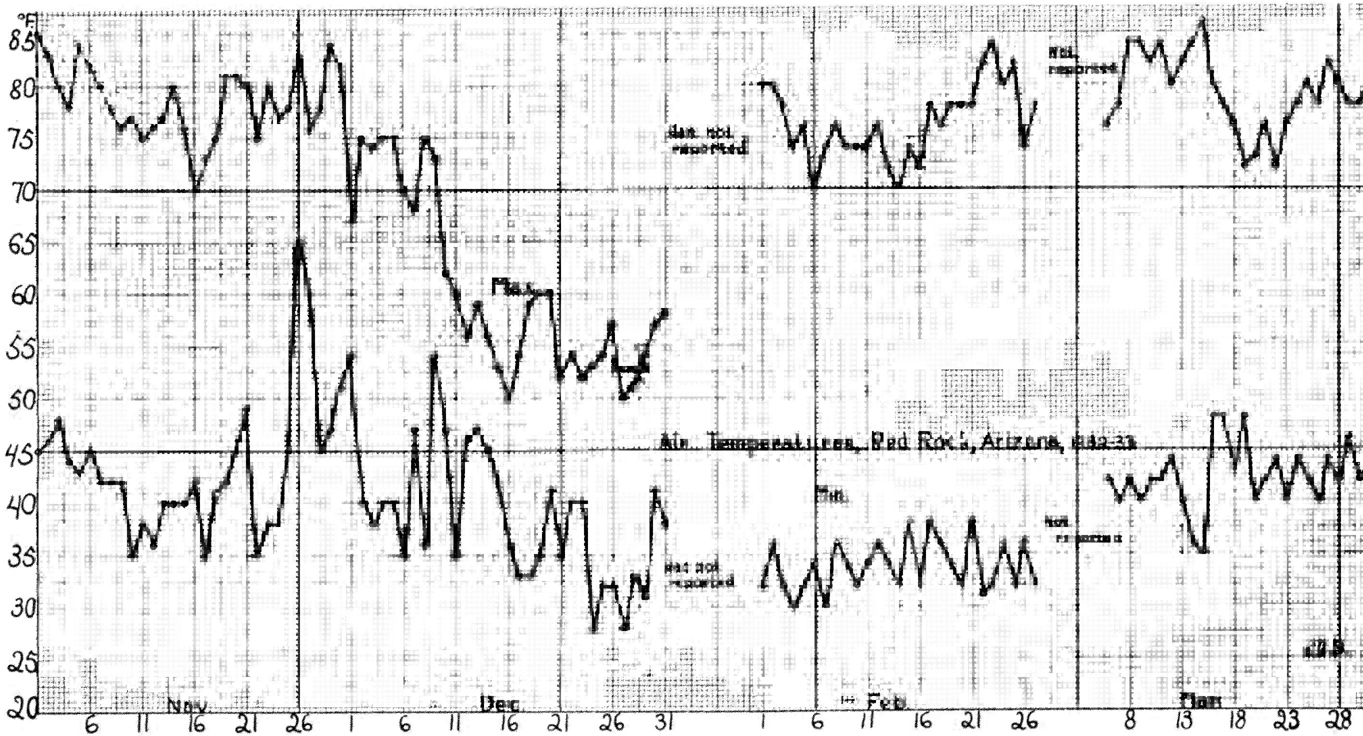

Figure 3.—Temperature curves for Red Rock, Arizona, just east of the Eloy district, for the months when sclerotiniose is present (1932-33).

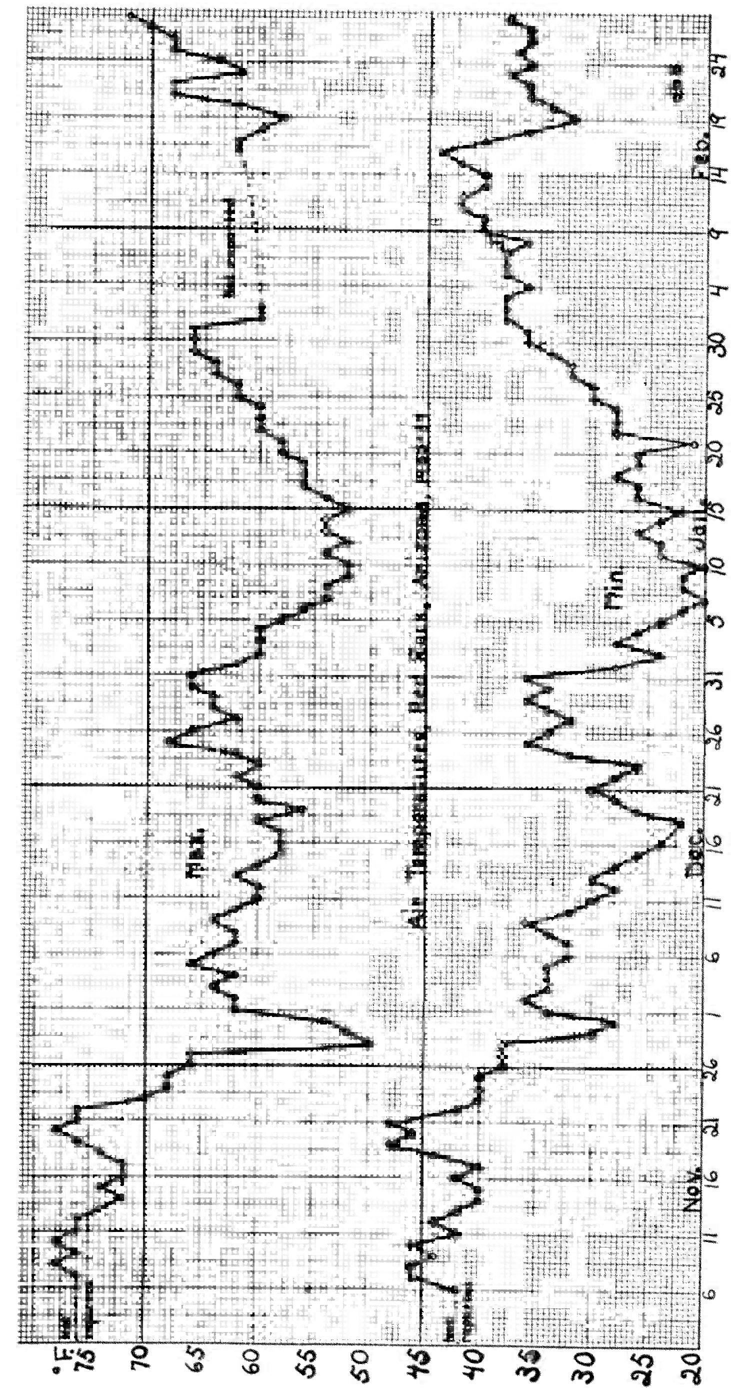

Figure 4.—Temperature curves for Red Rock, Arizona, just east of the Eloy district, for the months when sclerotiniose is present (1933-34).

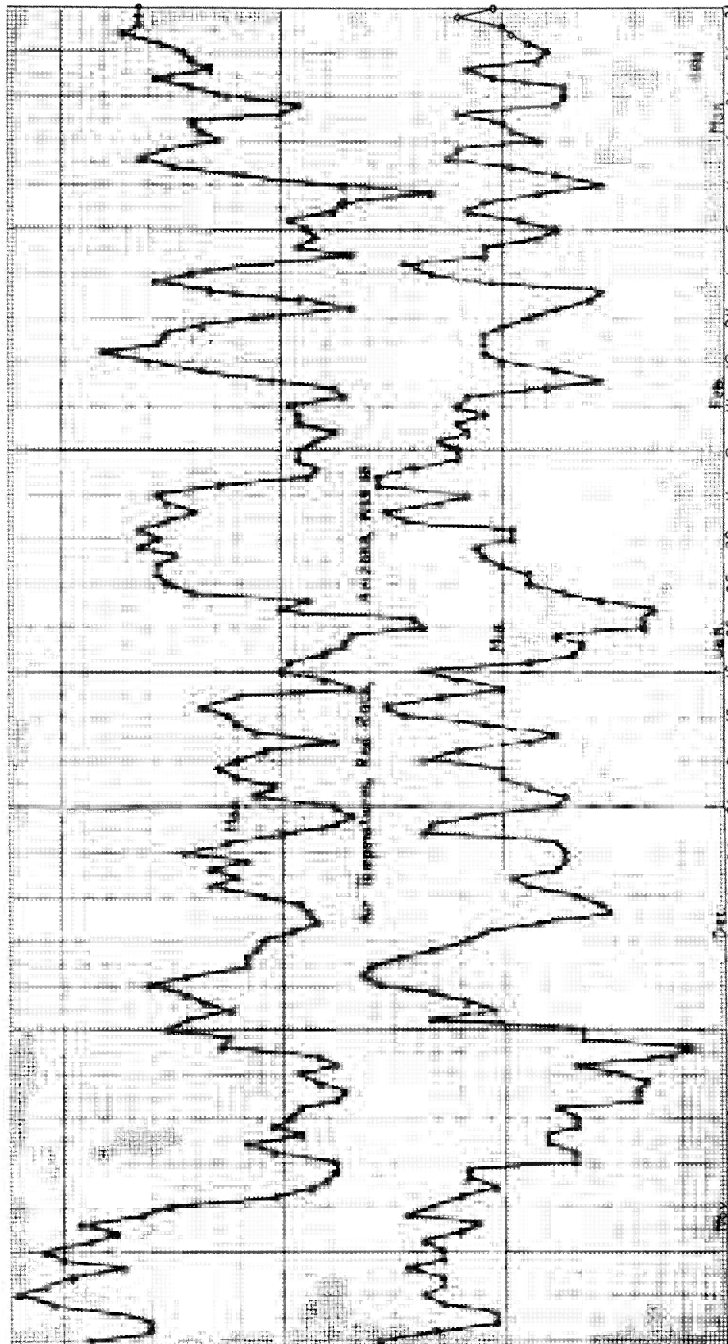

Figure 5.—Temperature curves for Red Rock, Arizona, just east of the Eloy district, for the months when sclerotiniose is present (1934-35).

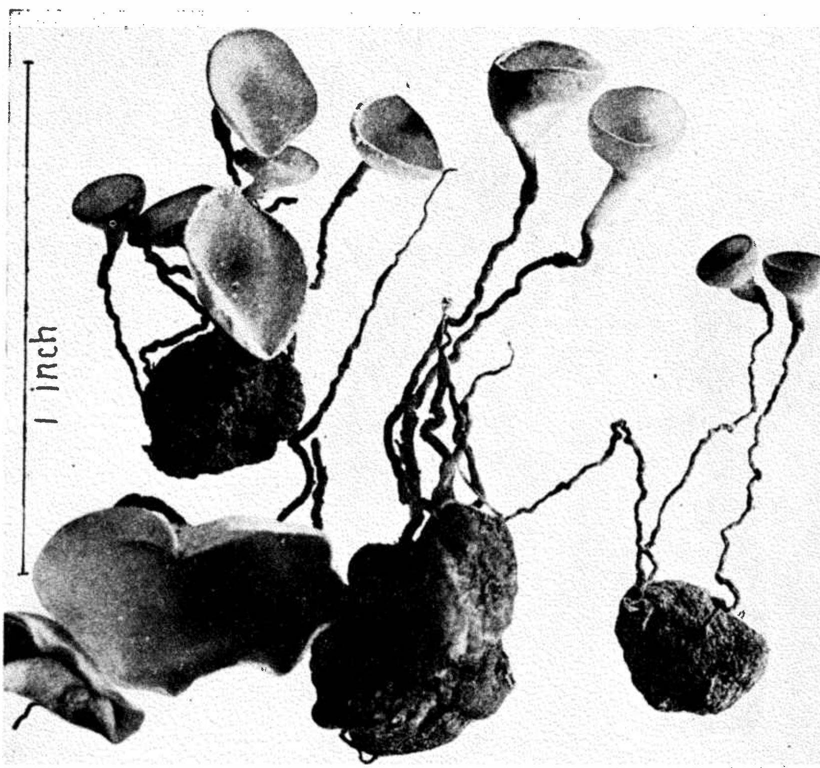

Plate IX.—Mushroom cups of the fungus *Sclerotinia sclerotiorum*, which have grown from the resting bodies (sclerotia). Resting bodies can make an average of ten mushroom cups. The cups contain spores (see Figure 1 and Plate XI).

tures in that part of the state appear to check the fungus. The sclerotia live through the summer to sprout when suitably cool weather arrives in early winter.

An analysis of the weather in two of the three districts in which sclerotiniose of lettuce occurs shows their similarity in winter in respect to cold nights and warm days. For the Eloy district only the temperature records reported from the United States Weather Bureau for Red Rock, some 16 miles east of Eloy, are available. Although the former is approximately 300 feet higher, the temperatures should afford a fairly accurate index of temperature changes in the Eloy district. Thus the month of November, 1931 (in which sclerotiniose of lettuce first became seriously destructive in the Eloy district) started with maximum temperatures around 90 degrees F. which prevailed during the first week (Figure 2); only through the last week of that month were there low maximum temperatures. The minimum temperatures, during

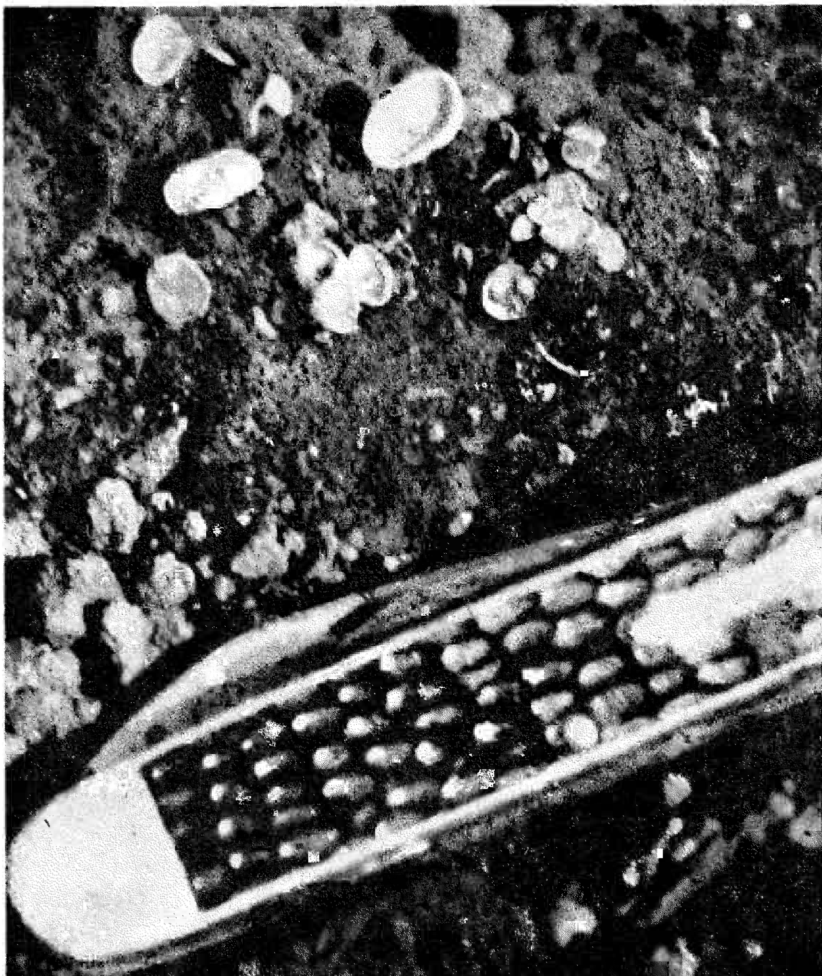

Plate X.—Mushroom cups of *Sclerotinia* found in the field. The first of the season 1934-35 in the Salt River Valley were collected on November 27; a few days later they were abundant. Spores are borne in little, erect, podlike sacks lining the inside of the cups; ripe spores are shot into the air and may be carried away to infect new fields.

the first week between 52 and 45 degrees F., rapidly decreased and mostly remained between 30 and 40 degrees F. Sclerotiniose was well developed by the last week in November.

Again, in the next three seasons in the Eloy district (figures 3, 4, 5), November started with hot days, and its maximum temperatures remained fairly high for the first two to three weeks, while the minimum temperatures were mostly 35 to 50 degrees F. Sclerotiniose was always active by the last week in November.

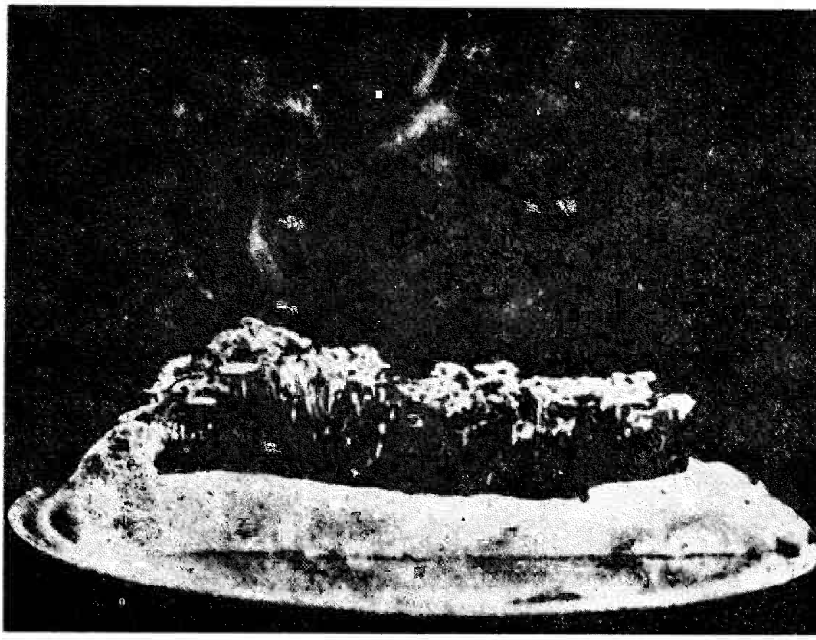

Plate XI.—Mushroom cups of *Sclerotinia*, the fungus which causes drop and watery soft rot, produce a cloud of spores as shown in the photograph. The spores are easily carried in the air and cause new infections in lettuce, cabbage, and other crops in winter. (After Chupp.)

Maximum temperatures were perhaps less important than minimum temperatures as a factor influencing sclerotiniose. In the season of 1934-35 the first fifteen days of November were characterized by maximum temperatures mostly above 80 degrees F. and reaching on November 6 a height of 95 degrees F. (Figure 5), while during the same period the nights were cool. Sclerotiniose appeared as usual.

In the Salt River Valley, in the season of 1934-35, the first fifteen days of November had maximum temperatures mostly between 81 and 95 degrees F. (Figure 6); the night temperatures at that time were chiefly between 50 and 58 degrees F. In contrast to this weather November, 1935, showed much lower maxima and minima; sclerotiniose began its destructive activities about ten days earlier than usual.

The effect of temperatures on sclerotiniose may be summarized by saying that the warm days and nights of spring, summer, and fall in southern Arizona inhibit the appearance of the disease in lettuce; when the nights become cool (between 32 and 50 degrees F.), although day temperatures may be high, sclerotiniose appears and becomes destructive. In seasons when both days and nights are cool sclerotiniose starts earlier and is most active. Although

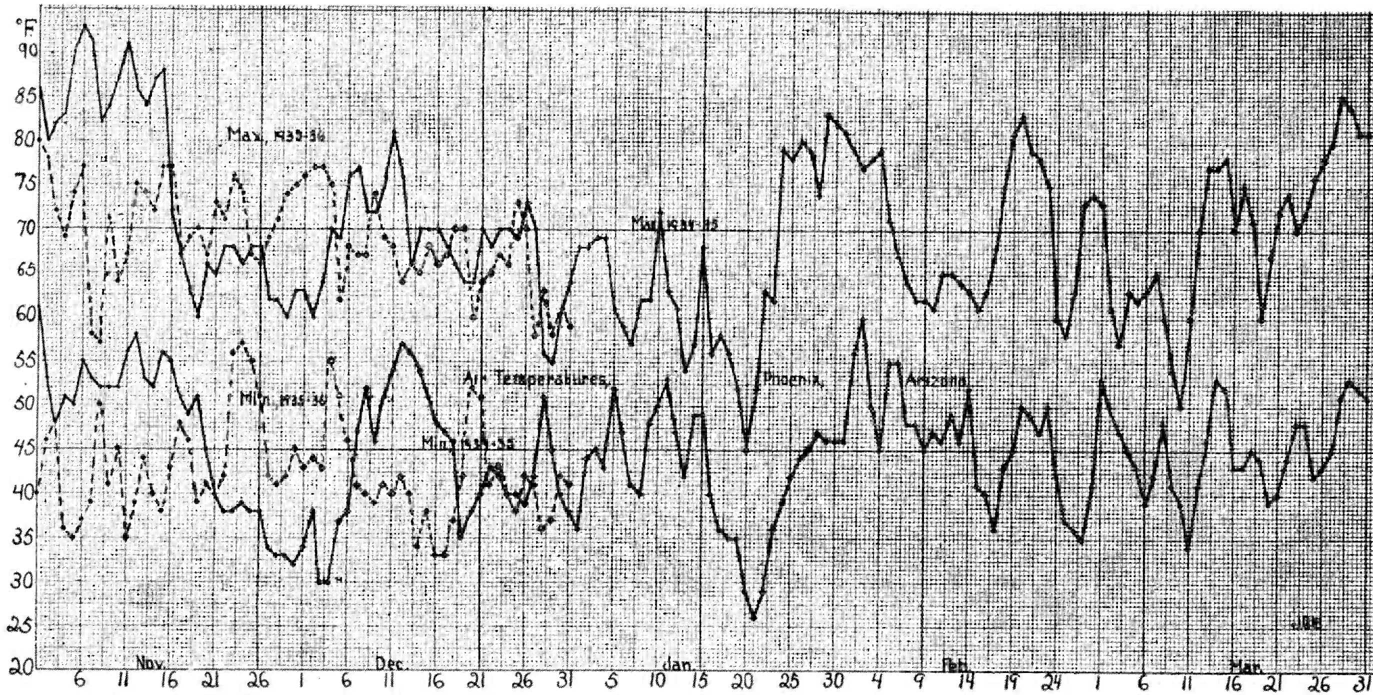

Figure 6.—Temperature curves for Phoenix, Arizona, for the months when sclerotiniose is active (1934-35), with November and December of the season 1935-36 for comparison. In the latter season maximum and minimum temperatures for the first sixteen days of November were much cooler than temperatures for the corresponding days of 1934-35; sclerotiniose appeared about ten days earlier.

Plate XII.—Lettuce dump in Arizona from which anyone may cart away heads and trimmings—a very efficient way to spread drop and watery soft rot of lettuce. Resting bodies and mushroom cups of *Sclerotinia* may develop here; their spores are then carried in currents of air to adjacent lettuce fields.

the high temperatures of spring, summer, and autumn prevent the vegetative growth of *Sclerotinia sclerotiorum*, the resting bodies are not killed. Low temperatures of winter, even when ice forms in lettuce heads and remains unthawed until midforenoon, apparently do not injure the fungus of sclerotiniose.

At altitudes appreciably above those of Eloy (approximately 1,560 feet) and Phoenix (1,074 feet) low temperatures prevail earlier in the fall and later in the spring; under such weather conditions sclerotiniose may be expected to appear earlier in the fall and to be destructive later in the spring. At the altitudes of Prescott, Springerville, Safford, Snowflake, and Duncan the disease might attack the summer crop of lettuce. Every care should be taken to keep the parasite out of these districts and other agricultural areas of the state with similar temperatures. Yuma Valley, with higher winter temperatures, has had very little loss caused by sclerotiniose, although the disease has been found in specimen lettuce heads received from that location.

The temperatures maintained in cars of lettuce on the way to market do not always prevent sclerotiniose from rotting the product. Losses from watery soft rot of lettuce in transit may be serious. According to Ramsey (10) 20 to 50 per cent of the cars of lettuce, carrots, and celery inspected by the Bureau of Agricultural

Economics of the United States Department of Agriculture showed decay caused by *Sclerotinia*, and the infection often averaged above 50 per cent, sometimes amounting to 100 per cent, of the shipment; Ramsey and Markell (11) also emphasize the loss of lettuce in transit.

The direct influence of soil types in the state on the prevalence of sclerotiniose is probably unimportant. Although we found no sclerotiniose in lettuce growing in the very sandy soils along the Agua Fria, the disease was present elsewhere in the crop on both light and heavier soils; its absence near the Agua Fria may have been accidental.

HOSTS

The following plants have been reported to be susceptible to the fungus which causes sclerotiniose of lettuce: *Aegopodium*, alfalfa, almond (green fruits), *Amaranthus, Angelica, Antirrhinum,* apple, apricot (green fruits), *Aquilegia, Argemone,* artichoke, *Asparagus, Asphodelus,* bean, beet, *Brassica,* broccoli, Brussels sprouts, cabbage, *Campanula,* Canada thistle, cantaloupe, caraway, *Cardamine,* carrot, cauliflower, celery, *Cerefolium, Cheiranthus, Chenopodium*, chicory, chili, China aster, Chinese cabbage, *Chrysanthemum,* clover, *Cnicus,* columbine, cotton, cucumber, *Dahlia, Delphinium,* Easter lily, eggplant, endive, fanweed, fennel, fig, flax, *Foeniculum, Forsythia,* garlic, ginseng, hemp, *Hibiscus, Ipomoea, Iris,* kale, kohlrabi, *Lamium, Lathyrus, Lavatera,* lemon (fruits), *Lobelia,* lupine, mangel-wurzel, *Melilotus,* melon, mulberry, mung bean, mustard, *Myosotis, Omphalodes,* onion, orange, parsley, parsnip, passion flower, pepper, *Petunia,* potato, pumpkin, *Pyrethrum,* radish, rape, red pepper, rhubarb, rock melon, rutabaga, rye (9), safflower, salsify, *Schizanthus,* Shasta daisy, *Silybum, Solanum citrullifolium, Sonchus,* sour orange, soybean, spinach, squash (17), strawberry, strawflower, sunflower, swede, sweet pea, sweet potato, tobacco, tomato, *Trigonella,* turnip, vetch, *Vicia,* violet, watermelon, *Zinnia.*

Of the plants listed as subject to attack by sclerotiniose the susceptibility of the potato[1] and possibly some others has been questioned. Ramsey (10) states the "results . . . indicate that the potato tuber is highly resistant to infection by *Sclerotinia.* This is in entire agreement with experiences in the market. Up to the present time not a single tuber has been found affected with *Sclerotinia* rot." Sclerotiniose of beets beyond suspicion has not been found by us, but we have observed a few small, decayed spots on beet roots at the base of water-soaked leaves; in the same beet field cups of *Sclerotinia sclerotiorum* were present. Ramsey (10) obtained only slight infection of beets in his inoculation experiments. On the other hand, cabbages (Plate XIII) have been vigorously attacked in Arizona in fields which bore infected lettuce

[1] A. H. Eddins reports that in Florida sclerotiniose directly attacks the main stem, branches, and leaves of the potato plant but not the tubers. Phytopathology 25:974, 1935.

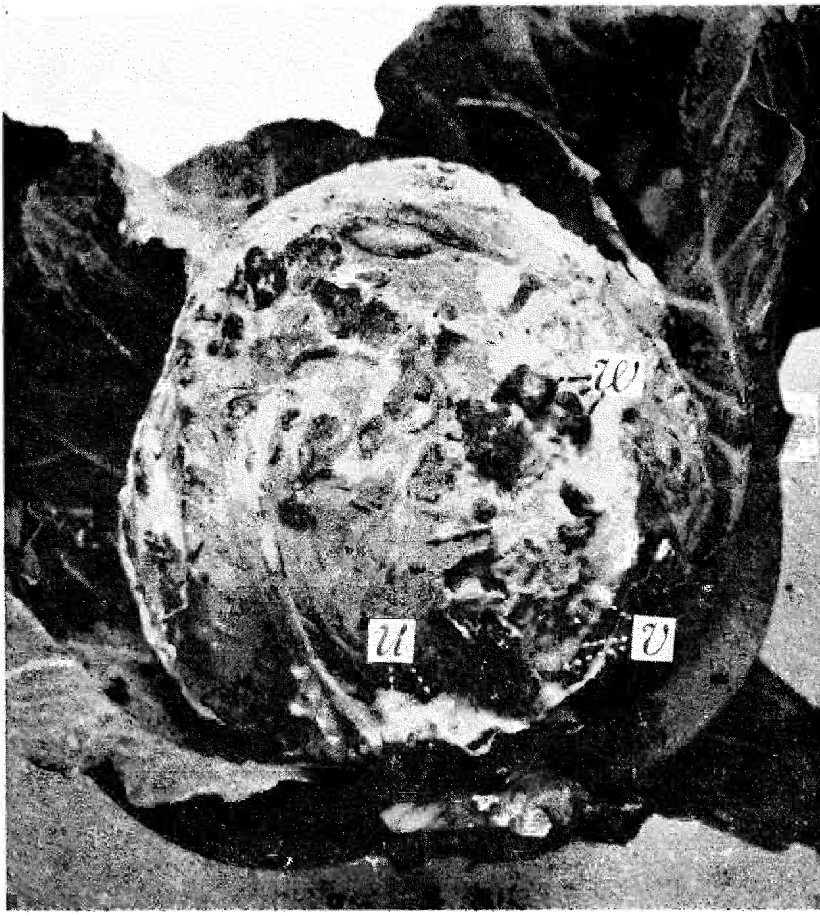

Plate XIII.—Cabbage as well as lettuce and more than one hundred other plants may be attacked by sclerotiniose. The fungus body and the sclerotia were exposed by the removal of the outermost, rotted leaf: *u*, white, cottony fungus body which also clearly appears above *v*; *v*, very young, white resting bodies; *w*, mature resting bodies.

the preceding year, and some loss from sclerotiniose of broccoli has been reported from one district.

Plants listed as susceptible to sclerotiniose which are grown in southern Arizona in summer probably will not be attacked by the disease because the prevailing temperatures are too high at that time of year. Susceptible plants which are grown on infected soil for winter crops will probably be attacked. Soils already infected with *Sclerotinia* should be planted to nonsusceptible winter crops. Fortunately grains (excepting rye) do not appear in the list of susceptible plants, and we find only a few instances on record in which alfalfa (14) and cotton (1) have been attacked.

CONTROL

Control of lettuce sclerotiniose in general, concerns the field, packing shed, railroad cars, the storehouse, and market. Since lettuce seed is planted directly in the field in Arizona, control of the disease in hotbeds does not concern the lettuce grower here.

The first act toward the control of sclerotiniose should be the prevention of the distribution of infective material that is now going on. Cull lettuce heads and trimmings are hauled to farms throughout the lettuce districts; so extensive is the practice of feeding lettuce refuse to livestock that some packing plants have no refuse dumps, the culls and trimmings being hauled away as rapidly as they are discarded. In the feeding pens and grounds not only may the sclerotia sprout, produce mushroom cups, and thus scatter spores into the air, but they also become mixed with the manure in which the fungus is scattered over the fields.

Dumping grounds of lettuce refuse (Plate XII) are a menace to surrounding farms. Some of them are ¼ mile or more in length In the refuse of the grounds, infected heads recently deposited cover multitudes of sclerotia from previous seasons. During the summer the grounds resemble the cinder yard around a railroad station. At least the cinderlike sclerotia should be raked up and burned.

A rule (which should be made and enforced by the lettuce growers' association) to restrict to railroad cars the movement of lettuce from packing sheds would help to check the spread of sclerotiniose. Occasionally heads of cull lettuce are retrieved from the refuse heaps and carried away for food; the infected trimmings from such lettuce are thrown away in house yards and the sclerotia remain to start the disease when conditions are favorable.

Once sclerotiniose is introduced into the field, control of the disease is difficult; in fact, literature fails to record any case of complete eradication. However, climatic conditions in Arizona are unlike those in any place where eradication of lettuce sclerotiniose has been attempted. The relatively high temperatures in the southern counties limit the activity of the fungus of sclerotiniose to the colder winter months; the problem is to get rid of the sclerotia which usually remain alive during the hot, dry months.

Investigators have noted the effect of temperatures on the rotting of sclerotia of *Sclerotinia*. Most of them who have recorded their observations on the subject agree that an extensive decay of the resting bodies occurs in moist soil in summer under the influence of high temperatures. The question still unsettled is whether deep plowing or shallow plowing is the better practice to facilitate the rotting of the sclerotia. Deep plowing places the sclerotia so far from the surface that two advantages result: the sclerotia are too deep in the soil to be brought up where they can germinate by ordinary cultivation; they are too deep to develop mushroom cups with spores which spread the disease. On the other hand, decay-causing bacteria and fungi as well as insects which can destroy vegetable matter are most numerous in the surface layers of the soil; also the fluctuation in soil moisture, which should help to break up the sclerotia, is greater at and near the surface. Joshi (7) advises deep plowing and clean weeding following the collection and destruction of infective material in the field. In Europe, Rehm (12) suggests deep plowing to destroy the sclerotiniose fungus, and in the United States the practice of deep plowing has been used and found successful by the Kentucky station (5). In this connection we believe the pasturing of sheep in harvested fields is advisable, for the animals very thoroughly clean up culls and infected heads. We have started experiments with sclerotia buried in the soil to determine their viability and rate of decay at different depths.

Following the question of plowing, that concerning the kind of crop to plant on infected ground arises. The farmer who wishes to do the best thing possible to eradicate the sclerotiniose fungus should, of course, grow an immune crop on infected soil. Otherwise the fungus will actively exist on the susceptible winter crop and may develop on a summer crop during cool weather in early summer. Another matter to consider is the relation of the crop to the mushroom cups of the fungus which grow from the sclerotia. A crop may be immune to the attack of the fungus but still may not be the best crop to select for infected land when spore dispersal is considered. For instance corn is immune to sclerotiniose, but if mushroom cups ripen between corn rows there is a chance, because of the loose nature of the cover, that the spores will be carried in air currents and infect adjacent susceptible crops. Barley, on the other hand, is not only immune but also forms a close cover which smothers the mushroom cups and thus prevents the spores from reaching air currents after they are discharged. For the same reason and also because the irrigation necessary to a crop helps to cause the rotting of the sclerotia, barley or wheat would be much better on infected soil than no crop at all. The sclerotia may remain alive for years when they are kept dry; fallow land in our climate should prove almost ideal for prolonging the life of the resting bodies.

Rotation of lettuce with immune crops may be supplemented by the roguing of diseased plants as a means for controlling sclerotiniose. Some lettuce growers have kept watch of their fields and have "lifted" plants infected with sclerotiniose as these have appeared. This practice is a good one, provided that it is adopted early enough in the development of field infection so that the cost of roguing is not too high. If diseased plants are removed before the resting bodies form, the soil does not become permanently infected; by drenching the spot of soil from which the sclerotiniosed plant is removed with copper sulphate solution, formaldehyde solution, Funginox, or other suitable disinfectant, even the threads of the fungus are killed.

The question of soil disinfectants always arises when diseases like sclerotiniose attack crops. Lettuce growers and others inter-

Plate XIV. — Lettuce seedstalk split lengthwise; young, white resting bodies of *Sclerotinia* at *y* and mature, black ones at *s*.

ested in the lettuce industry have frequently asked us whether some commercial fertilizer or other chemical compound can be found which will suppress or inhibit the growth of the resting bodies of *Sclerotinia* when applied to the soil; therefore experiments were performed to determine the effect of various fertilizers and other chemicals on the viability of the sclerotia of the fungus. In the first trials the sclerotia were merely soaked in the different chemical solutions and mixtures, thoroughly washed in water, and plated in Petri dishes. But so many molds grew from the sclerotia that other methods were tried. After a number of attemps the following treatment was found to be satisfactory.

Sclerotia to be used were plunged in 95 per cent alcohol, thoroughly washed in sterile water, and placed in bottles containing the chemical. After a given time, as shown by Table 1, they were washed in water, treated thirty seconds in a 1:1,000 mercuric chloride solution, rinsed again in sterile water, cut in two, and plated in Petri dishes containing sterile 2 per cent potato-dextrose agar. All sclerotia cultured came from the same source—namely, cabbage heads infected with sclerotiniose brought into the laboratory from the Phoenix district on January 17, 1936, and left in a large container until February 5. Sclerotia (about one pint from six heads) were picked off and spread out to dry before they were treated. Some sclerotia were as large as 30 by 10 by 3 mm.; only those 5 mm. or longer were used.

The results obtained from the study of the effect of various

TABLE 1.—EFFECT OF FERTILIZERS AND CHEMICALS ON THE VIABILITY OF SCLEROTIA.

Chemical	Strength	Ratio of pieces of sclerotia plated to pieces remaining viable after treatment, hours							
		12	24	30	48	72	114	192	236
Ammonium hydroxide	1:20		6/0		6/0	8/0	6/0	10/0	
	1:200		6/2		6/0	7/0	6/0	4/0	
	1:400		6/4		6/4	6/4	4/0	4/1	
	1:800		6/6		6/6	7/4	6/6	4/2	
Ammonium phosphate*	1:10		6/6		6/6	6/6	6/6	4/1	10/0
	1:100		6/6		6/6	6/4	6/4	4/0	
	1:200		6/6		6/6	6/6	6/4	7/0	
Ammonium sulphate	1:20	8/5	6/6	8/8	6/5	6/5			
	1:200	8/5	6/6	8/8	6/6	6/4			
Barbak†	1:10		6/0		6/0	6/0	6/0	6/0	
	1:100		6/4		6/4	6/2	6/0		
	1:200		6/0		6/4	6/4	6/2	6/4	
Calcium nitrate	1:10		6/6		6/4	6/6	6/6	8/8	
	1:100		6/4		6/4	6/6	6/4	4/4	
	1:200		6/5		6/6	6/4	6/6	4/4	
Copper oxychloride	1:20		6/0		6/0	6/0	6/0	4/0	
	1:200		6/6		6/6	6/6	6/6	8/8	
	1:400		6/6		6/6	6/6	6/6	6/6	
	1:600		6/6		6/6	6/6	6/6	8/8	
	1:800		7/7		6/6	6/6	6/6	6/6	
Copper sulphate* (Expt. 1)	1:20		6/4		6/4	6/6	6/6		
	1:200		6/6		6/6	6/6	6/6	4/1	
	1:400		6/6		6/6	6/6	6/6		

TABLE 1.—EFFECT OF FERTILIZERS AND CHEMICALS ON THE VIABILITY OF SCLEROTIA—*Continued.*

Chemical	Strength	Ratio of pieces of sclerotia plated to pieces remaining viable after treatment, hours							
		12	24	30	48	72	114	192	236
Copper sulphate* (Expt. 2)	1:20		6/2		8/1	6/2	6/0	8/0	
	1:100		6/6		8/8	6/2	6/6	6/0	
	1:200		6/6		8/8	6/4	6/6	4/2	
	1:400		6/6		6/6	6/6	6/6		
Cupric chloride*	1:20		6/0		8/0	8/0	6/0	6/0	
	1:100		6/0		8/0	8/0	6/0	8/0	
	1:200		6/6		8/8	6/4	6/0	8/0	
	1:400		6/6		8/8	6/6	6/4	4/0	
Cuprous oxide (blister)	1:20		6/6		6/6	6/6	6/6	2/2	
	1:200		7/6		6/6	6/6	6/6		
Cuprous oxide (Metrox)†	1:20		6/4		6/6	6/6	6/6		
	1:200		6/6		6/6	6/6	6/6	2/2	
Cyanamid	1:10		6/0		6/4	6/0	6/0	4/0	
	1:100		6/3		6/4	6/2	6/2	4/0	
	1:200		6/5		6/5	6/5	6/3	4/4	
Funginox	1:20		6/0		6/0	6/0	6/0	4/0	
	1:200		6/0		6/0	6/0	6/0	4/0	
	1:400		6/0		6/0	6/0	6/0	6/0	
	1:500		6/0		6/0	6/0	8/0	2/0	
	1:800		6/0		6/0	6/0	6/0	6/0	
	1:1000		6/0		7/0	6/0	6/0	6/0	
Mercuric chloride†	1:1,000	6/0	6/0	6/0	8/0	4/0			
	1:2,000	6/0	6/0	6/0	8/0	6/6			
	1:4,000	6/2	6/4		6/4	6/4	6/5		
	1:8,000	6/4	12/8	6/1	12/6	6/3	6/6	8/4	
	1:10,000		6/4		6/4	6/5	6/4	5/3	

TABLE 1.—EFFECT OF FERTILIZERS AND CHEMICALS ON THE VIABILITY OF SCLEROTIA—*Continued.*

Chemical	Strength	Ratio of pieces of sclerotia plated to pieces remaining viable after treatment, hours							
		12	24	30	48	72	114	192	236
Sulphur, wettable	1:20	7/7	8/8	6/6	6/6	4/4			
	1:200	6/6	6/6	6/6	6/6	4/4			
Sulphuric acid	5 % by vol.	6/0	6/0	7/0	7/0	6/0			
	4 % by vol.	6/0	6/0	8/0	6/0	6/0			
	3 % by vol.	6/0	6/0	8/0	6/0	6/0			
	2 % by vol.	6/0	12/0	6/0	12/0	12/0	6/0	6/0	
	1 % by vol.	6/5	12/1	6/0	12/0	13/0	6/0	6/0	
	½ % by vol.	6/6	12/9	7/4	12/5	12/7	6/6	6/0	6/0
	¼ % by vol.		6/6		6/6	6/6	6/6	4/0	
Treble superphosphate	1:20		7/7		6/6	6/6	8/0	6/0	
	1:100		6/6		6/6	6/6	6/6		
	1:200		6/6		6/6	6/4	6/6	8/6	6/0
Taylor's solution‡	full str.		10/8		6/0	6/0	6/0		
	1:10	6/6	12/9	6/6	12/2	10/0	6/0	2/0	
	1:100	6/6	12/10	7/6	12/11	6/6	6/6	4/4	
	1:200	6/6	7/7	6/5	6/6				
	1:400	6/6	6/6	7/7	6/6				
Tap water		6/6	12/11	6/6	12/12	6/6	6/4	8/6	6/4
		12 da. 8/4	14 da. 8/2	16 da. 8/2	18 da. 14/2	20 da. 14/0	23 da. 14/0	25 da. 14/0	

* Stimulated growth.
† Viable pieces showed suppressed growth.
‡ Supplied by H. W. Taylor, M. D., Picacho, Arizona.

chemicals on the life of the sclerotia produced by the sclerotiniose fungus are given in Table 1; the first figure in a ratio (for example, 6/2) gives the number of pieces of sclerotia cultured; the second figure, the number of sclerotial pieces which grew. Thus "6/2," under the column heading "12 hrs." and to the right of "mercuric chloride 1:4,000," means that six pieces were cut from sclerotia which had soaked twelve hours in 1:4,000 mercuric chloride solution; the six pieces were cultured and two of them remained alive; therefore the strength of mercuric chloride indicated would not prove satisfactory for disinfection purposes in the time given.

The table of experiments makes clear the fact that commercial fertilizers commonly used in our lettuce fields cannot be expected to kill sclerotia of *Sclerotinia sclerotiorum.* Strong applications of ammonium phosphate not only failed to destroy the germinating power of the resting bodies but actually stimulated the growth of the fungus parts—a result which would be expected from the viewpoint of the physiologist; ammonium sulphate possessed no practical value as a fungicide for the sclerotia, and the same statement holds for treble superphosphate. No doubt the use of ammonium sulphate against the Texas root-rot fungus of the soil prompted the suspicion among farmers that a fungicidal action against the resting bodies of *Sclerotinia* might also be found in the same commercial fertilizer. The former fungus, *Phymatotrichum omnivorum,* has sclerotia which are very small compared with those of *Sclerotinia sclerotiorum*; furthermore, fungi differ considerably in their respective relations to chemicals. The sclerotiniose fungus appears to be less sensitive to ammonium sulphate than *Phymatotrichum.*

Among the chemicals classed with disinfectants and which were applied to the sclerotia, Funginox and sulphuric acid stand out in the table above. Funginox is a commercial disinfectant which consists of a solution of mercuric chloride in hydrochloric acid; it should prove useful for killing the sclerotia of *Sclerotinia* in small garden plots and seed beds, and for drenching the soil in the field following the roguing of sclerotiniose-infected plants; formaldehyde is preferable for disinfecting implements and the feet of workers and farm animals.

Sulphuric acid in pure, 1 per cent solution killed the sclerotia which remained in the acid thirty hours or longer. Allowing for dilution caused by soil moisture and for the neutralization of the acid by alkali and other salts in the soil, a stronger concentration should be needed to kill sclerotia in the field. Based upon a water-holding capacity of 16 per cent (assuming that the soil will hold the same quantity of acid), a price of $16 per ton for the acid, saturation to the depth of a plow-furrow, and a 2 per cent solution of sulphuric acid, the cost per acre for killing the sclerotia would be approximately $80 exclusive of labor. This estimate does not take into account the weakening of the acid by chemical reaction in the soil, which would make more acid necessary in some soils; neither does it take into consideration, on the other hand, the fertilizing value of the acid nor the possible returns from the result-

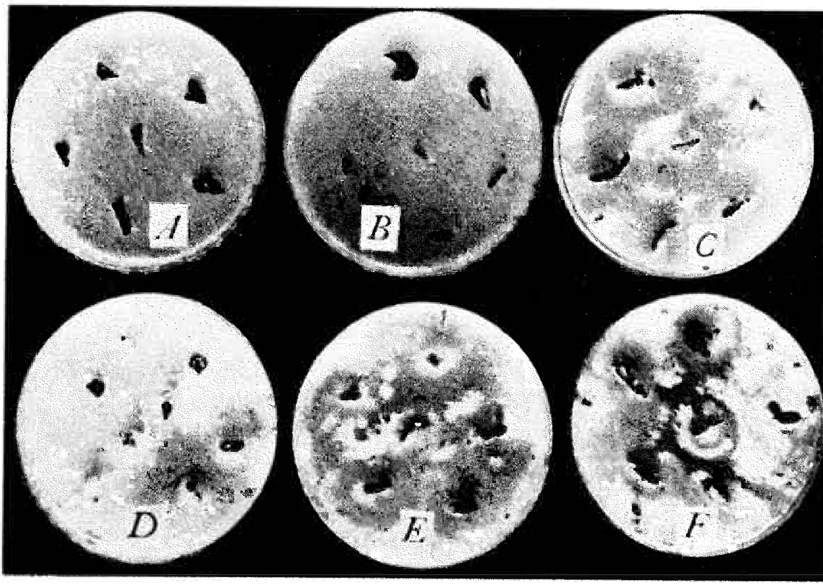

Plate XV.—Effects of various treatments on the sclerotia of the sclerotiniose fungus. All sclerotia were treated for twelve hours in: *A*, 2 per cent sulphuric acid; *B*, mercuric chloride 1:2,000; *C*, tap water; *D*, ammonium sulphate 1:20; *E*, wettable sulphur 1:20; *F*, Taylor's mixture 1:10. *A* and *B* show no growth. Photographs taken seven days after platings were made.

ing improved physical condition of nonporous or "tight" soils. The cost of treatment is perhaps too high to make it practicable except on small plots or for drenching the soil after roguing diseased plants.

Comments on the other chemicals mentioned in Table 1 appear to be unnecessary, excepting Taylor's preparation. This compound, said to protect lettuce plants from sclerotiniose in some way, is based upon a secret formula and manufactured locally. Used in full strength in our experiments, it killed sclerotia which were immersed in it for forty-eight hours or longer; somewhat diluted it possessed little or no fungicidal value.

The control of sclerotiniose of lettuce in shipment, storehouse, and market depends to considerable extent upon the control of the disease in the field and the harvesting and packing operations. In harvesting lettuce, care should be taken to discard heads with obvious infection; in the packing house the selection should be continued and the infected parts of usable heads cut and trimmed off. This is not so easy as it might be. Incipient infection in the stem is indicated only by the water-soaked appearance in many cases; unless the stem is cut above the water-soaked region, rot of the head is likely to continue with the first favorable environmental conditions. The value of careful cutting and trimming was demonstrated by the United States Department of Agriculture some years ago. The investigators reported that "carefully cut lettuce developed far less decay in transit than commercially cut lettuce" and that "the combination of careful cutting and precooling enabled the lettuce to reach its destination in almost perfect condition and to hold up much better on the market than lettuce handled in the usual manner" (11). The present method of icing lettuce for shipment approaches in effect the precooling practice described in older publications; therefore there remains to be emphasized more care in eliminating diseased heads during harvesting and trimming operations.

A more or less local problem in connection with lettuce disease concerns the consumer as well as the local marketmen. Lettuce is frequently offered for sale locally which would not be considered fit for the larger markets. This lettuce is trucked without refrigeration, sometimes over considerable distances. In the winter the trucked lettuce is not so bad if properly selected for grade at the start; in spring and in fall, when the weather is warmer, it does not keep well. Often the effect of the warm air in transit is increased by allowing the lettuce to stand in the sun on the unloading platform for several hours; if such lettuce does not decay in the vegetable market, it may do so in the pantry of the consumer who ultimately pays the bill.

Sclerotiniose can not be absolutely prevented in shipment by any temperature that is safe for lettuce, although temperatures of 40 to 45 degrees F. have been proved by Ramsey (10) to limit the spread of the disease and its development in sound heads. As previously stated, the selection of healthy heads in field and packing shed is the best insurance against lettuce losses in transit and market.

SUMMARY

Head lettuce, a major money crop in Arizona, is attacked by sclerotiniose, otherwise called "drop" and "watery soft rot." Sclerotiniose is widespread in the United States; it may affect more than one hundred plants besides lettuce; it inflicts losses in the field, in transit, in market, and in storage.

The cause of sclerotiniose in Arizona is the fungus, *Sclerotinia sclerotiorum.* Two related species, *S. minor* and *S. intermedia,* which behave in a similar manner toward lettuce have not yet been recorded in this state; every practical means should be used to exclude them.

Sclerotiniose is spread by spores, resting bodies, cull lettuce, and trimmings. The spores are very abundantly produced, short-lived, and wind-borne; resting bodies (sclerotia) are also abundantly produced, long-lived, carried on diseased lettuce, culls and trimmings, and in soil on implements, the feet of men and animals, and especially in irrigation and floodwaters. The fungus threads of the causal fungus, *Sclerotinia,* may grow from plant to plant

in crowded rows on moist soil. That sclerotiniose can be carried on or in lettuce seed has not been proved.

Soil moisture in irrigated lettuce fields is always sufficient for the activity of the sclerotiniose fungus where lettuce can be grown.

Temperature is the most important environmental factor influencing the appearance of sclerotiniose. The causal fungus can attack lettuce in southern Arizona at the lower elevations only during late fall, winter, and early spring.

Sclerotia or resting bodies, like tubers and bulbs of flowering plants, carry the fungus plant through the severe conditions of summer; when kept dry the sclerotia may live for eleven years. Considerable evidence exists to support the belief that extensive rotting of sclerotia occurs in moist soils when soil conditions other than moisture are unfavorable for the growth of the fungus. Experiments with tap water suggest that flooding infected fields for more than eighteen days might kill large numbers of sclerotia.

Soil types of the agricultural districts of this state which are favorable for lettuce culture are probably also favorable for the growth of *Sclerotinia.*

A list of the known hosts of *Sclerotinia sclerotiorum* is given.

Control measures for sclerotiniose herein discussed include sanitary measures, deep plowing and crop rotation with immune plants, the roguing of infected plants, and the use of fertilizers and soil disinfectants. In connection with the last mentioned, a series of experiments is reported.

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