

SCLEROTINIA STEM AND CROWN ROT OF ALFALFA IN THE SAN JOAQUIN VALLEY

C. A. Frate

ABSTRACT

Sclerotinia stem and crown rot of alfalfa has become a widespread and serious problem in portions of the central San Joaquin Valley in years with wet winters. The causal fungus is thought to be *Sclerotinia sclerotiorum* and both established plants and seedlings can become infected. Very little research has been done in California on this alfalfa disease, but local observations and information from other areas provide insight into the disease cycle and potential management strategies. Cool temperatures and wet conditions in the crop canopy due to rain and fog are needed for disease development. The fungus has a wide host range, including many species in the composite and crucifer families, which makes control more difficult. The current recommendation for established stands is to minimize the crop canopy during winter months by a timely grazing or green chop harvest combined with good weed control. Although September and early October plantings result in seedlings being exposed to the rainy months when disease occurs, the advantages of early planting appear to outweigh risks from this disease.

Key Words: alfalfa, *Sclerotinia*, stem rot, crown rot, white mold

Introduction. Stem and crown rot of alfalfa caused by the fungus *Sclerotinia* occurs worldwide in temperate growing regions. Two species, *S. trifoliorum* and *S. sclerotiorum*, are commonly associated with this disease of alfalfa as well as other forage legumes such as red clover and vetch. *S. trifoliorum* sensu Kohn is most commonly associated with this alfalfa disease in Europe and the United States. However, *S. sclerotiorum* sensu Kohn has been identified as the species infecting alfalfa in Washington state and numerous legumes in the southeastern states. Microscopic examination is needed to differentiate the two species. Although a systematic sampling and identification of *Sclerotinia* isolates infecting alfalfa in the central San Joaquin Valley has not occurred, limited investigation indicates that *S. sclerotiorum* is the predominant, if not the only, species causing disease in this location. Knowing the exact species is not critically important because both species cause similar symptoms and have similar disease cycles.

The disease cycle and timing of infection discussed in this paper are based on San Joaquin Valley conditions where rainfall occurs primarily from November through March, and winter temperatures usually range from the 30's (° F) to the 60's (°F). Tule fogs are common and in some years remain for days and weeks without clearing even in afternoons. Alfalfa varieties planted in the southern part of this area are generally in the fall dormancy classes of 8's and 9's. In the central and northern parts of the valley, more dormant varieties in the 5 to 7 classes may be planted.

Disease Symptoms. The first obvious symptom is wilting or flagging of stems. When examined, infected stems usually have a light tan to bleached area somewhere between the base of the stem and the stem tip. It is usually soft and at times "mushy." Any plant tissue at the distal portion of the stem, that is, on the tip side of the infected area, will be wilting and dying. Leaves usually remain

on the stem. If the canopy is moist from rain, fog, or dew, signs of the fungus can be seen as white strands (called mycelium) growing on the stem and spreading onto adjacent stems and leaves or even onto the soil. Eventually, infected stems die. The fungus is also capable of growing into the crowns if prolonged favorable environmental conditions occur. Fortunately, even though numerous stems die, crowns often survive.

It is the presence of the white mycelia or stands of the fungus that occurs when conditions are right that gives the disease the name “white mold” in some crops such as beans. Although the official name when the disease occurs in alfalfa is stem and crown rot, many growers and consultants refer to it as white mold.

In addition to white mycelium that is evident on the surface of infected plants when moisture is plentiful, a key diagnostic feature is the presence of sclerotia. Sclerotia are made up of fungal strands that have condensed to form small hard black structures. They range in size from .03 to .31 inches in diameter (0.85 to 8 mm). They form as the host’s food base diminishes or when environmental conditions are not favorable. Some sclerotia form inside infected stems; these are cylindrical in shape. Others form at the base of infected stems and are irregularly shaped. These externally formed sclerotia fall to the soil surface where they survive during summer when hot, dry weather is not favorable for disease development. Sclerotia in dead stems may fall to the ground with the stems or be harvested and taken off the field.

Environmental Conditions. Moisture is the most critical factor for disease development. Moisture is needed for initial infection and continued growth of mycelia. Without rain and fog, dew would not usually be enough for disease to begin and spread. Once rain and fog occur, the crop canopy plays a significant role in maintaining humidity. The taller and thicker the stand, the longer moisture and humidity will be favorable for disease.

Winter temperatures in the San Joaquin Valley are not limiting to disease development as the optimum temperatures for *S. trifoliorum* are 50-68° F and should be similar for *S. sclerotiorum*. These temperatures are common during winter months.

Once humidity and temperatures are not conducive, the disease will disappear. By late March or April as temperatures increase, rain is less frequent, and fog is absent, it is hard to find diseased plants.

Severe stem and crown rot developed in many Tulare County alfalfa fields in the winter of 1985/86. About 14 inches of rain fell from November through April, and fog was almost continuous during January. In that year a few seedling fields were disced because they were so badly infected. In dry years, the disease is hard to find. Since 1985/86, the disease has been a problem in wet and foggy years and the geographic area where severe infestations have occurred has increased in size. Reports of severely affected fields, previously heard mostly from Kern and Tulare Counties, have been received from Madera, Merced, and Stanislaus Counties.

In most years when the disease is important, December and January are the months when the fungus seems most active. However, in the winter of 1998/99, even though there were some early

December rains, the disease was most prevalent in the latter half of February.

Disease Cycle. To understand a disease it is necessary to know how the pathogen is introduced or spread to a field and how it survives when the disease is not active. A sketch of the disease cycle can be found in Figure 1. Sclerotia play a very important role in this disease. During the active phase of disease sclerotia are formed and fall to the ground either directly or in old stems. They remain dormant in and on soil during summer, and this is how *Sclerotinia* survives hot conditions. In fall when soil temperatures and soil moisture are right, sclerotia germinate to produce one or more spore-bearing structures called apothecia (singular is apothecium). Apothecia are small structures, 0.1 to 0.4 inches in diameter, orange-brown in color, and are found on the soil surface. Within the apothecia are hundreds of spores (ascospores) that the fungus forcibly ejects into surrounding air currents. These ascospores travel on wind currents to adjacent fields and even further. When they land on an alfalfa leaf and moisture is present, they germinate and grow into the plant tissue, starting an infection. Sclerotia can also germinate directly to produce mycelium that grows and invades nearby plant tissue; however, germination in which apothecia are formed is believed to be more common and more important.

There is some indication in the literature that leaf senescence or frost injury will enhance the ability of ascospores to infect tissue or for the fungus to spread. Once infection starts, the fungus continues to grow in the plant, killing the tissue. This is when the wilting stems and the “white mold” are visible. As the disease progresses or when the weather changes, new sclerotia are produced within or at the base of stems. These fall to the ground where many will survive to germinate in following years. In a severely diseased alfalfa field in Washington state, researchers counted over 1200 sclerotia in a square yard area of which 37% were found in the stems, 44% on the surface residue, and 19% either on the soil surface or within the top inch.

The percentage of viable sclerotia in soil will decrease over time, but field studies in Israel demonstrated that a small percentage, 2 to 5.5%, were still viable 7 years after an infected host crop was removed. Bacteria and fungi, such as *Trichoderma sp.*, in soil will parasitize some sclerotia. Some will also be eaten by larger soil organisms.

Studies on another species, *S. minor*, demonstrated that sclerotia survive the digestive tract of a crossbred heifer. This paper cited an earlier study where *S. sclerotiorum* survived but at lower percentages (<1%) when fed to sheep.

Another very important factor in this disease is that both species of *Sclerotinia* have wide host ranges. They infect, survive, and reproduce on other host plants. Sclerotia formed on these other hosts germinate to produce apothecia whose ascospores can infect alfalfa. *S. sclerotiorum* has been reported to infect 361 species of plants in 225 genera including 62 species of the Composite Family, 52 species of the Legume Family, and 32 species in the Crucifer Family.

Apothecia can be found in alfalfa fields that were infected the previous winter. They are often at the base of plants or, if the alfalfa was drilled, in the drill row where there are no plants, presumably the plants having been killed by *Sclerotinia* the preceding year. Apothecia can be found in vineyards and orchards and other commercial crops, either as a result of infection of the crop or of weeds.

Winter grown garbanzos in the San Joaquin Valley, carrots in Kern County, and pistachios are three examples of susceptible crops.

Economic Impact. There is little documented information on yield losses due to *Sclerotinia* stem and crown rot in the central San Joaquin Valley. The disease is sporadic in that it is only serious in wet years and, even at that, the number of fields affected and the percentage of fields is highly variable. Established fields may look seriously hurt and a significant number of stems might be killed, but crowns usually survive and regrowth is healthy. There are cases of seedling fields that have been disced under or established fields that appeared to be thinned out by this disease with subsequent lower yields in the following production season. One difficulty in obtaining yield loss data is that there is not a good control that provides information on what yields would be without the disease.

The potential for loss is highest in seedling fields. Small plants with no crown are most at risk to be killed if infected. November and December plantings result in small seedlings at the most vulnerable time of the year for infection: December and January. On the other hand, there would be little canopy in these late plantings, allowing them to dry out on a sunny or breezy day which could minimize the severity of disease.

Studies on the optimum planting date in the San Joaquin Valley have shown that September and early October are best. Warm temperatures at that time lead to rapid alfalfa emergence and growth. Alfalfa seedlings are better able to compete with weeds, and when winter weeds grow rapidly in November through January, alfalfa plants are large enough to be sprayed with postemergence herbicides. The yield advantage the first year, compared to later plantings, has convinced many growers to plant in September and October. The one disadvantage to this early planting date, aside from the change necessary in crop rotation patterns, is the risk of *Sclerotinia* stem and crown rot. With early stand establishment, nondormant varieties can be a foot or more in height and the canopy closed by the time environmental conditions favor this disease. In 1996, a number of early planted fields had high levels of disease by mid-December. Some growers stated that they wouldn't plant in September again. But by late spring, the fields had recovered and yielded well. Each of four growers contacted who had high levels of *Sclerotinia* in their fields that December continue to plant new stands in September. It is possible that with September plantings, seedlings have developed a crown by December, allowing them to survive infection better than plants that are planted later and that are not as well developed when disease occurs.

Control Strategies. A lack of alternatives leaves cultural methods as the only means of control. There are no fungicides registered on alfalfa for this disease. Even if fungicides were an option, coverage and timing would be difficult. Crop rotation is of minimal value because of the wide host range of the fungus and the airborne spores that can come from adjacent fields. Biological controls, while showing promise in lab studies, have not proven practical in the field. Breeders are selecting for resistance but this effort will take time before commercial varieties with high resistance are available.

Cultural practices appear to offer the best management strategies at this time. For established stands, going into the rainy season with little canopy and good weed control should reduce the extent and

severity of disease. These practices will lower humidity in the canopy, reducing under most circumstances the duration during which conditions are favorable for disease. There is no experimental evidence to demonstrate whether these practices are successful in lowering disease and reducing yield loss, but there is anecdotal evidence of fields that had been partly harvested before a rain. Later the uncut sections had widespread disease and the short cut areas had only a few isolated focal points of disease.

For new stands, one option is to wait to plant until February in order to miss the months in which conditions are most favorable for disease. However, compared to September and early October plantings, the reduction in yields when planting is delayed does not seem to be worth it—at least according to the growers who are planting early and who have experienced some high infection years. New fields planted in September appear to withstand relatively high levels of infection during the first winter without obvious long-term effects.

There are some options to management of the early planted fields. Some growers have applied paraquat (Gramoxone) in December when plants were at least 10 inches tall to burn back foliage in order to open the canopy. Two small trials have been conducted in Tulare County to evaluate this strategy. The first trial was conducted in a field planted to moisture in September of 1996. There were 3 replications of 4 treatments: 1) untreated check; 2) mowed on January 7, 1997; 3) mowed on January 7, 1997, and sprayed with Gramoxone at 6.5 fl oz/acre; and 4) unmowed but sprayed with Gramoxone at 13 fl oz per acre. Individual plots were 6 ft by 20 ft. The Gramoxone burned most of the foliage in both treatments in which it was sprayed. Small foci of *Sclerotinia* infection sites were observed in all plots at the time of treatment. A minimum of three infection sites were flagged in each plot and the diameter of the infection site was measured. The diameter of these same spots was measured again on March 20, 1997. All plots were also mowed on that day. Approximately 4 inches of rain fell in January of 1997, but hardly any rain occurred after January. Yield results, based on a 3 ft x 17 ft swath, and the changes observed in the diameter of the infection sites from January 7 to March 20 are shown in Table 2.

Results from this trial were not conclusive, in part due to the low number of replications and because conditions were not conducive for disease after January. There were no significant differences among treatments either in yield or in disease assessment; however, there were intriguing trends. There was an indication that mowing and Gramoxone treatments reduced yields compared to the untreated check. This is not unusual. When weeds are controlled yields are often less than in untreated checks because there are no weeds contributing to yield. Secondly, it is not common to mow alfalfa in January when it was just planted in September. Obviously the plants had not fully recovered by the March 20 harvest. However, these plots looked very good compared to the check because they had few weeds. Another possible trend was that the treatments might have reduced disease or at least the diameter of infection centers. Mowing by itself was not as helpful as Gramoxone.

A second trial was conducted in 1997/98 to again evaluate mowing and paraquat but also included an unregistered fungicide to help determine yield loss. The field was planted to a nondormant variety in September. Plots were 6 ft x 25 ft with a center 3 ft swath harvested for yield data. Treatments were: 1) untreated control; 2) paraquat (Gramoxone at 13 fl oz./acre); 3) fungicide

(Ronilan at 1.5 lbs/acre applied 3 times); 4) mowed; 5) mowed plus a paraquat application (Gramoxone at 13 fl oz/acre); and 6) mowed plus fungicide (Ronilan at 1.5 lbs/acre applied 3 times). These treatments and the results are in Table 3. The field was drilled in rows which allowed skips in the planting line, due to *Sclerotinia* infection, to be measured. In this trial, mowing plus fungicide was the only treatment to significantly reduce the amounts of skips compared to the unmowed control. Yields were taken from three cuttings. In the first cutting at the end of April, the unmowed check was not significantly different from any of the other treatments. Fungicide treatments, whether mowed or unmowed, resulted in the highest yields (about 400 lbs/acre more than unmowed or mowed plots). Paraquat by itself did not reduce yields compared to the unmowed control, but mowing plus a paraquat treatment had the lowest yield. In the second cutting, the fungicide treatments and the unmowed paraquat treatment tended to yield higher than other treatments. By the late July cutting, there were no differences among the treatments. Subsequent cuttings were not taken because it was noted that some areas of the plots did not get adequately watered during irrigations which led to a high variability in the data.

These two trials do not provide clear-cut information on the effectiveness of burning back new growth with paraquat to minimize this disease. It did not increase disease. Yields are often lower when paraquat is used, but that reduction is often due to the reduced amount of weeds in paraquat treated plots compared to untreated plots. Mowing by itself did not produce dramatic results. Mowing plus paraquat appeared to reduce skips in the drill row. However, yields were reduced in the first cutting. Due to concerns about soil compaction, mowing a young stand does not seem to be a practical control method and is not recommended at this time.

In summary, there are still many questions about this disease in the central San Joaquin Valley and relatively few answers. In wet years it continues to be serious and the geographic area in which the disease is severe is spreading to counties in the central and northern San Joaquin Valley.

It is believed that *S. sclerotiorum* is the major species in the area, but a thorough systematic survey of isolates from different geographic areas within the valley and among various crops has not been done. A detailed study on yield loss due to stem and crown rot on alfalfa has not been done. It is unknown what percent of infected plants, either seedlings or established, die. It is not known how well management practices such as weed control or late cutting affect disease incidence and severity. Do herbicides such as Gramoxone have a direct impact on the fungus? What role does frost injury have in disease incidence and severity? What, if any, are the long-term effects on stand longevity due to *Sclerotinia*?

Research on this disease can be difficult because of the need for favorable environmental conditions. In the past, trials have been established but then there was no disease because there was little rain that year. The interest of growers (and researchers!) is directly related to weather. In dry years, the disease is out of sight and out of mind. With diminishing public funds, it is harder for University researchers to conduct trials without outside funding. Commitments are made to other projects and then when a "good *Sclerotinia*" season occurs, it is hard to find time to conduct a thorough study.

Table 1. Yield and disease data from 1996/97 *Sclerotinia* management trial in newly established alfalfa, Tipton, California

Treatment	Average increase in diameter of infection spots (in.)	Average dry matter yield/plot (lb.)
Untreated check	6.7	3.1
Mowed 1/7/97	4.7	2.7
Mowed + Gramoxone 1/7/97	1.7	2.4
Gramoxone 1/7/97	2.0	2.3
	NS	NS

Values are averages of three means. The trial was planted in September 1996. Mowing and Gramoxone treatments were applied January 7, 1997. Infection areas were measured January 7 and March 20, 1997. Plots were harvested on March 20, 1997.

Table 2. Stand loss and yields from 1997/98 *Sclerotinia* management trial in newly established alfalfa, Tipton, California¹

Treatment ²	Skips in the drill row (inches)	Yields (tons/acre)		
		4/28/98	6/3/98	7/22/98
Unmowed	13.8 ab	1.22 abc	1.21 bc	1.32
Paraquat	14.5 a	1.24 abc	1.33 a	1.12
Fungicide	14.1 a	1.45 a	1.30 ab	1.13
Mowed	15.2 a	1.19 bc	1.19 c	1.12
Mowed + paraquat	10.6 bc	1.09 c	1.27 abc	1.14
Mowed + fungicide	10.1 c	1.44 ab	1.36 a	1.17
<i>Probability</i>	.02	.04	.06	NS
<i>Coefficient of variability</i>	17%	13%	6%	9%

¹ Nondormant alfalfa planted September 1997. Plots were 6 ft by 25 ft with 4 replications. Values within a column followed by a common letter do not differ significantly at P = 0.06 or less.

² Plots mowed on 12/19/97. Paraquat (Gramoxone) applied at 13 fl oz/acre on 12/19/97. Unregistered fungicide (Ronilan) applied at 1.5 lbs/acre on 12/19/97 and two additional applications in January 1998.

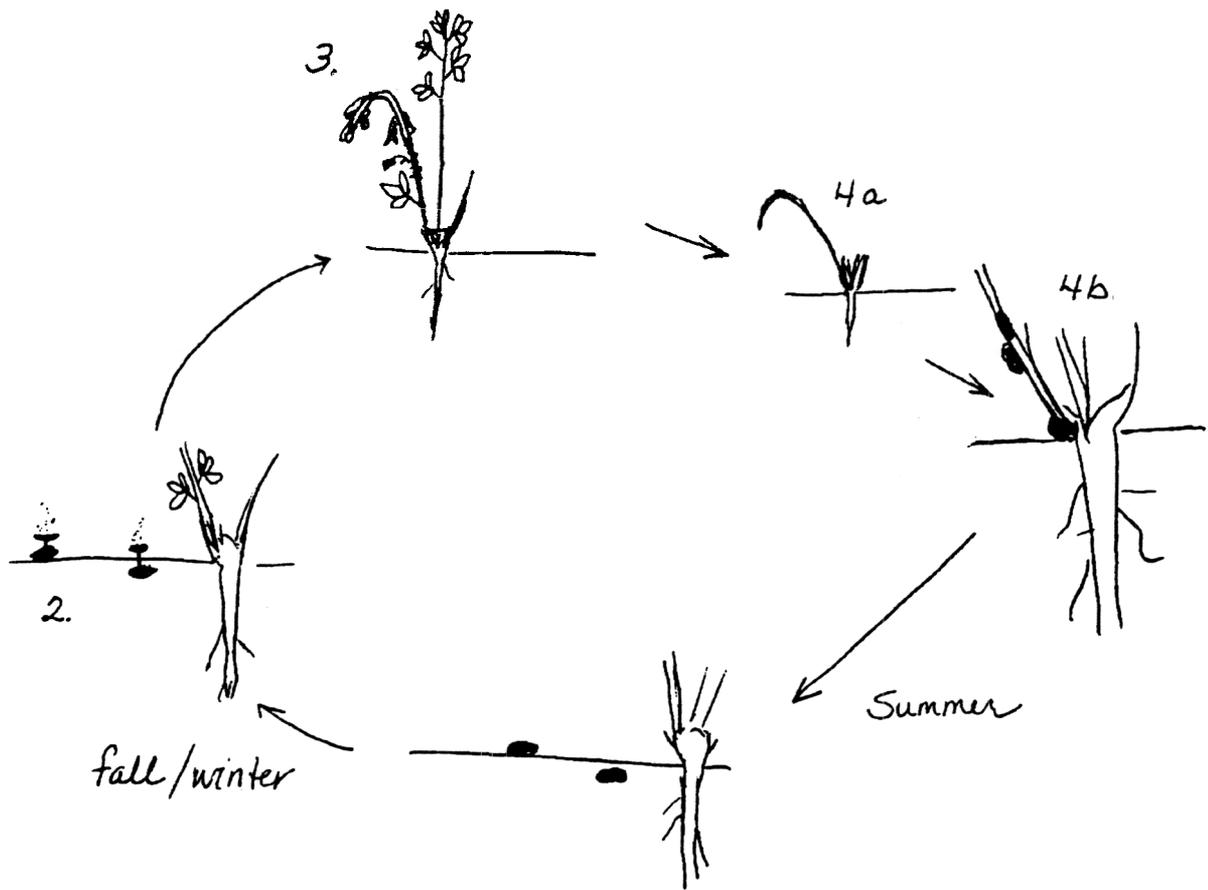


Figure 1. Disease cycle of *Sclerotinia* on alfalfa

1. Sclerotia formed last winter are on or near the soil surface waiting for right conditions of moisture and temperature to germinate.
2. Sclerotia have germinated to produce apothecia. Apothecia eject ascospores into the air where they are blown to adjacent plants or neighboring fields. If an ascospore lands on a host plant and there is sufficient moisture, it will germinate and infect the host.
3. Alfalfa plant with infected stem. Leaves beyond the infection point are wilting. Leaves below the site of infection are still healthy.
- 4a & 4b (enlarged). Sclerotia forming at base of, and within, the stem. The stem is now infected and dead all the way to the crown. Sclerotia within the stem may be harvested. Sclerotia on the stem surface will fall to the ground and wait until the following fall/winter to germinate.

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