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

C. A. Frate[1]

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. Many questions remain about the fungus and disease management in the central San Joaquin Valley but resources for research are limited.

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 they 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 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 this area are generally in the fall dormancy classes of 8's and 9's.

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[1]C. Frate, UCCE Farm Advisor, Tulare County, 2500 W. Burrel Avenue, Visalia, CA 93291-4584; cafrate@ucdavis.edu; Published In: Proceedings, 27th California Alfalfa Symposium, 10-11 December, 1997, Visalia, CA, UC Cooperative Extension, University of California, Davis.

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-.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.

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 disked because they were so badly infected. In dry years, the disease is hard to find. Following the high disease levels in 1985/86, a large field trial was initiated for the winter of 1986/87, but rainfall that year was less and there was not enough disease to continue the trial.

Winter temperatures 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. Even years with severe disease levels, by late March or April as temperatures increase, rain is less frequent, and fog is absent, it is hard to find diseased plants.

It is not known why the Tulare County area is hardest hit in terms of the percentage of fields infected and the severity of disease compared to other counties in the San Joaquin Valley. This area receives more rain than Kern County to the south but much less than counties to the north. Fog is common in the winter but not necessarily more than in other areas. Varieties grown toward the southern end of the San Joaquin Valley are more nondormant than those planted further north. The increased growth in winter would result in more canopy and therefore more humidity, encouraging disease development.

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 proceeds to grow in the plant, killing the tissue. This is when the wilting stems and the "white mold" is visible in the field. 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, 2-5.5%, 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. Table 1 has a list of some common winter weeds and a few crops found in the San Joaquin Valley that belong to these families.

Apothecia are found in vineyards and orchards in the Tulare County area and other commercial crops are infected. Winter grown garbanzos in the San Joaquin Valley, carrots in Kern County, and pistachios are three examples. However, areas in which other crops show serious *Sclerotinia* problems are not always the same areas where *Sclerotinia* is a large problem in alfalfa. For example, *Sclerotinia* practically wiped out a garbanzo field in San Joaquin County, but stem and crown rot has not been a significant problem on alfalfa in that area.

Economic Impact. There is no 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 disked 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. 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 would minimize the severity of disease.

Previous studies on the optimum planting date in the Tulare area showed 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 most 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, plants are a foot or more in height and the canopy is 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 last December, planted new stands this September. It is possible that with September plantings, seedlings have developed a crown by December and may be able to survive infection better than plants that are planted later and are not as well developed when disease occurs.

Control Strategies. Fungicides have been tested in other parts of the United States and one is registered for control of this disease. Beside the fact that no effective fungicides have a label in California, the extended period of time when our conditions are conducive to disease and the continued growth of alfalfa in the winter months make it likely that repeated fungicide applications

would be required for control. However, it would be worthwhile to test fungicides to determine yield loss and to verify whether or not they would be effective under our conditions.

Crop rotation to nonhost crops might reduce residual sclerotia after an infected crop was removed, but two factors influence the effectiveness of this strategy. First, in addition to planting nonhost crops, weeds must be controlled as they may serve as hosts. Secondly, and perhaps most importantly, air blown ascospores can infect a crop even if the field is completely clean of sclerotia.

Biological control has also been studied. At least 30 species of fungi and bacteria as well as some insects have been reported to parasitize or antagonize sclerotia of *Sclerotinia* species. Only a few, such as *Coniothyrium minitans* and *Trichoderma spp.*, have been studied to any extent. Although these organisms have been effective in lab studies, the problem is their distribution in fields and the practicality of their use. In addition, there is still the problem of ascospores blowing in from other areas to initiate infection.

Genetic resistance is the ideal solution and there is evidence that there is some genetic tolerance that could be bred into varieties, but at this time there are no alfalfa varieties with sufficient tolerance to significantly reduce disease. There is not much expectation for high resistance to be incorporated and available in commercial varieties in the near future.

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 fields, 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 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. One small trial has been conducted in Tulare County to evaluate this strategy. The field was planted to moisture in September of 1996. There were three replications of four 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 diameters of these same spots were 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 trends that may be worth further investigation. There is 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, the 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. These treatments are worth further evaluation in trials with more replications.

Several growers have applied Gramoxone to their September planted fields that had high levels of *Sclerotinia* stem and crown rot. The impact on disease is inconclusive.

In summary, there are still many questions about this disease in the central San Joaquin Valley and relatively few answers. In wet years it causes much concern with growers in the Tulare County area. Recently, the disease has been noticed in surrounding counties, but whether it will become as widespread as it is in Tulare County is not known. Why the disease is not as serious in counties further to the north which have higher levels of rainfall also is not understood.

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 documented 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 that year 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. If the 1997/98 winter lives up to the forecast for predicted rain (whether it is due to El Niño or not!), there should be ample opportunity to see the disease and apply some of the

recommendations. However, without extra funding detailed studies on some of the basic questions will not occur.

Table 1. List of common winter-growing weeds and crops that are potential hosts of *Sclerotinia spp.*

Composite Family (Sunflower, Aster)	
Pineapple weed	*Matricaria matricaroides*
Annual sowthistle	*Sonchus oleraceus*
Common groundsel	*Senicio vulgaris*
Mayweed	*Anthemis cotula*
Crucifer (Mustard Family)	
Black mustard	*Brassica nigra*
Swinecress	*Coronopus didymus*
Wild radish	*Raphanus sativus*
Shepherd's purse	*Capsella bursa-pastoris*
London rocket	*Sisymbrium irio*
Legume Family	
California burclover	*Medicago polymorpha*
Vetches (common, hairy, wooly pod)	*Vicia spp.*
Garbanzo	*Cicer arietinum*

Table 2. 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.

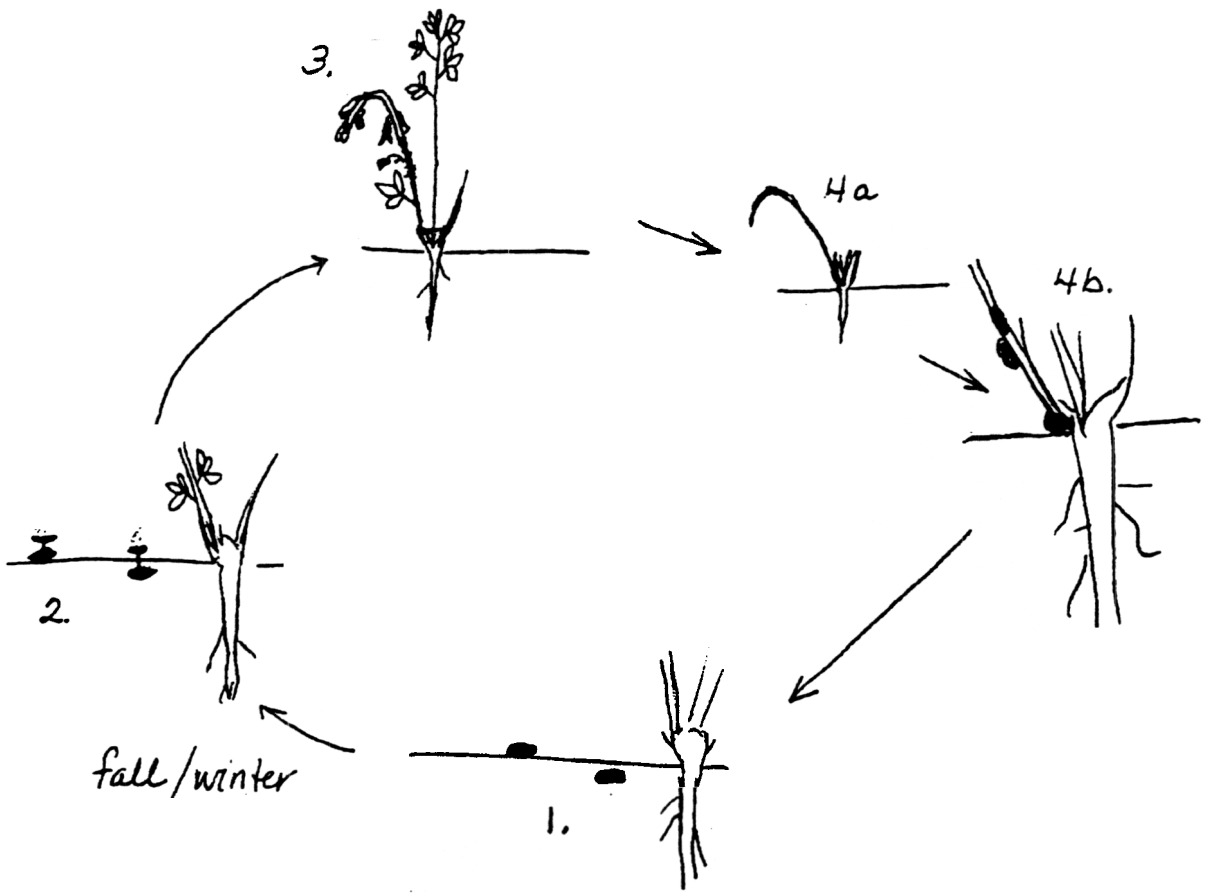

Figure 1. Disease cycle of *Sclerotinia* on alfalfa

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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