PP276

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Integrated Management of White Mold on Vegetables in Florida[1]

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Host Range

Brussels sprouts, cauliflower, cabbage, carrot, collards, eggplant, green beans, lettuce, pepper, potato, squash, melon and other cucurbits, and tomato are some of the vegetable crops grown in Florida that are susceptible to one of several *Sclerotinia* spp. that cause a disease often referred to as white mold (Figures 1 and 2). Collectively, *Sclerotinia* spp. can cause disease in more than 400 plant species. Lettuce drop, head rot of cabbage (Figure 3), *Sclerotinia* stem rot of collards (Figure 4), *Sclerotinia* crown and root rot, pink rot, and watery soft rot are other common names of diseases caused by *Sclerotinia* spp., and they are often descriptive of the symptoms.

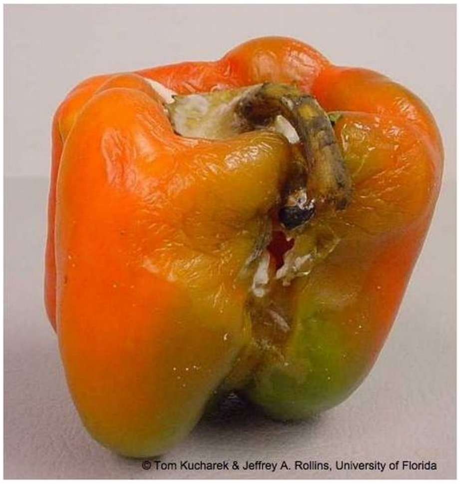

Figure 2. White mold of bell pepper caused by *S. sclerotiorum*. (Credit: Tom Kucharek and Jeffrey A. Rollins)

Figure 1. White mold of tomato caused by *Sclerotinia sclerotiorum.*

Figure 3. Head rot of cabbage caused by *S. sclerotiorum*.

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Figure 4. Collards infected by *S. sclerotiorum* break off from the crown region.

Symptoms

White mold causes water-soaked lesions on the leaves and the crown of the plant (Figure 5), head rot (Figure 6), fruit rot (see Figure 2), and stem rot on infected vegetables (Figure 7). The necrotic areas of the plant are often covered with a fluffy mass of white mycelia, as seen in cabbage (Figure 8), brussels sprouts (Figure 9), and tomato (Figure 10). The hyphae of the mycelium (mass of fungal strands) gradually aggregate together and condense with the accumulation of melanin to form dry structures called sclerotia (Figure 11).

Figure 5. Water-soaked regions on the leaves and the head of cabbage leading to white mold growth.

Figure 6. Head rot of cabbage caused by *S. sclerotiorum*. (Credit: Hank Dankers)

Figure 7. Stem rot and growth of *S. sclerotiorum* on collards.

Figure 8. Fluffy white mycelial growth on an outer leaf of *S. sclerotiorum*-infected cabbage. (Credit: Hank Dankers)

Figure 9. Brussels sprouts infected with *S. sclerotiorum*. The infection normally starts from the top of the plant.

Figure 10. *S. sclerotiorum* growth and sclerotia formation on a tomato fruit with soft rot symptoms. (Credit: Hank Dankers)

The sclerotia can be seen attached to the moldlike mycelium that is formed on the infected

Figure 11. The sclerotia (black in color) of *S. sclerotiorum* formed from the aggregation of the mycelial hyphae on a cabbage leaf. (Credit: Hank Dankers)

area of the plant; upon severe infection, it is also visible on the soil line. The sclerotia are black in color and vary in size from a few millimeters to a centimeter (Figure 12). On brussels sprouts, the infected area takes on a unique bird's nest appearance at the top of the plant (Figure 13). Severe tissue degradation that leads to rotting is a major symptom in most of the vegetable crops infected by *S. sclerotiorum* (Figure 14). In some crops, like green beans, pepper, and tomato, mycelia are not always observed on the stem, but actually grow internally where sclerotia develop as well (Figure 15). The infected stems have a blighted appearance (Figure 16).

Figure 12. Sclerotia (black in color) of *S. sclerotiorum* from infected collards.

Causal Agent

The ascomycete fungus *S. sclerotiorum* is the primary causal agent for white mold. In addition, two other species of *Sclerotinia*, *S. mino*r and *S. trifoliorum*, are disease problems in the United States. *S. minor* is primarily a pathogen of lettuce, celery, carrot, and peanut; *S. trifoliorum* is known to infect green beans and legumes and is similar in biology and morphological characteristics to *S. sclerotiorum*. *S. sclerotiorum* produces large (2–10 mm in

Figure 13. Characteristic bird's nest appearance of brussels sprouts infected with *S. sclerotiorum*. Notice the white mycelial growth and sclerotia on the infected sprouts. Discoloration of the outer sheath of sprouts can also be seen.

Figure 14. A bell pepper field severely infected with *S. sclerotiorum*. (Credit: Ken Pernezny)

Figure 15. Mycelial spread and sclerotia formation inside the blighted stem of an *S. sclerotiorum*-infected pepper plant. (Credit: Ken Pernezny)

diameter) sclerotia, while *S. mino*r produces smaller sclerotia (0.5–2mm), and this is one of the distinguishing features. However, the major differentiation is the primary modes of infection used by these two species to infect a plant. *S. minor* infects by eruptively germinating sclerotia that are near the taproot system of the plant; therefore, it is primarily a soilborne organism. Spore production by *S. minor* is rarely seen in nature. Lesions mostly develop on the stem, followed by vascular invasion of the mycelium,

Figure 16. Stem blight of tomato caused by *S. sclerotiorum*. The plants exhibit wilting due to the infection.

which leads to plant wilt and collapse. In contrast, while *S. sclerotiorum* can also be soilborne, it primarily infects plants through airborne ascospores (Figure 17). The ascospores land on the plants and produce mycelia that invade the tissues rapidly, which leads to plant collapse.

Figure 17. Ascospores (circular in shape) inside the asci (the cylindrical saclike structure) that promote the aerial spread of *S. sclerotiorum*. (Credit: Hank Dankers)

Disease Cycle

Sclerotia are the primary survival structure for *Sclerotinia* spp. and are capable of remaining dormant for several years in soil. The fungus can enter a field through various means, including contaminated seed and plant debris (Figure 18), movement of infected soil on farm equipment, and movement through surface water. Sclerotia overwinter and germinate, producing either mycelia that can directly infect the basal region of the stem of certain plants (this process is referred to as "mycelogenic germination"; Figures 19b–23), or forming a small, mushroomlike fruiting body called an apothecium (this process is referred to as "carpogenic germination"; Figure 19a). In carpogenic germination, the apothecium produces numerous asci that contain specialized spores known as ascospores, which are discharged and blown by wind to aerial portions of the plant. The ascospores produce mycelia that subsequently invade the plant.

Figure 18. Survival of sclerotia on plant debris.

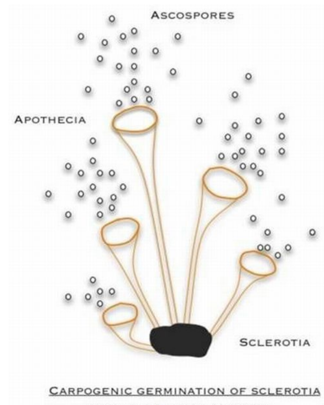

Fig. 19a. Carpogenic germination of sclerotia by formation of mushroomlike apothecia, which release ascospores into the environment that invade the aerial parts of the plant. *Note*: Picture is not drawn to scale.

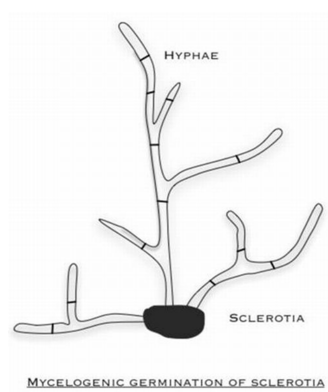

Fig.19b. Mycelogenic germination of sclerotia by formation of hyphae that invade the plants from below and beside the soil line. *Note:* Picture is not drawn to scale.

Figure 20. Growth of the mycelium; the vegetative part of *S. sclerotiorum* from a dry sclerotium on an artificial medium.

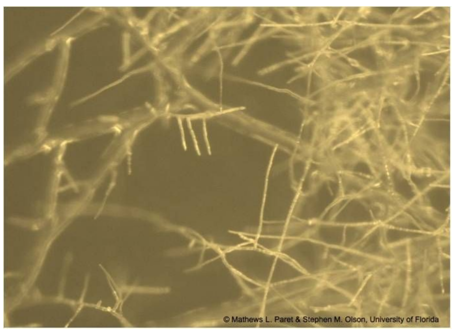

Figure 21. Network of fine white mycelial filaments called hyphae on an artificial medium.

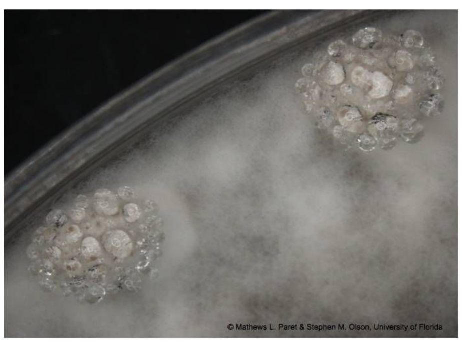

Figure 22. Aggregation of hyphae on an artificial medium.

Figure 23. Mature sclerotia with a melanized outer layer on an artificial medium.

Management

The first step in white mold management is avoiding the spread of the fungus through surface water, farm equipment, farm workers, and seed or planting material. An important aspect in the spread of the fungus is that each apothecium (Figure 17) releases millions of ascospores that are rapidly spread by wind. Therefore, vegetable fields should be monitored regularly for disease, recognizing that areas where white mold occurred previously are likely to be problematic in subsequent seasons. The disease can be successfully managed by integrating the approaches described below.

Field Plowing

Sclerotia of *S. sclerotiorum* can germinate carpogenically from depths of 4–5 cm below the soil line. Therefore, infested crop debris should be deep tilled with a moldboard plow before planting the next crop in the field. This will move the sclerotia into deep layers of the soil where they will not germinate. However, this is only a good management strategy for a single season, as subsequent tillage will bring the buried sclerotia back to the surface in the next growing season.

Crop Density Management

Optimum row spacing of the plants must be kept to create a microclimate condition that is not favorable for survival of the fungus. In addition, varietal selection is important to prevent excessive overlap of the leaves of adjacent plants. This will ensure good airflow that will reduce high moisture conditions in vegetable production.

Irrigation Management

Leaf moisture is a key aspect in the development of white mold. *S. sclerotiorum* spreads primarily during flowering or in the early stages of plant growth when ascospores can easily colonize the plant due to high levels of water on the leaves. The duration of leaf wetness should be reduced in vegetable cultivation under sprinkler irrigation systems. This can be achieved by initiating an early-morning irrigation schedule to allow sufficient time for the leaves to dry during the day. Subsurface drip irrigation is known to be less conducive to disease development than furrow irrigation in the case of lettuce drop caused by *S. minor*. Previous studies indicate that the combination of high temperature, high soil moisture, and reduced oxygen in irrigated fields can reduce the survival of *Sclerotinia* spp.

Crop Rotation

Because sclerotia can survive in soils for many years, crop rotation can only be successful if long-term rotation is practiced. Rotation with nonhost crops, such as corn, wheat, and sorghum, can reduce the number of viable sclerotia of *S. sclerotiorum* in the soil. In the case of lettuce drop caused by *S. minor*, rotation of broccoli with lettuce has been previously shown to reduce the number of sclerotia in the field. Canada thistle, Jerusalem artichoke, lambsquarters, mustard, nightshade, pigweed, ragweed, shepherd's purse, sow thistle, velvetleaf, and vetch are common weeds described before as hosts to *S. sclerotiorum* and should be eradicated from the production area of susceptible crops. The United States Department of Agriculture plants database (http://plants.usda.gov/) can be used to identify these weeds.

Varietal Selection

Early-maturing varieties that have less of a tendency to spread should be selected when possible. Resistant sources to the white mold fungus in vegetables are scarce. However, high levels of resistance to *S. sclerotiorum* have been noticed in various *Capsicum* spp.

Biological Control

Management of *S. sclerotiorum* using the fungus *Coniothyrium minitans* is effective in reducing the disease. Dried spores of this biological control agent can be sprayed on pathogen-infested plant debris at the end of a growing season and on soil before planting. The parasitized sclerotia produce fewer apothecia, which reduces disease incidence. *Streptomyces lydicus*, *Bacillus subtilis*, and *Bacillus pumilis* are other biological control agents that can be used for disease management. Biocontrol agents that are currently labeled for use in Florida are provided in Table 1.

Chemical Control

Fungicides are available for chemical control and are labeled for use in some vegetable crops in Florida. Fungicides that are currently labeled for use in Florida are provided in Table 2.

Control measures should be undertaken early in the season to reduce chances of severe infection and to reduce the buildup and carryover of sclerotia to the following season. An integrated management practice incorporating the various available cultural, biological, and chemical control methods is essential for the successful management of white mold on vegetable crops in Florida.

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Table 1. 2010 registered biological control agents for management of white mold on vegetables

Crop	Chemical	Fungicide group*	Maximum rate/acre/		Minimum days to harvest	Remarks
			Application	Season		
Lettuce Celery	Contans® WG (*C. minitans*** CON/M/91-08)	NC	6 lb			Apply to soil surface and incorporate prior to planting, during planting, or during transplanting.
Lettuce Beets Carrot Celery Parsley Radish Spinach	Actinovate® AG (*S. lydicus* WYEC 108)	NC	12 oz		0	Apply to soil through irrigation, as a seed treatment, or to foliage as a spray. See label for details.
Lettuce Beets Carrot Celery Parsley	Companion® L (*B. subtilis* GB03)	NC	1 gal		0	Can be applied in field, greenhouse, or in hydroponic production. See label for details.
Lettuce Beets Carrot Celery Parsley	Rhapsody® (*B. subtilis* QST 713)	NC	6 qt		0	See label for details.
Lettuce Carrot Spinach	Serenade® Max (*B. subtilis* QST 713)	NC	3 lb		0	See label for details.
Carrot	Sonata® (*B. pumilis*)	NC	4 qt		0	Begin application soon after emergence or transplanting, and when conditions are conducive for disease development. Repeat application at intervals of 7–14 days or as needed. Use higher rates and shorter intervals under high disease pressure.

*Sorting is based on the mode of action of the different chemistries and is known as the FRAC (Fungicide Resistance Action Committee) code (fungicide group). NC = not classified (materials of biological origin).

***C. minitans – Coniothyrium minitans*; *S. lydicus – Streptomyces lydicus*; *B. subtilis – Bacillus subtilis*; *B. pumilis – Bacillus pumilis*

Note: Follow label instructions before applying fungicides to crops. The list above is based on available labels in 2010. Extension agents of respective counties should be consulted prior to application.

Table 2. 2010 registered fungicides for management of white mold on vegetables

Crop	Chemical	Fungicide group*	Maximum rate/acre/		Minimum days to harvest	Remarks
			Application	Season		
Broccoli Cabbage Cauliflower Collards	Endura® (boscalid)	7	9 oz	18 oz	0 (Broccoli, Cabbage, Cauliflower) 14 (Collards)	Limit of two applications per crop. See label for details.
Lettuce	Botran® 75W (dichloran)	14	5.33 lb	5.33 lb	14	See label for details.
	Iprodione 4L AG/ Nevado® 4F/ Rovral® 4F (iprodione)	2	2 pt	6 pt	14	See label for details.
	Endura® 70 WG (boscalid)	7	11 oz	22 oz	14	See label for details.
	Switch® 62.5WDG (cyprodinil/ fludioxonil)	9 & 12	14 oz	56 oz	0	Alternate with fungicides that have different modes of action after two applications. See label for details.
Celery	Botran® 75W (dichloran)	14	2 lb	5.33 lb	7	Direct spray at the base of the plant.
Potato	Topsin® M WSB, T-Methyl (thiophanate-methyl)	1			21	See label for details.
	Rovral® 4F/ Nevado® 4F / Iprodione 4L (iprodione)	2	2 pt	8 pt	14	Limit of four applications per crop.
	Terraclor F (pentachloron-itrobenzene-PCNB)	14	10 pt	15 pt	45	At planting or see label for white mold.
	Omega® 500 F (fluzinam)	29	8 oz	3.5 pt	14	

Table 2. 2010 registered fungicides for management of white mold on vegetables

Tomato	Quadris® (azoxystrobin)	11	6.2 fl oz	37.2 fl oz	0	Limit of six applications per crop. Must alternate or tank mix with fungicide from a different group.
	Amistar® 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Limit of six applications per crop. Must alternate or tank mix with fungicide from a different group.

*Sorting is based on the mode of action of the different chemistries and is known as the FRAC code (fungicide group).
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