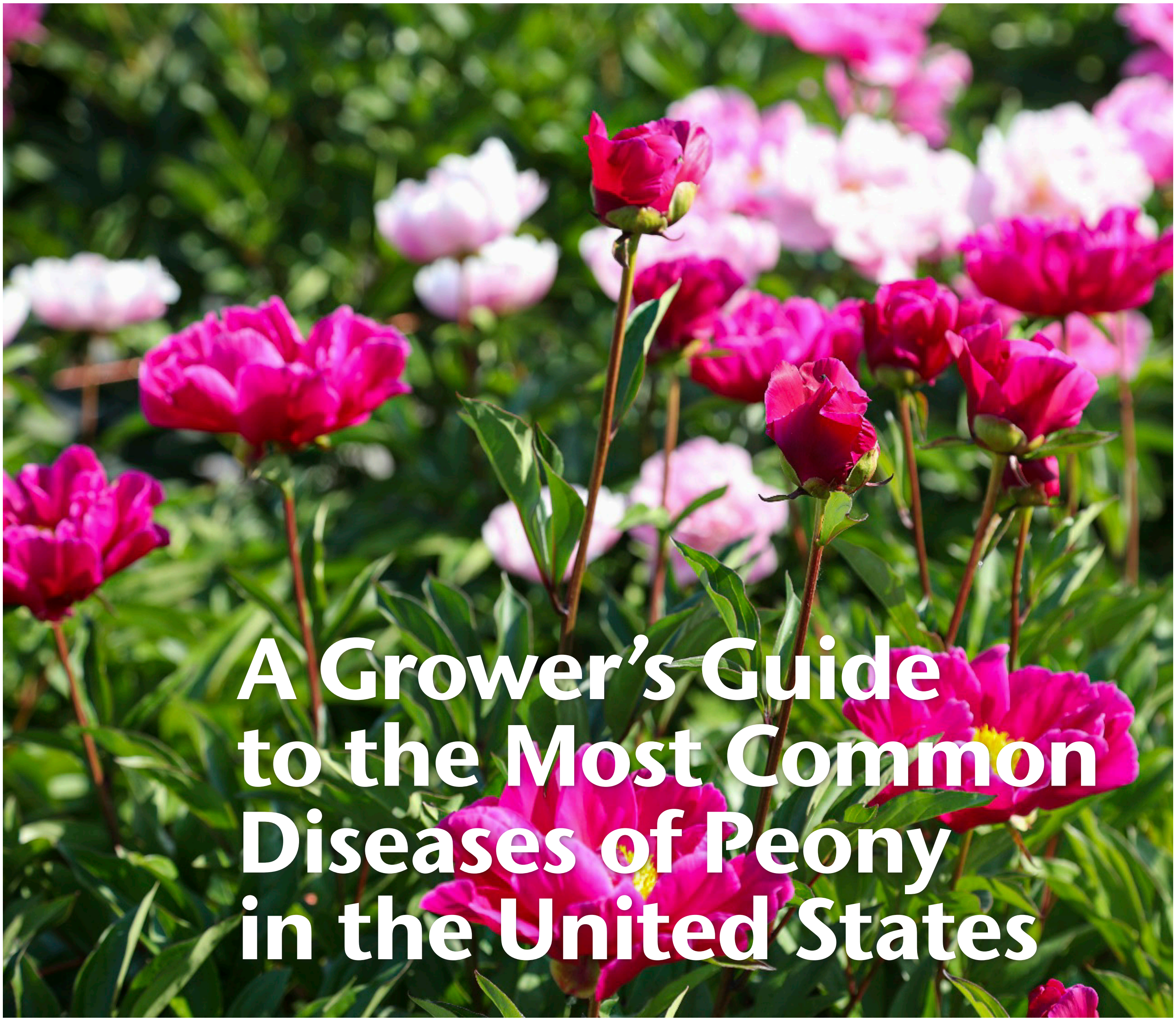

A Grower's Guide to the Most Common Diseases of Peony in the United States

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Andrea R. Garfinkel, Plant Pathology Research Lead, Oregon CBD (formerly Washington State University)

Gary A. Chastagner, Plant Pathologist and Extension Specialist, Washington State University

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A GROWER'S GUIDE TO THE MOST COMMON DISEASES OF PEONY IN THE UNITED STATES

Peonies are hardy, long-lived perennials grown commercially and privately for their large, showy flowers. Peonies are typically considered relatively easy to grow; however, there are a number of pathogens and pests that affect peony health. Many of the disease issues on peonies can be mitigated with the implementation of general cultural management strategies while other diseases require more specific approaches. The purpose of this publication is to provide a basic introduction to plant diseases and plant disease management and also to familiarize growers and homeowners with the most common diseases of peony in the United States, including how to identify and manage them.

Introduction to Plant Diseases

There are four main disease-causing agents of plants: fungi and fungal-like organisms, bacteria, viruses, and nematodes. In addition to these biotic agents, plants can also be affected by a number of physiological abnormalities that are caused by "abiotic" or non-living factors. The majority of biotic plant diseases, including those of peony, are caused by fungi. The epidemiology, symptoms, and management of diseases caused by each one of these four pathogen groups may vary. Understanding the type of disease is an essential first step in management due to these differences.

Unlike human disease management which often is focused on curing infected individuals, plant disease management involves the prevention of disease prior to development. Once a disease is recognized in the field or landscape, the goal of management is to prevent further spread or impact of the pathogen. Management strategies may also be targeted to eradicate the pathogen by means of sanitation. In other instances, plant disease management is focused on preventing introduction of the pathogen to a field or landscape site.

Proper diagnosis is key to the management of plant diseases. It is important to consider that not all symptoms are caused by pathogens. Insect and other animal pests as well as environmental conditions, such as poor nutrition, water stress, or adverse temperatures, can also produce symptoms that may be easily confused with a disease. In other cases, normal plant processes, such as senescence or fall dieback, may be confused with disease. Even when a disease is present, it may not be possible to identify the disease based on symptoms alone. Accurate diagnosis often requires the presence of visible structures, signs of the pathogen, or isolation from diseased tissues. The ability to distinguish between a healthy plant, a sick plant, and a plant with a physiological abnormality may require practice and initial consultation with a plant diagnostician. Diagnosticians may use a variety of laboratory approaches, such as isolation and culture of the organism, pathogen identification using a microscope, or DNA analysis.

The Value of Cultural Management

Cultural management is a general term used to describe multiple non-chemical methods of disease control. Cultural management is targeted at both reducing the risk of disease outbreak and reducing the severity of disease development during an epidemic. Examples of cultural management include purposeful modification of the environment in which a plant is growing or modification of postharvest storage conditions; exclusion of the pathogen from the area in which the crop is being cultivated; sanitation of planting stock, the growing environment, or tools used in cultivation; the use of resistant cultivars; and modification of planting dates or location to avoid conditions favorable for infection and disease development. Effective cultural management strategies can vary among diseases; however, there are numerous general recommendations that can be broadly applied to a wide range of pathogens.

Some of the most important cultural management strategies for fungal and bacterial pathogens are those that reduce the occurrence and duration of leaf wetness. Many fungal and bacterial plant pathogens require moisture on the leaf surface for successful infection or spread, therefore, strategies for reducing leaf wetness are encouraged for many of the peony diseases listed in this publication. Such methods for reducing leaf wetness include switching to drip irrigation from overhead irrigation, irrigating during periods of the day to promote quick drying of the leaf surface (such as the early morning), or increasing plant spacing to promote solar radiation and airflow through the crop canopy.

Removal of infected plant tissues from the field or landscape throughout or at the end of the season, commonly referred to as "sanitation," is another important, broadly-applicable cultural management strategy. A number of plant pathogens overwinter in crop residue left in the field after the growing season. The pathogen's propagules, such as fungal spores, can be produced in crop residues and initiate infections the following spring when peony plants emerge. Removing or destroying the foliage from the previous year's crop can be an effective means for limiting the amount of the pathogen that survives in the field. For other diseases, sanitation may mean total removal of the plant, or "rogueing," to prevent further spread of the pathogen. Sanitation is much more effective as a means of limiting disease development when there is only a single infection cycle per year than when there are multiple cycles of infection. Mid-season removal of infected plant parts can be helpful in reducing spread but can be costly in terms of time and effort and is not always practical or effective, especially on a large scale. Sanitizing tools can also help reduce the spread of some fungi, viruses, and bacteria.

Site selection can also influence diseases. For example, avoiding poorly drained sites will reduce the risk of diseases such as Phytophthora root rot.

Lastly, selecting pathogen-free planting material is important for pathogens that can be moved with rootstocks, the tuberous roots of the peony which are used as the propagative material. The pathogens for which pathogen-free planting stock is an important cultural management strategy are described below.

Other specific cultural management strategies will be given below where appropriate for disease management.

Notes on Pesticide Use

"Pesticide" is a general term used for synthetically or naturally derived products that are used to control certain target organisms. In the case of agricultural pesticides, these products are specifically formulated to kill or limit the growth of plant pathogenic fungi (fungicides), bacteria (antibiotics or bactericides), or nematodes (nematicides). Efforts to control viral infections in plants by direct application of chemicals (viricides) have met with minimal, if any, practical success; however, viral vectors (certain fungi, insects, nematodes, etc.) can be controlled in an effort to reduce the spread of virus diseases. Most fungicides and antibiotics are considered "protective," insofar as they protect healthy tissue from becoming infected. These products kill or prevent the growth of pathogen propagules on the plant surface or in the soil. Rarely do these protective products have any "curative" action; in other words, they are not effective against existing infections. Nematicides can be used to kill nematodes prior to, upon, or after feeding activity on the host. Most agricultural pesticides are applied directly to host tissue; however, in some cases, pesticides can be used to eliminate pathogens from infested soil.

Pesticides can be effective at managing plant diseases, but their efficacy can vary considerably depending on the type of pathogen being controlled, the type of product used, the application timing and coverage, the persistence or residual activity of the product, and various environmental and cultural factors. Not all pesticides are effective against all pathogens, so accurate diagnosis is critical. Prior to any pesticide application, it is important to check the label to ensure that a product is labeled for use on peonies and is effective against a particular pathogen.

Systemic Acquired Resistance and Induced Systemic Resistance

Biologically- and chemically-derived pesticide products to elicit systemic acquired resistance (SAR) and induced systemic resistance (ISR) are also currently being explored in the field of plant protection as a practical approach to managing plant diseases. SAR and ISR describe a series of molecular-level interactions in the deployment of a plant's natural defense system against attack from plant pathogens. Products designed to elicit SAR and ISR responses prime plants for challenge by plant pathogens, thereby reducing infection frequency or severity. While the efficacy of these products is currently limited as compared to conventional-type pesticides, research on these products is ongoing, and a number of products are available on the market for a wide range of pathogen-crop combinations, including for cut flowers.

Resistance to Pesticides

The development of pesticide resistance is a concern in agricultural systems. Resistance is the phenomenon by which a pathogen population ceases to be sensitive to a pesticide, thereby reducing the efficacy of the pesticide product. Proper pesticide use takes into consideration this risk and implements strategies to reduce the risk of the development of resistance, such as rotating products with different modes of action or using tank mixes. Some pesticide-target combinations are more at risk for resistance development than others. The Fungicide Resistance Action Committee (FRAC) is an international group dedicated to tracking the development of fungicide resistance and disseminating information on the classes of fungicides available, including those most at risk for resistance development. More information relating to the risk for resistance to specific classes of fungicides can be found at the FRAC website.

While pesticides may be used to manage certain diseases, they are most effective when combined with cultural management strategies in what is considered an "integrated" pest management approach (often shortened to "IPM"). Effective IPM strategies also rely on early detection of diseases by diligent field monitoring and observations of disease progress following treatments to ensure they are working properly.

In this guide, only general recommendations for pesticides will be given due to the changing nature of products and product labels. Growers are encouraged to consult local Extension publications, such as the Pacific Northwest Disease Management Handbook, for updated recommendations on specific pesticides (Pscheidt and Ocamb 2019).

Fungal and Fungal-Like Diseases of Peony

Anthracnose

Symptoms and signs—Purple-red, circular to irregularly-shaped spots on foliage (Figure 1a), and elongate cankers on the stem with sunken centers (Figure 1b). Severe infections can cause twisting or curling of the stem around the infection site. Salmon-colored spore-bearing structures called acervuli (Figure 1c) can be seen within infected tissue during humid conditions and are a key diagnostic sign for this disease. When acervuli are not present, centers of foliar lesions and stem cankers appear ashy gray.

Cause—Multiple species of fungal pathogens in the genus *Colletotrichum*. Reports of anthracnose caused by *Gloeosporium* can also be found, although this pathogen has never been officially reported on peonies in the United States. Both fungi will produce diagnostic salmon-colored acervuli. Reports of *Gloeosporium* on peony have indicated that this fungus produces lesions more black to gray in color than those caused by *Colletotrichum*.

Disease cycle and conditions that favor disease development—Anthracnose pathogens overwinter in leaf litter and debris. Spores of anthracnose fungi are largely disseminated by watersplash. Periods of prolonged leaf wetness encourage spore germination and infection.

Management—Reduce leaf wetness, especially avoiding overhead irrigation if possible, and practice end-of-season sanitation by removing leaves and stems. Some fungicides may also be effective in preventing anthracnose on peony; however, specific efficacy information for peony is not available and limited information is available relating to application timing. For a current list of fungicides registered for anthracnose on peonies, see the Pacific Northwest Disease Handbook (Pscheidt and Ocamb 2019).

Botrytis Gray Mold

Symptoms and signs—Botrytis gray mold is one of the most widespread and common diseases of peony. *Botrytis* can attack all parts of peony plants and can cause a decay and dieback of emerging shoots, brown lesions on the foliage that can expand down the petiole into the stem, and basal stem decay on shoots (Figure 2). Foliage on shoots with basal stem lesions (Figure 2a) often turn purple prematurely (Figure 2b). Lesions and decayed stems sometimes display concentric zonation of alternating light and dark brown (Figure 3a). Flowers and buds with exposed petals are extremely susceptible to Botrytis gray mold (Figure 3b). Although *Botrytis* does not cause aborted flower buds, these buds are commonly colonized by the pathogen during the growing season. Fuzzy gray growth, consisting of fungal structures that produce airborne spores, can be seen on infected tissues during humid conditions (Figure 3c). If no fuzzy growth is present, incubating tissue in a plastic zip-top bag with a moist paper towel may cause the gray growth to develop after one to two days, which is a good diagnostic sign that is used to identify this disease. Gray mold can also cause significant losses during the postharvest storage, shipment (Figure 4), and display of flowers. It is unclear how frequently infection occurs on peony roots in the field, but survival structures called sclerotia (see more on sclerotia below) have been observed on peony roots from cold storage (Figure 5).

Figure 1. Symptoms and signs of anthracnose on peony. Photos: A.R. Garfinkel.

Figure 2. Basal stem decay of peony due to infection by *Botrytis*: (a) Infection of the lower shoot at the soil surface will often cause shoots to turn purple (b). Photos: G.A. Chastagner.

Figure 3. Symptoms of botrytis gray mold on peony, including (a) a typical “zonate” lesion caused by *Botrytis* showing alternating dark and light concentric circles, (b) flower bud decay, and (c) shoot tip dieback showing fuzzy gray growth on the plant tissue. Photos: A.R. Garfinkel.

Cause—Multiple species of fungi in the genus *Botrytis*. Different species of *Botrytis* may have varying aggressiveness on peony. Some, such as *Botrytis paeoniae* have a limited host range, while the ubiquitous *Botrytis cinerea* has been reported on more than 1,400 hosts. Identification of the exact *Botrytis* species responsible for infection requires molecular and microscopy-based laboratory tests and cannot be done based on symptoms alone. While an exact species diagnosis is difficult in the field, signs of the pathogen can often be seen directly from observing infected host tissue, allowing for visual confirmation of infection generally by a *Botrytis* species.

Disease cycle and conditions favoring disease development—The fungus overwinters in decayed plant material as sclerotia (small, black, resistant structures). Sclerotia on infected rootstock can potentially spread the pathogen into new planting sites. Sclerotia in overwintered plant debris on the soil surface produce spores which infect above-ground tissues during periods of moderate temperatures and leaf wetness. Following this initial infection, additional spores are then produced on infected plant tissue (seen by the naked eye as fuzzy gray growth, described in “Symptoms and signs”). These spores are released to initiate additional infections during the growing season, especially during cool, wet conditions. Leaf wetness is required for spore germination and infection. It is unclear if the infection of emerging shoots can result from direct mycelial (mycelia are the webby or thread-like structures that make up the body of the

Figure 4. Postharvest rot of peony flowers in storage due to infection by *Botrytis*. Photo: G.A. Chastagner.

Figure 5. Sclerotia of *Botrytis* on a tuberous root that was removed from cold storage. Photo: A.R. Garfinkel.

fungus) growth from sclerotia in contact with the emerging shoot or spores. The postharvest decay of flowers can result from infections that occurred prior to harvest or from spores present on the flower buds after harvest.

Management—Cultural management strategies include establishing plantings with disease-free rootstock, reducing periods of leaf wetness, removal of flowers prior to dieback, and sanitation, especially removal of flowers before their petals fall and the removal of foliage at the end of the growing season. For cut flower producers, buds not being harvested for sale should be removed to prevent any blooming of flowers in the field. A number of fungicides have been shown to be effective at managing Botrytis gray mold; however, some fungicides, such as azoxystrobin (available for both homeowners and commercial growers) and iprodione (commercial use only), should be used with caution due to the high risk for fungicide resistance development in *Botrytis*. A current list of recommendations for managing Botrytis gray mold on peony can be found in the Pacific Northwest Disease Handbook. While most commonly applied to the foliage just after emergence of the shoots and during the growing season, some growers also apply fungicides to the crown of plants after removal of the stems in the fall (check the pesticide label to make sure this application method is allowed). Some growers will also use a propane burner to reduce the amount of plant residue that is left in the field after removal of the stems and foliage in the fall. Cultivars differ in their susceptibility to Botrytis gray mold, with Itoh hybrids being among the least susceptible and peonies of coral color the most.

A list of cultivars tested in the 1930s and their relative resistance to *B. paeoniae* are seen in Table 1.

For commercial production, management of *Botrytis* on cut flowers in storage is dependent on rapid cooling of stems and storage of stems at 34°F. Although the optimum temperature for growth of *Botrytis* ranges from 60 to 78°F, it can grow at temperatures down to freezing. In addition to low storage temperature, it is important that there is as little variation in temperature as possible to cut down on the potential for moisture condensation on buds, which favors spore germination. The use of oxidizers, such as ozone, as well as fungicide applications to the buds may also help reduce decay development.

Table 1. List of peony cultivars and their relative susceptibility to *Botrytis paeoniae*.

Susceptibility	Cultivars
Resistant	Akalu, Argus, Arthemise, Attraction, Avalanche, Balliol, Baroness Schroeder, Baron James Rothschild, Black Prince, Cavalleria Rusticana, Chalice, Christine Gowdy, Christine Ritcher, Comte de Nanteuil, Dorothy, Dorothy Echling, Dorothy E. Kibby, Ella Wheeler Wilcox, Eucharis, Eureka, Fragrans, Fulgida, General Bertrand, General Cavaignac, Gloire de Chenonceaux, Glorious, Flory of Somerset, Gretchen, Griff Thomas, Hermes, Hogioku, Iten-shikai, King of England, Kumagaye, Lady Bellew, Lady Mayoress, L'étincelante, Lord Salisbury, Luetta Pfeiffer, Madame Lemoinier, Madame Schmidt, Maud L. Richardson, Meissonier, Monsieur Boucharlataine, Mrs. Gwyn-Lewis, Mr. L. van Leeuwen, Old Silvertip, Petite Renée, Plutarch, Princess Ellen, Purpurea Superba, Queen Wilhelmina, Red Bird, Ruigegno, Sarah Bernhardt, Speedwell, Sweet Home, Yeso
Moderately resistant	Admiral Dewey, Agnes Mary Kelway, Albâtre, Albert Crousse, Alfred de Musset, American Beauty, Archie Brand, Asa Gray, Augustin d'Hour, Aunt Ellen, Béranger, Bullock, Carnea Elegans, Carnot, Charles Binder, Charles Verdier, Charlotte Cushman, Clarisse, Comet, Conqueror, Couronne d'Or, Daubenton, Daybreak, Dorchester, Dorothy Kelway, Duchess of Portland, Duke of Devonshire, Edwin Forrest, Emile Lemoine, Enchantment, Eternal Ciety, Etta, Faust, Favorite, Festiva Maxima, Flambeau, Frances Shaylor, Graziella, Grizzel Muir, Gypsy, Henry Avery, Hon. Mrs. Portman, Innocence, John Fraser, June Day, Jupiter (Calot), Kelway's Queen, La Coquette, Lady Alexandra Duff, Lady Somerset, La Fraicheur, Lake of Silver, La Perle, La Sublime, La Tulipe, La Vestale, L'étincelante (Dessert), Lord Lytton, Louis van Houtte, Mabel L. Franklin, Madame Coste, Madame de Guerle, Madame de Vatry, Mademoiselle Gaillant, Mafeking, Mary L. Hollis, Masterpiece, Mathilde de Roseneck, Mazie Terry, Monsieur Paillet, Monsieur Pasteur, Muchelny, Norfolk, Octavie Demay, Pallas, Phoebe Cary, Pierre Duchartre, Pink Enchantress, Princess Maud, Queen of Beauty, Rauenthal, Rhoda, Rubicunda, Ruth Brand, Simonne Chevalier, Sir Robery Gresly, Snowflake, Sosthenes, Sully Prudhomme, Torquemada, Triumphata, Trojan, Venus, Victoria, Ville de Nancy, Waterloo, Welcome Guest
Susceptible	Adam Bede, Agnes Barr, Amalthea, Armand Rousseau, Bertha, Camille Calot, Canariensis, Carlotta Grisi, Carnea Triumphans, Caul, Chrysanthemiflora, Comte de Cussy, Comte de Paris, Countess of Clancarty, Daniel d'Albert, Delachei, Duc de Cazes, Duc de Wellington, Eastern Beauty, Edmond Lebon, Etienne Mechin, Frances Shaylor, General Grant, Grandiflora, Jules Calot, Lady Beresford, Lutetiana, Madame de Verneville, Madame Emile Galle, Madame Hutin, Magnifica, Marie Lemoine, Marquise d'Ivry, Mathilde Méchin, Meadowvale, Monsieur Chevreul, Mrs. Lowe, Myrtle, Pottsi, Princess Beatrice, Pulcherrima, Queen's Perfection, Roem de Boskoop, Sappho, Sea Foam, Snowball (Hollis), Souvenir de Gaspard Calot, Strasbourg, Sunrise, Thomas S. Ware, Torch, Triomphe du Nord, Turana, Vicomtesse de Belleval, Virginie, Virgo Maria, Viscountess Folkestone, Whitleyi
Very susceptible	Antione Porteau, Armandine Méchin, Assmanshausen, Belle of France, Charles Toche, General Bedeau, Grandiflora Lutescens, Irma, Lutea Plenissima, Nivea Plenissima, Paradise, Territorial, Victoire Modeste

Adapted from *Varietal Susceptibility of the Peony to* Botrytis paeoniae as published in the journal *Phytopathology* by R. Winters in 1930.

Measles (Also Known as Leaf Blotch)

Symptoms—Symptoms on foliage can range from large, purple-red spots (Figure 6a), chestnut brown on the underside, to purple-red flecking on stems, petioles, and foliage (Figure 6b). Flecking symptoms can often be confused with “red spot” caused by *Mycocentrospora acerina* (see below). The fungus can also attack the bud (Figure 6c). In humid conditions, dark olive spores can sometimes be observed on infected tissue using a hand lens. Measles is one of the most common diseases of peony in the United States.

Cause—Fungal pathogen named *Graphiopsis chlorocephala* (formerly known as *Cladosporium paeoniae*).

Disease cycle and conditions favoring disease development—The fungus overwinters in desiccated plant material from the previous season. Spores are produced on debris during periods of humid conditions and are disseminated by splashing droplets of water and insects. Leaf wetness is required for spore germination and infection. Although spores can be borne within infected host tissue, the role of these spores in the disease cycle is unclear.

Management—Follow general cultural management strategies to reduce leaf wetness and practice sanitation, especially at the end of the season. Some fungicides are effective in protecting plants from infection by this pathogen. Current recommendations for fungicides against measles on peonies can be found in the Pacific Northwest Disease Handbook. Research conducted by Meuli in 1937 indicates that cultivars ‘Augustin d’Hour,’ ‘Mathilde de Roseneck,’ ‘Louis Van Houtte,’ ‘Edulis Superba,’ ‘Jules Calot,’ ‘Gigantea,’ and ‘Humei Carnea’ are resistant to leaf blotch whereas ‘Oshkosh White,’ ‘Felix Crousse,’ and ‘Livingstone’ are susceptible. Limited information is available on newer cultivars, but observations have indicated that cultivar ‘Sarah Bernhardt’ seems to be quite resistant, while ‘Kansas’ is quite susceptible.

Figure 6. Symptoms of measles on peony, including (a) large purple-red spots on the foliage, (b) flecking on foliage, and (c) purple discoloration and lesions on the flower bud. Photos: G.A. Chastagner (Figure 6a) and A.R. Garfinkel (Figures 6b and 6c).

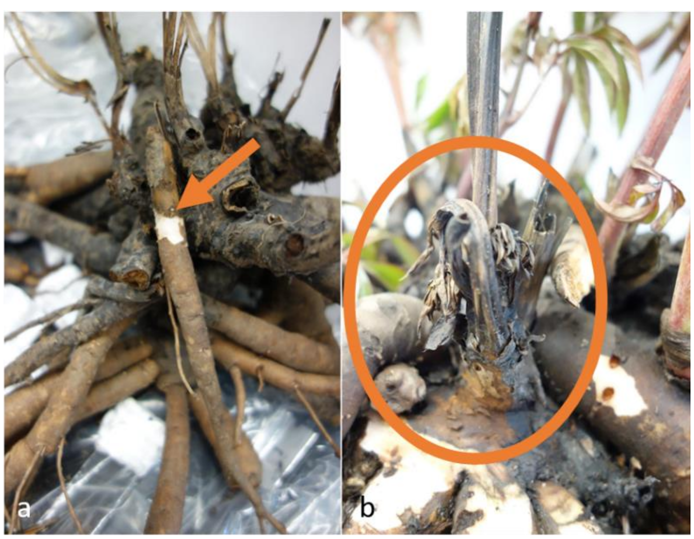

Figure 7. Symptoms of Phytophthora root rot on peony, including (a) a chocolate brown lesion surrounded by healthy, white root tissue and (b) collapse of small, emerging shoots. Photos: A.R. Garfinkel.

Phytophthora Root Rot and Shoot Blight

Symptoms and signs—Chocolate brown lesions on tuberous roots (Figure 7a). Blighted emerging shoots become dark brown to black and often appear collapsed (Figure 7b), but no spores are borne on the tissue as seen with Botrytis gray mold (previous section). Infected roots may send up only a few shoots in the spring or may fail to emerge entirely.

Cause—The fungal-like organism *Phytophthora cactorum*. This organism belongs to a group often referred to as the “water molds,” because it produces swimming spores that spread the disease.

Disease cycle and conditions favoring disease development—Infection by *P. cactorum* is favored by high soil moisture or standing water. In wet soil conditions and moderate temperatures, the fungus releases swimming spores which are attracted to root tissues and initiate infection. The fungus can survive in soils for numerous years, even in the absence of a host.

Management—Avoid planting in areas with standing water or oversaturating soil during irrigation. Avoid dividing or moving infected plant material and irrigating plants with water from streams or ponds that might be contaminated with the pathogen. Infected plants should be removed along with surrounding soil to prevent spread. Some soil fungicide drenches are effective at minimizing infection frequency in other crops, but no specific information is available on peonies.

Pilidium concavum *(Proposed Name: Tan Spot)*

Symptoms and signs—Uniformly tan-colored foliar lesions (Figure 8a) with irregular to circular margins. Under humid conditions, orange to tan wet spore masses can be observed in concentric rings in infected tissue (Figure 8b) which turn hard and dark brown with age and tissue senescence.

Cause—The fungal pathogen *Pilidium concavum*. This organism has only recently been found on peonies in the United States but has previously been found infecting tree peonies in China. *P. concavum* was recently reported as causing tan spot on strawberries in California.

Disease cycle and conditions favoring disease development—Little is known about the disease cycle of this pathogen on peonies or in other cropping systems. Pathogenicity trials on strawberry have indicated that infection is not possible without wounding. Pathogenicity trials on peony were successful with mycelial plugs with and without wounding under high humidity conditions at 20°C (68°F) (Garfinkel and Chastagner 2019).

Management—Follow general cultural management strategies for fungal plant pathogens, such as reducing leaf wetness and practicing sanitation. There is no information available about the efficacy of fungicides against this pathogen on peonies.

Powdery Mildew

Symptoms and signs—Powdery white growth on the surface of above-ground plant tissues, including leaves (Figure 9a and 9b), stems (Figure 9c), and flower buds and carpels. The plant tissue directly beneath the infection can turn purple as a wounding response. Small, sand-grain sized, orange-yellow (immature) to black (mature) structures called chasmothecia that produce the sexual spores of this pathogen can be observed among the white growth later in the fall (Figure 9b).

Figure 8. Symptoms and signs of *Pilidium concavum* infection on peony, including (a) a tan-brown lesion and (b) a brown lesion with wet spore masses visible. Photos: A.R. Garfinkel.

Figure 9. Powdery mildew symptoms on peony (a, b) foliage and (c) stems. The overwintering structures, chasmothecia (b), can be seen on foliage later in the season. Photos: A.R. Garfinkel.

Cause—Fungi in the genera *Erysiphe* and *Podosphaera*.

Disease cycle and conditions favoring disease development—Powdery mildew pathogens overwinter as chasmothecia and release their spores under high relative humidity. Asexual spores, called conidia, are produced throughout the season borne from the white powdery fungal growth on the leaf surface. Unlike other fungal plant pathogens, powdery mildew species do not require free moisture on the leaf surface for germination of spores and infection. Fungal infection is favored by shade.

Management—Typical cultural management strategies to reduce leaf wetness are not effective with powdery mildews as these fungi do not require moisture for spore germination. In fact, applications of water to foliage have been used as a disease management strategy to limit powdery mildew. Increasing solar radiation to the foliage by wide spacing or careful site selection can help reduce infection frequency. Fungicides are available to prevent infection, and some products exhibit limited curative (sometimes also referred to as "kick-back") activity and can limit disease development on recently infected foliage. Fungicides commonly used against powdery mildew species are those that are sulfur- or petroleum-based or those in the DMI (sterol-biosynthesis inhibitor) or QoI (quinone outside inhibitor) groups of fungicides. Fungicide resistance can be a problem with some fungicides.

Red Spot (Alternative Proposed Name: Licorice Spot)

Symptoms and signs—Small red flecking (Figure 10a) to purple-red ringed lesions with ashy gray centers (Figure 10b). Symptoms can be easily confused with those of measles caused by *Graphiopsis chlorocephala* (see Figure 6). Spores are not usually evident within the lesions. Stems are often disproportionately affected; however, the fungus can infect all above ground tissues. Foliage infected with the fungus can display "shot hole" symptoms where the centers of lesions fall out, leaving a hole in the leaf tissue. Infections on roots begin as orange, water-soaked lesions and turn brown to black with age.

Figure 10. Symptoms of infection by *Mycocentrospora acerina* on peony. The photos show (a) red lesions on the stem and (b) a close-up of a stem lesion. Photos: A.R. Garfinkel.

Cause—The fungal pathogen *Mycocentrospora acerina*. This pathogen was found for the first time on peonies in Chile in 2015 and is a common pathogen of plants in the Apiaceae family, such as carrot, celery, caraway, and parsnip.

Disease cycle and conditions favoring disease development—Although limited information is available on peonies, studies on other hosts show that this fungal pathogen has the ability to persist for years in the soil in the absence of a host as a special spore type called chlamydospores. Fungal spores (called conidia) that initiate disease are dispersed by water splash during cool conditions. Free moisture on the leaf surface is required for infection.

Management—Reduce leaf wetness and splash which may disperse the pathogen. Especially avoid splashing of soil onto foliage. Sanitation at the end of the season is only marginally effective as the fungus can persist in the soil absent of a host for many years. Information is not available on the efficacy of fungicides against this pathogen in peonies. However, several fungicides have been successfully used to control this pathogen in other floricultural crops.

Southern Blight

Symptoms and signs—Infected plants may fail to emerge, have weak or stunted shoots, or be completely killed (Figure 11a). Infected shoots or roots are often covered in coarse white fungal growth (Figure 11b). Small, hard, orange to reddish-brown sclerotia develop on infected tissues (Figure 11c).

Cause—The fungal pathogens *Sclerotium rolfsii* and *Sclerotium delphinii* (also known as *Sclerotium rolfsii* var. *delphinii*). These pathogens, particularly *S. rolfsii*, have a very broad host range, including a number of flower, bulb, and vegetable crops. *S. rolfsii* is a warm weather-loving pathogen and considered to be primarily associated with disease in the southern regions of the United States, whereas the more cold-tolerant *S. rolfsii* var. *delphinii* is more commonly associated with disease in more northern latitudes.

Disease cycle and conditions favoring disease development—Southern blight fungal pathogens can be endemic or introduced into a field with planting material. The fungus can overwinter or survive for years in the soil as sclerotia, a specialized resting structure of the fungus. Sclerotia germinate to produce mycelium that grows at or near the soil surface to infect a host plant. The fungus moves plant-to-plant by mycelial growth. As the host tissue dies, additional sclerotia are produced that remain dormant until the next growing season. Although the fungus has the ability to produce spores, they are largely considered unimportant in the disease cycle. Movement of contaminated soil on tools and equipment can spread the disease throughout a planting.

Management—Southern blight is a very difficult disease to control. Prevent the introduction of southern blight fungi into a new field by purchasing clean planting stock. Infected plants should be rogued along with the surrounding soil. Sanitation of tools and equipment is helpful in limiting the spread of this pathogen. In commercial plantings only, fungicides can be applied to peony roots as a preplant dip or as a soil treatment. Observations suggest that cultivar resistance may be present in peonies to Southern blight. In Figure 11a, the cultivar in the foreground, 'Paula Fay,' has been completely killed due to a southern blight infection, where the cultivar in the background ('Dr. Alexander Fleming') remains unaffected.

Figure 11. Symptoms of southern blight on peony, including (a) complete plant death, (b) a white, coarse mycelial mat that can develop surrounding the plant crown, and (c) orange to reddish-brown sclerotia can be seen on the base of the stems. Photos: G.A. Chastagner.

White Stem Rot (Also Known as White Mold)

Symptoms and signs—Conspicuous white growth on stems (Figure 12a). Hard black structures called sclerotia can form on stems (Figure 12a). Chocolate brown to purple lesions can form on foliage (Figure 12b) which are difficult to distinguish from Botrytis gray mold, but do not form the fuzzy gray growth seen in *Botrytis* infections (see Botrytis gray mold above).

Cause—The fungal pathogen *Sclerotinia sclerotiorum*. This pathogen has a wide host range and is often a problem in some common vegetable crops, such as beans and cole crops.

Figure 12. Symptoms of white mold on peony, including (a) conspicuous white growth on stems and large, black sclerotia and (b) foliar lesions. Photos: A.R. Garfinkel (Figure 12a) and A. DeBauw (Figure 12b).

Disease cycle and conditions favoring disease development—The fungus overwinters as sclerotia on plant material or in soil. The sclerotia germinate to form small, brown, cup-shaped structures that produce spores that become airborne and infect foliage. The sclerotia can also germinate to produce mycelium (the thread-like structure of the fungus) and infect tissue in contact with the soil surface. Infections are favored by cool, wet conditions, and leaf wetness is required for spore germination and infection. Unlike *Botrytis*, there are no spores produced on infected host tissues during the growing season.

Management—General cultural management strategies to reduce leaf wetness can prevent early-season foliar infections. Most infections likely originate from surrounding plant hosts, infested soil, or planting stock, therefore, choosing a field free of the pathogen and clean planting stock are important. Rogue infected plants and surrounding soil. Some fungicides are effective at reducing the number of sclerotia in the soil. Current recommendations of fungicides to manage white mold in peonies can be found in the Pacific Northwest Disease Handbook.

Bacterial Diseases of Peony

Xanthomonas Blight (Also Known as Bacterial Leaf Spot)

Symptoms and signs—Purple leaf spots (Figure 13a) which can coalesce into a greater blight of shoots (Figure 13b), including flower buds. Bacterial streaming can sometimes, but not always, be seen from infected tissue observed under a compound microscope.

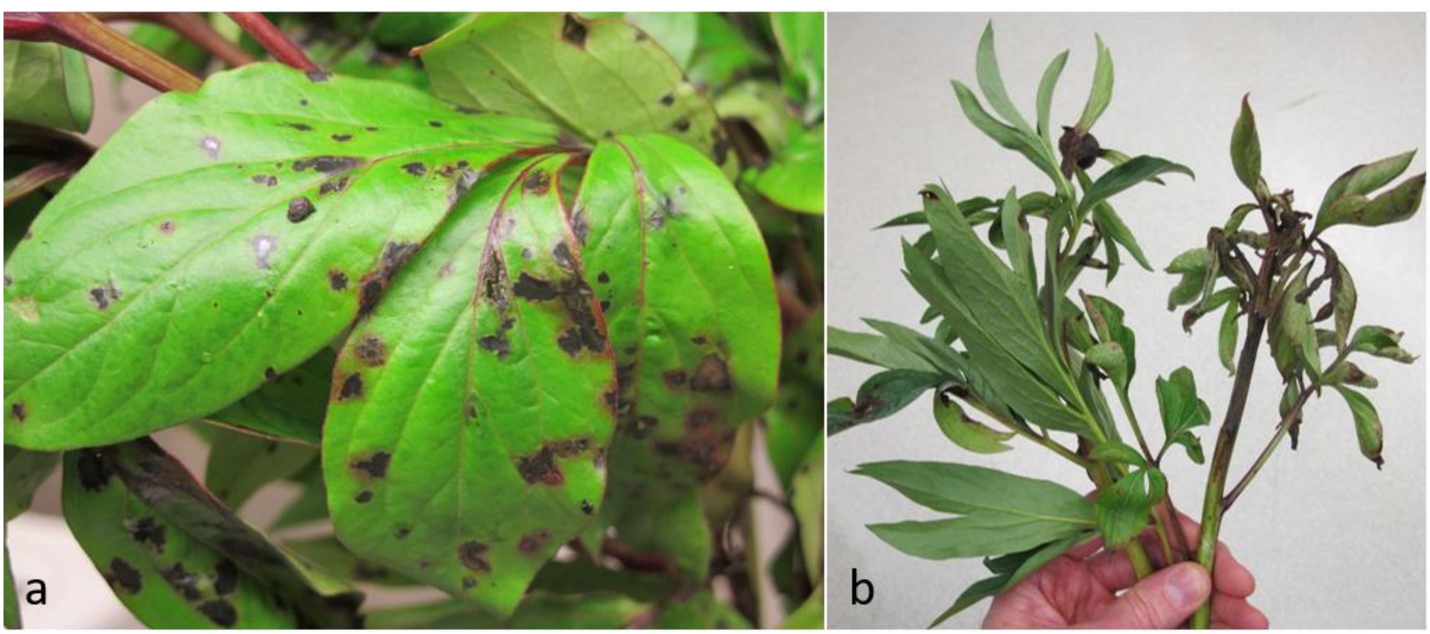

Figure 13. (a) Purple leaf spots and (b) shoot dieback caused by *Xanthomonas*. Photos: North Carolina State University Plant Disease and Insect Clinic.

Cause—Bacterial pathogen in the genus *Xanthomonas*.

Disease cycle and conditions favoring disease development—Bacterial pathogens typically require high moisture conditions for infection and often require wounding for entry into the host. Bacteria likely survive in plant debris.

Management—Reduce leaf wetness using cultural management strategies to avoid spread and infection. Minimize wounding of tissues which can serve as entry points for the pathogen. Sanitation at the end of season may help reduce overwintering of the pathogen. Start with clean planting stock to avoid introduction of the pathogen to a new field.

Virus and Virus-Like Diseases of Peony

Tobacco Rattle Virus (TRV)

Symptoms and signs—TRV is one of the most common pathogens of peony. Symptoms include discrete yellow and green alternating ringspots (Figure 14a), line patterns or banding (Figure 14b), mottling, or blotching. In certain conditions, symptoms can appear orange or purple. Symptoms may be transient, showing up during cooler periods of the season and disappearing during warmer weather. Although symptoms may disappear, the plant is still infected. Even when symptoms appear on only some parts of the plant, it should be assumed that the entire plant is infected. The actual virus particles cannot be seen without the aid of an electron microscope.

Cause—RNA virus called *Tobacco rattle virus* (previously called *Peony ringspot virus* or *Peony mosaic virus*). This virus has a wide host range and infects many crop and non-crop plant species.

Disease cycle and conditions favoring disease development—*Tobacco rattle virus* is likely introduced into a field with infected plant material. The virus is transmitted from plant to plant by feeding activity of stubby root nematodes (nematodes in the genera *Paratrichodorus* and *Trichodorus*). The role of mechanical transmission of TRV by machinery or tools is unclear but is currently thought not to play a large role in transmission. Observations suggest that this virus has very little impact on the growth of peonies, and recent research indicates that there is no difference in the postharvest vase life of flowers from infected and non-infected plants.

Management—There is no cure for TRV; infected plants can be rogued to prevent potential for further spread of the virus. Removal of symptomatic tissue only is not effective since the

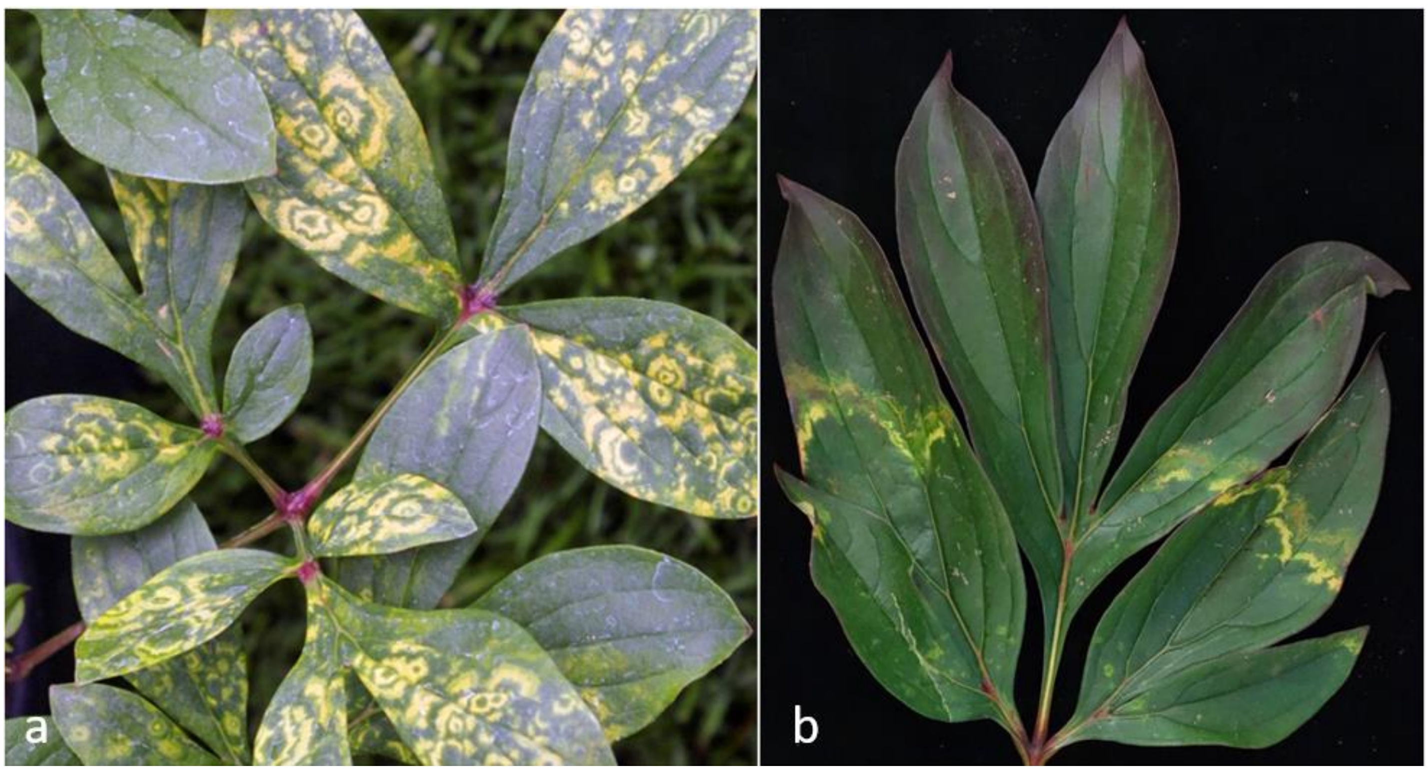

Figure 14. Symptoms of tobacco rattle virus on peony, including (a) ringspots and (b) banding. Photos: G.A. Chastagner (Figure 14a) and A.R. Garfinkel (Figure 14b).

plant is systemically infected. In the absence of the nematode vector, the risk of transmission of the virus is likely low, but studies have not been conducted on the possibility of mechanical TRV transmission in peonies via tools. No effective management exists for the nematode vector. Clean planting stock is essential to preventing introduction of TRV into a new field. Infected plants (such as weedy hosts) in the area may also serve as a source of virus; therefore, minimizing non-crop hosts in and around the field is recommended. See Tobacco Rattle Virus *in Peonies: A Reference Guide for Cut Flower and Rootstock Producers* for more information on TRV management in peonies (Garfinkel et al. 2017).

Lemoine Disease

Symptoms—Roots have irregular swellings on tuberous and fine roots (Figure 15a). Yellowing can be observed in the root cross section (Figure 15b). Diseased plants often show reductions in growth or flowering. The cultivar 'Alice Harding' has been reported to have root symptoms without growth reductions (Don Hollingsworth, unpublished data). It is recommended that a plant diagnostician observe the roots and confirm that root knot nematodes are not present if Lemoine disease is suspected (see more information on root knot nematodes below).

Cause—Definite cause unknown; virus suspected.

Disease cycle and conditions favoring disease development—There is no information available on the epidemiology of Lemoine disease.

Management—There are no management recommendations for Lemoine disease as the cause of the disease is unknown. Some may choose to remove symptomatic plants. There are reports that digging up a plant and cutting out symptomatic root tissue while leaving one eye (growing point) may produce a healthy, flowering plant.

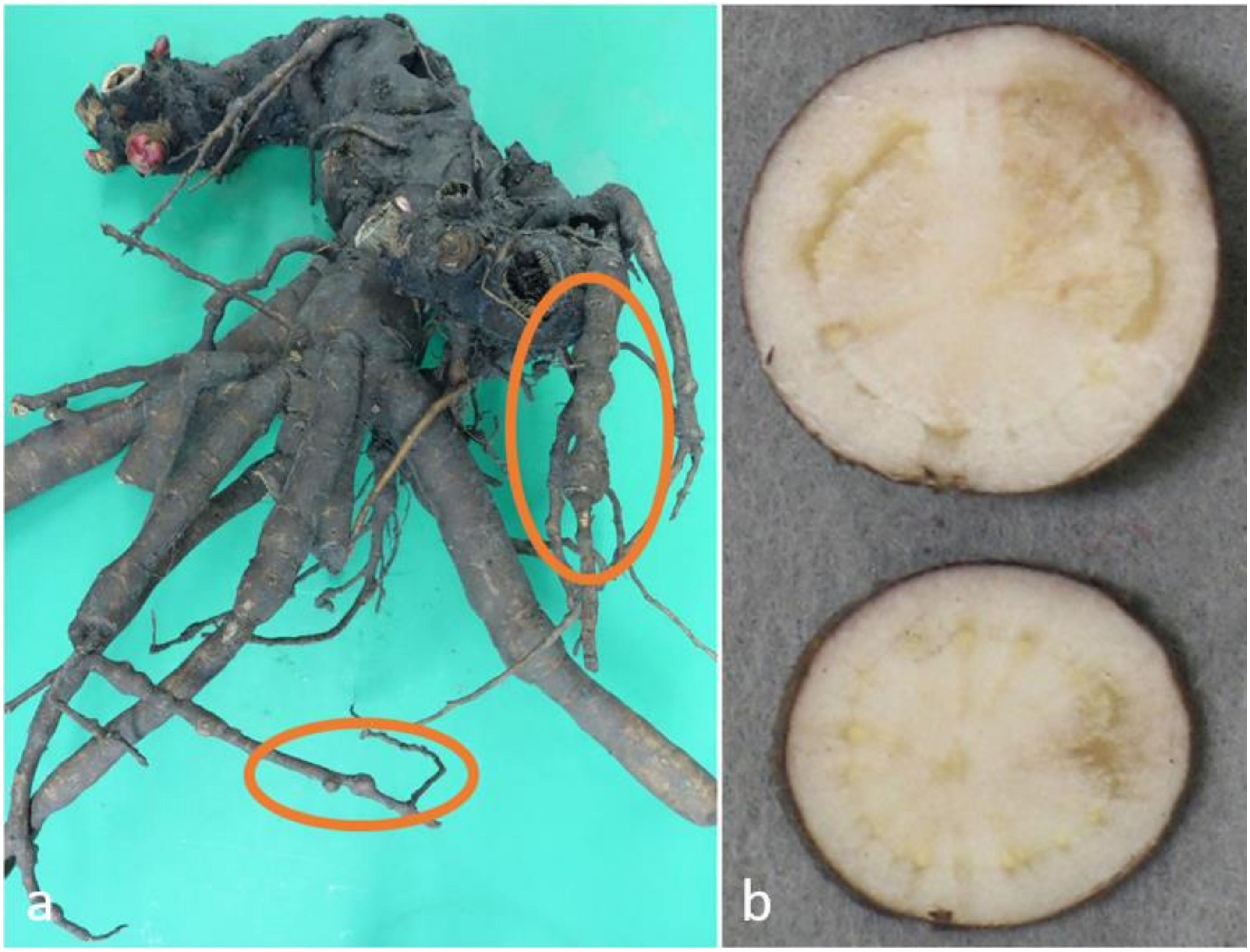

Figure 15. Symptoms of Lemoine disease on peony, including (a) irregularly swollen roots and (b) yellow occlusions in the root tissue. Photos: A.R. Garfinkel.

Other Virus and Virus-Like Diseases

Several other virus and virus-like diseases of unknown cause have been reported on peonies. These include: *Tomato spotted wilt virus*, *Alfalfa mosaic virus*, *Cucumber mosaic virus*, *Citrus leaf blotch virus* (Gress et al. 2017), *Cycas necrotic stunt virus*, *Lychnis mottle virus* (Shaffer et al. 2018), peony leaf curl, and crown elongation/witches' broom. Given the similarity in symptoms between a number of these diseases, laboratory tests are required to identify specific viruses associated with diseased plants. The prevalence and impact of a number of recently described viruses on the production and quality of flowers is unknown.

General recommendations relating to the control of these diseases involves the planting of healthy planting stock, controlling vectors (if known), sanitization of pruning tools if the virus can be spread mechanically, and the removal and destruction of infected plants.

Nematode Diseases of Peony

Foliar Nematodes

Symptoms and signs—Angular purple leaf spots that are limited by (do not cross) the major leaf veins (Figure 16a), eventually leading to complete necrosis of the foliage in severe cases (Figure 16b). Nematodes can be seen under the microscope when cut-up sections of infected tissue are mounted in water.

Cause—Nematodes in the genus *Aphelenchoides*. These are small, microscopic roundworms that feed within leaf tissue, causing disease.

Disease cycle and conditions favoring disease development—Foliar nematodes can survive in a desiccated state for years in leaf litter and debris at the soil surface. In the presence of moisture, the nematodes become active and move through films of water up the stems and across leaf surfaces. Foliar nematodes move longer distances through water-splash and transportation of infected plant material.

Management—Cultural management to reduce leaf wetness can help prevent movement and dispersal of foliar nematodes. Remove diseased tissue at the end of the season, in which the nematode can overwinter. While some insecticides greatly suppress the activity of foliar nematodes and can reduce the nematode population, none are known to totally eliminate foliar nematode from an infected plant.

Root Knot Nematodes

Symptoms and signs—Spherical swellings called "galls" on fine feeder roots. Above ground, plants may appear stunted, chlorotic, or water stressed. The nematode can be observed in the cross section of galls with a microscope. Check symptoms against those of Lemoine disease (above) if root knot nematode is suspected. See photos and additional information on root knot nematodes from the Canadian Peony Society (n.d.).

Cause—Nematodes in the genus *Meloidogyne*.

Disease cycle and conditions favoring disease development—Nematodes can be endemic in a field or introduced with planting stock. Female nematodes become associated with fine-diameter roots to form galls at feeding sites. Eggs are produced within the galls. Generation times can be as short as two weeks. Root knot nematode eggs are long-lived in the soil in the absence of a host.

Management—Hot water dips can kill nematodes that have already infected roots. The USDA Animal Plant Health Inspection Service (APHIS) recommends exposing roots to 118°F for 30 minutes to control root knot nematode on peony (see the USDA Treatment Manual for more information [2019]). Hot water dips help to reduce the likelihood of introduction of the nematodes into a new field on planting stock. Clean planting stock is an important element in managing root knot nematodes. Nematicides, applied as a fumigant to soil, can also kill the root knot nematode. However, fumigants may only be used by properly trained and licensed professionals; they are not available or appropriate for home garden use.

Figure 16. Symptoms of foliar nematodes on peony, including (a) vein-delimited lesions and (b) leaf necrosis. Photos: G.A. Chastagner (Figure 16a) and L.M. duToit (Figure 16b).

Recommended Further Reading

General Plant Pathology and Plant Disease Management:

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Riley, M.B., M.R. Williamson, and O. Maloy. 2002. Plant Disease Diagnosis. *The Plant Health Instructor*.

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By
Andrea R. Garfinkel, Plant Pathology Research Lead, Oregon CBD
(formerly Washington State University)
Gary A. Chastagner, Plant Pathologist and Extension Specialist,
Washington State University

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