



A number of foliar fungal diseases can affect crucifer crops. Three fungal pathogens have emerged recently in western Oregon where epidemics of black leg, light leaf spot, and white leaf spot have been occurring since 2014. Black leg has been detected sporadically in Oregon since the 1970's but historically black leg has caused significant problems wherever crucifers were grown. Crucifer seed rules have been in place within Oregon, Washington, and other markets to protect crucifer crops from black leg. Light leaf spot is new to North America, but has been reported in other regions of the world where it is known to cause significant seed yield losses of winter oilseed rape. Light leaf spot and black leg can both result in reduced yields or quality, depending on disease incidence and severity in vegetable and seed fields. White leaf spot has been previously reported in the US, but management has not normally been needed except in the southeastern US. White leaf spot may be less of an economic threat to crucifer production in the Pacific Northwest, compared to the risks from black leg and light leaf spot.

The complete host range for these three diseases is not known at this time but it is likely that all *Brassica* and *Raphanus* crops grown in the Pacific Northwest are susceptible to some degree. These three diseases may be found on volunteer *Brassica*, *Raphanus*, and *Sinapis* species as well as crucifer weed species including little bittercress (*Cardamine oligosperma*), western yellowcress (*Rorippa curvisiliqua*), field pennycress (*Thlaspi arvense*), wild radish (*Raphanus sativus*), shepherd's purse (*Capsella bursa-pastoris*), hedge mustard (*Sisymbrium officinale*), and field mustard or birdsrape mustard (*Brassica rapa* var. *rapa*). The fungi which cause black leg, light leaf spot, and white leaf spot produce wind-blown spores on infected residues, beginning with fall rains, and may continue spore production through spring months if weather conditions remain moderately cool and wet. Fall-planted and over-wintered crucifers are at greatest risk for outbreaks of these three diseases compared to spring or summer crucifer crops.

Black leg. The fungus that causes black leg, *Phoma lingam* (sexual stage: *Leptosphaeria maculans*) can cause spots on leaves, stems, petioles, or pods; stem cankers may occur at the base of the main stem (figures 1 and 2). Initially, leaf spots are pale and irregular (figure 1A), becoming roundish or oval, ashy gray in color, with tiny, black fruiting bodies (pycnidia) dotted across leaf spots (figures 1B, 2A). The center of older leaf spots may fall out during heavy rain, leaving a shot-hole that typically contains a narrow band of dead plant tissue with associated pycnidia. Stem cankers are typically elongated with a dark, purplish border (figures 1C, 2B, 2C), and can develop near the soil line, sometimes extending below the soil surface (figure 2H). Cankers may also develop higher up on the stem, this commonly occurs on kale and broccoli (figures 2D, 2G). Black leg stem infections are not superficial, inner stem infection can be found upon breaking open stems or scraping back the epidermal layer (figure 1D). Plants can be stunted (figure 2C), and this may be the first symptom noticed with seedborne infections. Infected plants may exhibit wilting during warm, sunny days. Plants may collapse from stem rot (figures 2E, 2I), or fall over from poor root anchorage. Storage roots of turnip, rutabaga, and radish may become infected (figure 2F), as well as the upper root portions in other crucifer crops. After harvest of infected vegetables, the fungus can continue to grow in storage if temperature is above 35°F. Symptoms on seed pods are usually rare and inconspicuous, but pod infection can lead to infection of the developing seed. Wounding of plants by insects, herbicides, or other injuries can increase disease severity. *Sclerotinia*, *Botrytis*,

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and other pathogens can infect black leg lesions and eventually mask symptoms and signs of black leg. Black leg-infected storage roots are prone to co-infection by bacterial soft rot pathogens as well.

The black leg fungus can survive in association with infected plant residues (figure 1H) until the plant debris fully decomposes, which can take up to 4 years, depending on residue management practices and environmental conditions. *Phoma lingam* can also be seedborne, surviving for years in infested seed. Planting of *Phoma*-infested seed can lead to large economic losses due to seedling die-out, severe stunting, yield reductions in surviving plants, and the cost to prevent perpetuation of disease via infected crop residues. Plants that develop from infected seeds may have a black stripe inside seedling stems or tiny leaf spots on the cotyledons, both of which are easily overlooked. Seedlings that survive will be stunted and sunken lesions can be found at the base of the plant, at or below the soil line (figure 1E).

The fruiting bodies of the asexual stage (*P. lingam*) are observed as tiny black dots (pycnidia) on spots or cankers (figure 1F). Pycnidia produce spores (figure 1G) (pycnidiospores) that are dispersed by splashing rain or irrigation water, and can lead to disease build-up in a field. Workers and equipment spread spores when moving through a diseased field during wet conditions. Following wet or humid and cool conditions, spores are forcibly exuded from a pycnidium as pinkish to purplish matrix known as a cirrhus (figure 1F). Pycnidia also form on infected plant residues after harvest, especially on the lower main stem and upper crown, enabling the pathogen to survive years, until the plant residues decompose. Fruiting bodies known as pseudothecia are produced by the sexual stage of the black leg pathogen, *Leptosphaeria maculans*, and form on infected plant debris, releasing the sexual spores (ascospores) (figures 1H, 1I). Ascospores may be wind-blown at least several miles during cool, windy conditions after or between rain events, even during dry periods that last only a few hours. In fall-planted crucifer crops or winter weeds, pseudothecia can form on infected plant parts the following spring or summer, prior to harvest, and continue forming on infected plant residues that remain on the soil surface after harvest. The ascospores develop and mature during cool (46-60°F), moist conditions that are typical during fall, winter, and spring in many areas of the Pacific Northwest. In spring-sown crops, pseudothecia do not form on infected crop plants until after harvest.

Under current Oregon Department of Agriculture crucifer black leg seed rules (OAR 603-052-0860), crucifer seed stock (canola, cabbage, broccoli, kale, radish, turnip, forage crucifers, etc.) intended for commercial planting in Oregon must be accompanied by an official test stating that the untreated seed is free from black leg. Currently, Oregon Department of Agriculture seed rules also require that crucifer seed must be treated with either an approved fungicide or hot water (122°F for 15 to 25 minutes) to control seedborne *Phoma*, both of which will control *Phoma* infections on seed that occur at rates below seed-test detection thresholds. Homeowner seed packets, 0.5 oz size or smaller, are exempt from these rules.

Light leaf spot. The fungus that causes light leaf spot, *Cylindrosporium concentricum* (sexual stage: *Pyrenopeziza brassicae*), can infect leaves, stems, and pods of *Brassica* and radish crops; subsequently growing in a systemic manner throughout the plant, except into the roots. Oilseed winter rape is very susceptible, seed yield losses up to 22% have been reported in Europe. Turnip cultivars, including 'Barkant' and 'Purple Top White Globe', appear to be very susceptible in the Pacific Northwest. *Brassica* species grown as vegetables in other areas where this disease occurs have blemish defects that result in a decrease in yield quality but not typically yield quantity. Cauliflower is of particular concern due to the vulnerability of developing curds to infection. Wet conditions and cool temperatures around 59-61°F are optimum for symptom development. However, symptoms will develop over a wider temperature range while infections will occur at

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cooler temperatures; the optimal temperature for infection is reported to be 50°F. Plants infected during autumn may remain symptomless through late winter or early spring, as occurred during 2015 and 2016 with *Brassica* crops in western Oregon.

Small, brown to blackish specks or discolored patches may be observed on infected cotyledons or true leaves, and develop into irregular, brown lesions (figures 3B-D), olive-brown coloration of tissues surrounding leaf spots and associated leaf veins may be observed on the underside of affected leaves or atop leaf midribs. The lesions may develop cracked centers as they dry, and sometimes turning black. This fungus often cohabitates with other pathogens so foliar symptoms can be quite variable due to the presence of other microbes. Leaf lesions can coalesce, causing death of leaves and severe defoliation. Leaf distortion may occur and foliar symptoms can be confused with virus, frost, or herbicide injury. Stem lesions consist of superficial, elongated, brownish streaks with an olive-brown to grayish-black margin (figure 3A). Infected plants may be severely stunted. Flower infections can cause seed abortion. Pods infected while immature can appear distorted, while pods infected later appear healthy but may contain whitish spore masses. Cauliflower will have a brown discoloration of curds while Brussels sprouts exhibit black lesions. Light leaf spot also can result in plants being more susceptible to winter-kill or cold injury.

Ascospores of the sexual stage, *Pyrenopeziza brassicae*, develop in fruiting bodies (apothecia) on infected plant residues. Ascospores are released after a period of wetness and wind-dispersed. Asexual spores of *C. concentricum*, known as conidia (figure 3E), spread by splashing rain or irrigation water and can result in increased disease within a field, potentially infecting seed pods. Seed infection is favored by cool, wet conditions but transmission to seedlings reportedly occurs at low levels. However, infected seed is the critical route for bringing light leaf spot onto an uninfected farm or into new regions. Wind-blown ascospores are produced on infected plant residues, including volunteer or weedy crucifer plants, so planting in or adjacent to a crop field which had light leaf spot brings high risk of future light leaf spot outbreaks. Planting infected seed can also give rise to disease outbreaks.

White leaf spot and gray stem. The fungus that causes white leaf spot and gray stem, *Pseudocercospora capsellae* (sexual stage: *Mycosphaerella capsellae*), can infect leaves, stems and pods of *Brassica* species as well as radish and horseradish; fall-planted turnip seed crops appear to be quite susceptible in western Oregon. Chinese cabbage, rutabaga, turnip and mustards are reported to be very susceptible to white leaf spot in Europe, where also seed losses up to 15% have been reported in oilseed winter rape due to white leaf spot. Temperatures of 50 to 60°F and moist conditions promote disease development. Tan, irregular or roundish spots first develop on leaves, especially the leaf tips and margins, and become ashy gray to white with a brown margin and sometimes a yellow halo (figures 4A, 4B). With magnification, long, white, icicle-like conidia (figures 4D, 4E) can be observed on spots. With age, the leaf spots turn dark brown due to the initiation of the sexual stage (pseudothecia). The center of older lesions may fall out, resulting in a shot-hole appearance. Foliar lesions may coalesce when the disease is severe, resulting in defoliation. Stem lesions are superficial, elongated, and brown, and turn an ashy-gray to white with a brown margin (figure 4C); there is a distinct boundary between diseased and healthy tissue on infected stems. Pod infections start as small brown spots that expand, turn gray-white, and develop numerous tiny dark fruiting bodies (pseudothecia). Pod infections are more likely during cool, wet spring conditions; however, seed transmission is not thought to play a major role in disease spread.

Ascospores of the sexual stage, *M. capsellae*, develop from pseudothecia produced on infected plant residues starting in the autumn, and are wind-dispersed following rain or dew events. Conidia of the asexual stage, *P. capsellae*, develop beginning in late fall, are spread relatively short distances by splashing rain or irrigation water, and can lead to disease build-up in a field.

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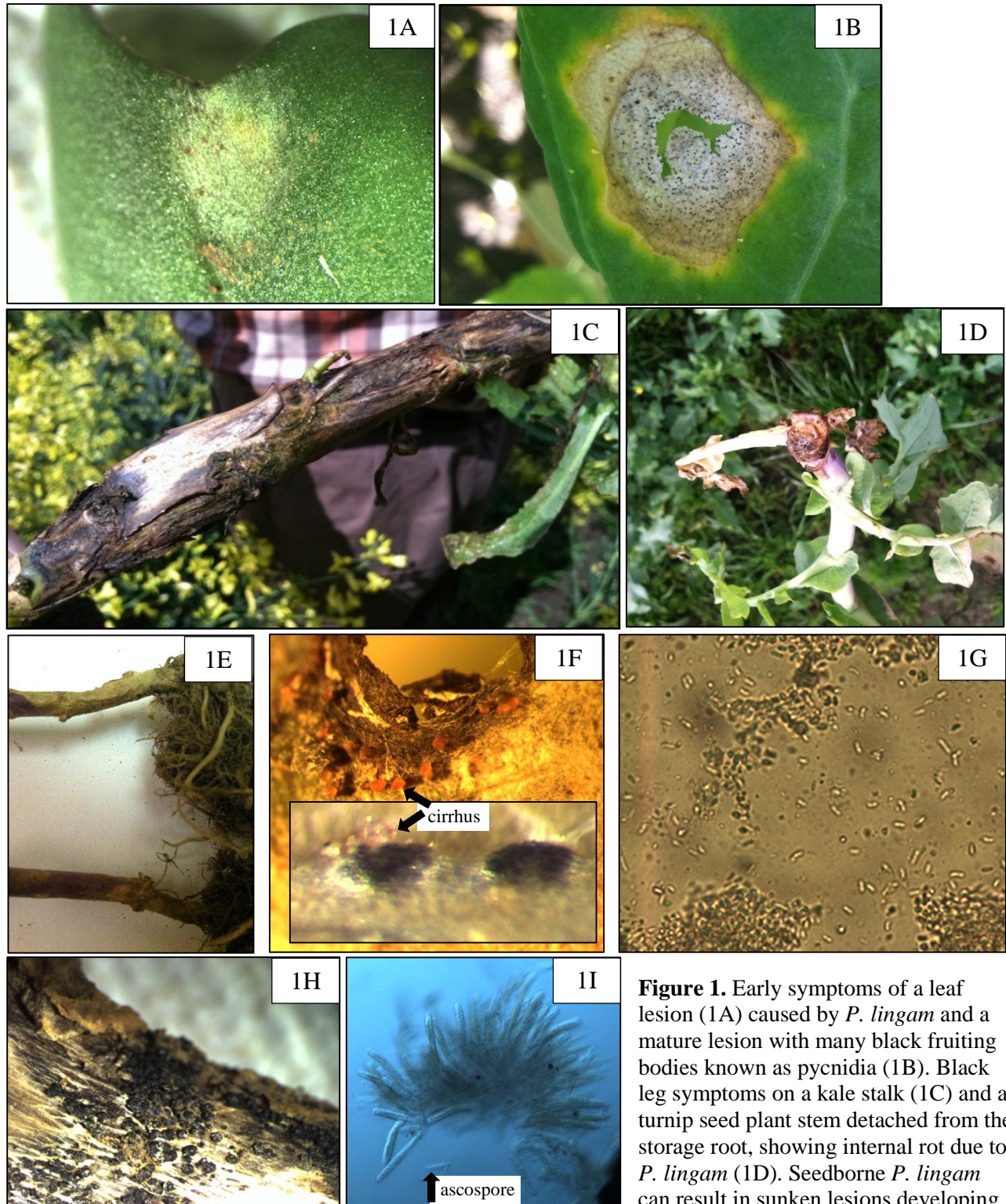


Figure 1. Early symptoms of a leaf lesion (1A) caused by *P. lingam* and a mature lesion with many black fruiting bodies known as pycnidia (1B). Black leg symptoms on a kale stalk (1C) and a turnip seed plant stem detached from the storage root, showing internal rot due to *P. lingam* (1D). Seedborne *P. lingam* can result in sunken lesions developing

on the base of stems that will form pycnidia (1E). During wet conditions, pycnidia of *P. lingam* imbibe moisture and produce a pink to purplish ‘ooze’ (cirrus) filled with conidia that are splash-dispersed (1F). Pycnidiospores of *P. lingam* under 200X magnification (1G). Pseudothecia (1H) are produced on infected crop residues, especially lower stem portions. Each pseudothecium produces elongated sacs of spores known as asci (1I) that are filled with ascospores which can be wind-blown at least several miles.

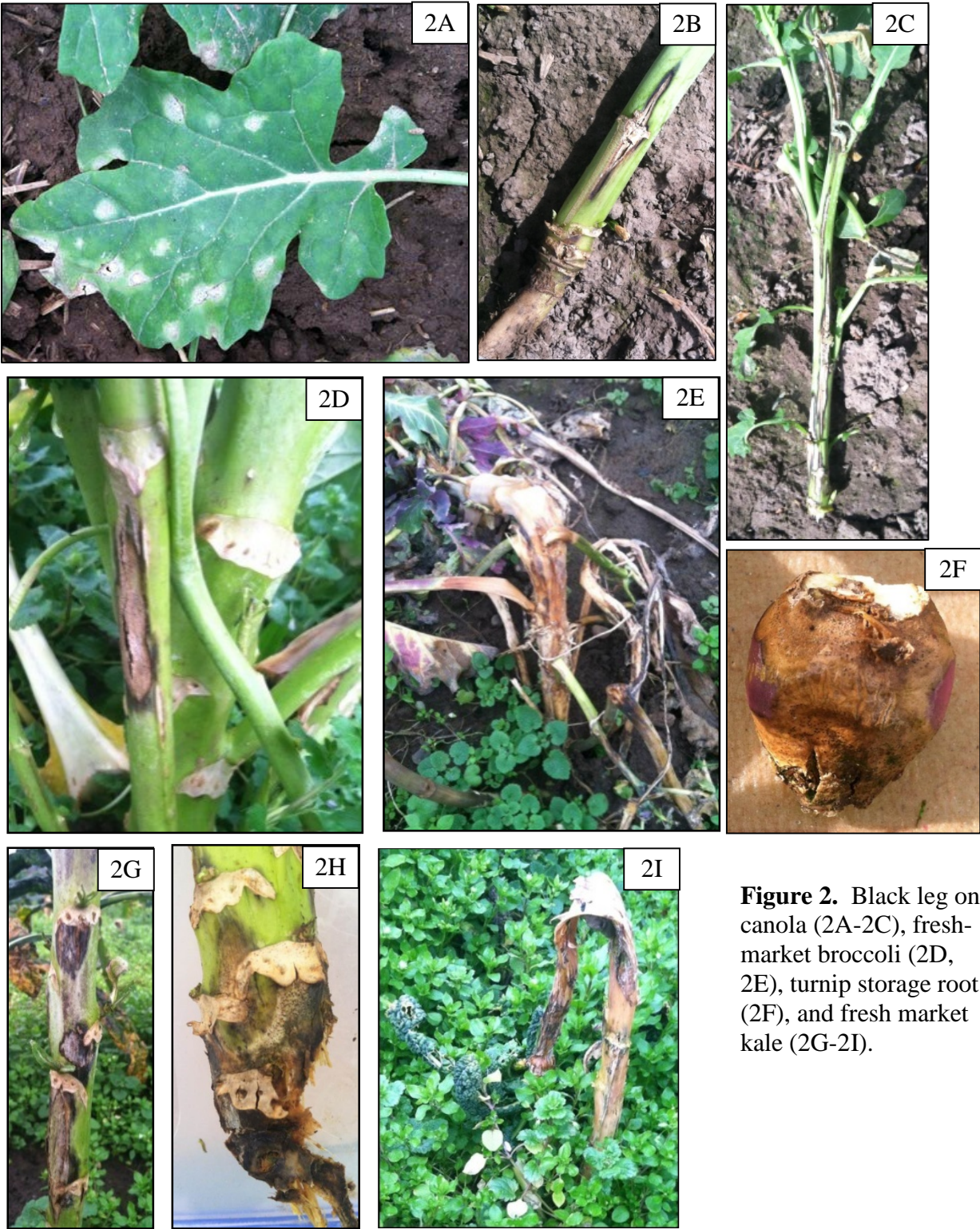


Figure 2. Black leg on canola (2A-2C), fresh-market broccoli (2D, 2E), turnip storage root (2F), and fresh market kale (2G-2I).

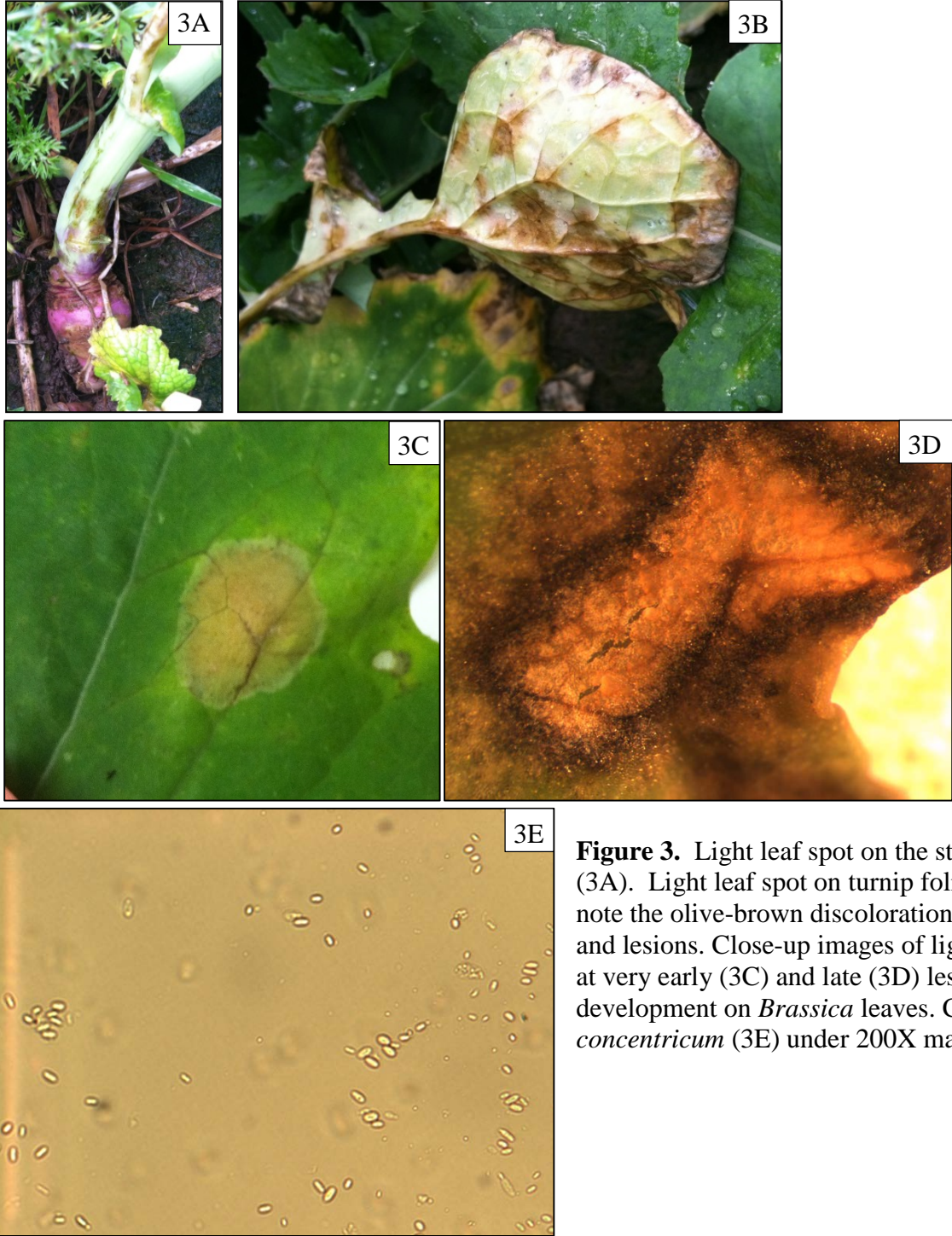


Figure 3. Light leaf spot on the stem of turnip (3A). Light leaf spot on turnip foliage (3B), note the olive-brown discoloration along veins and lesions. Close-up images of light leaf spot at very early (3C) and late (3D) lesion development on *Brassica* leaves. Conidia of *C. concentricum* (3E) under 200X magnification.

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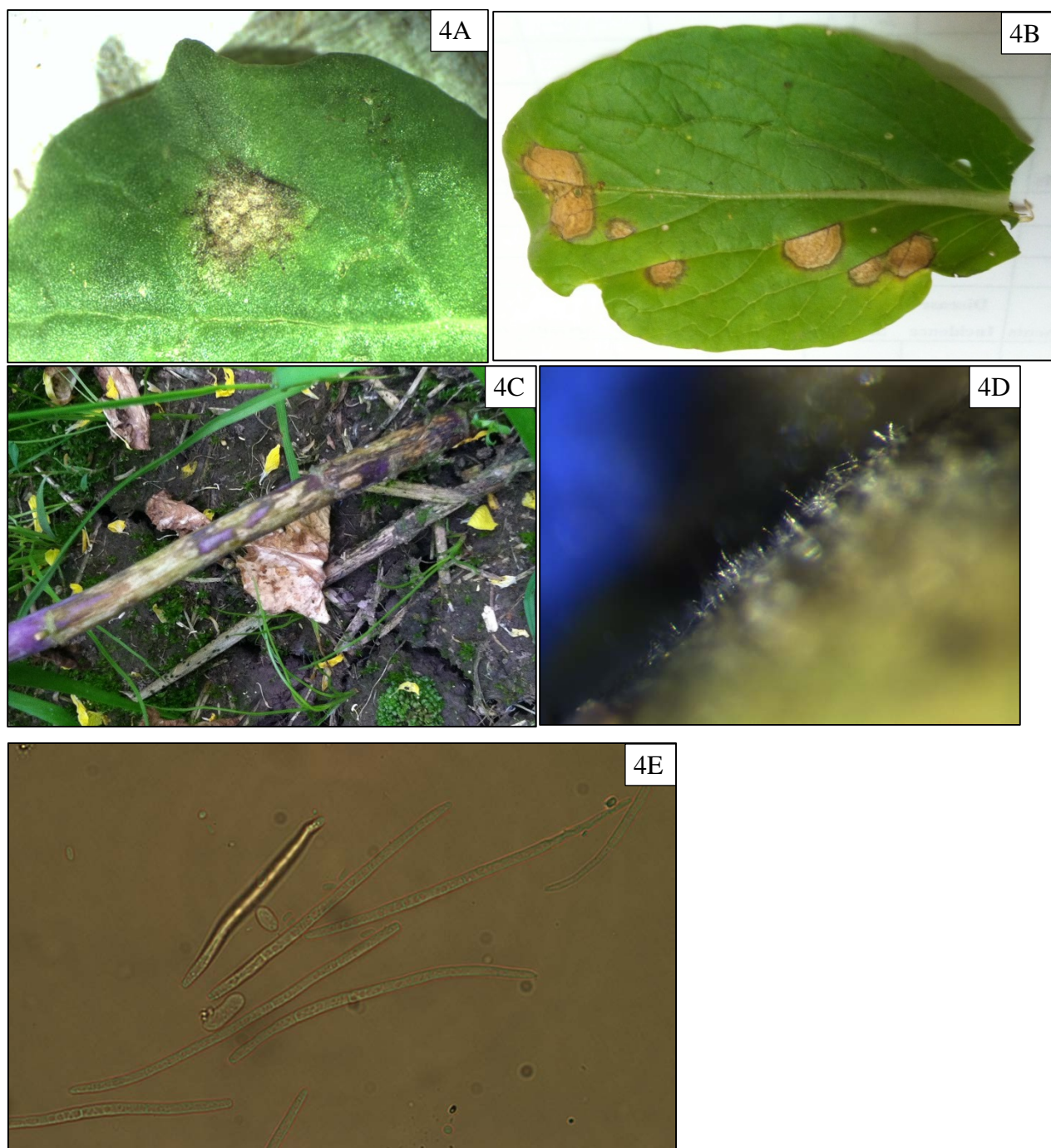


Figure 4. Early development of a white leaf spot lesion on a *Brassica* leaf (4A) and a mature white leaf spot lesion (4B). Gray stem on turnip stems (4C). Close-up image of a white leaf spot lesion on a canola leaf showing the characteristic white, icicle-like conidia (4D) produced by *P. capsellae*. Long, needle-shaped conidia (4E) of *P. capsellae* under 200X magnification.

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Management. In order to avoid widespread disease outbreaks, management of black leg, light leaf spot, and white leaf spot is critical for all crucifer crops including seed, vegetable (fresh market or processing), forage, and cover crops. Use of the following methods are critical to prevent introduction these pathogens and for reducing their spread once disease occurs on farm; these cultural control techniques are essential on organic farms to manage black leg and light leaf spot:

- Only plant seed that has been tested and certified to be free of *P. lingam*. Under current Oregon Department of Agriculture seed rules (OAR 603-052-0860), crucifer seed stock (canola, cabbage, broccoli, kale, radish, turnip, forage crucifers, etc.) intended for commercial planting in Oregon must be accompanied by an official test stating that untreated seed is free from black leg (*Phoma lingam*=*Leptosphaeria maculans*; *P. biglobosa*).
- Rotate out of crucifers for at least three years.
- Avoid planting in or adjacent to a site where disease has occurred within the last 3 to 4 years; planting within a quarter of a mile of a field containing black leg-infected crop residues brings a high risk for black leg.
- Control cruciferous weeds and volunteers as these are hosts for black leg and leaf spot diseases.
- Plant resistant cultivars, if available.
- For transplant seedbeds, avoid planting near crucifer crops and use at least a 5-year rotation.
- Do not dip transplants in water before transplanting.
- Inspect fields and seed beds for symptoms of black leg and leaf spot diseases.
- Rid diseased fields of infected crop residues as soon as possible after harvest by intensive flailing with subsequent burial, deep plowing, or physical removal of plant debris. High speed shallow tillage disks are especially valuable, doubly so in no-till systems. Pseudothecia of these pathogens will not develop on residues incorporated into the soil, only on residues remaining on the soil surface. Reducing infected crop residues is critical to minimize sexual recombination of these fungi, and the associated possibility for increased virulence or fungicide resistance.

Current Oregon Department of Agriculture crucifer black leg seed rules require that crucifer seed stock intended for commercial planting must be treated with approved fungicides or hot water to control seedborne *Phoma*. Fungicides registered in Oregon for crucifer seed treatments and shown to be effective on seedborne *Phoma* include Coronet, Mertect 340-F, and Rovral 4F. Mertect (SLN OR-100014) and Rovral (SLN OR-140013) can be used on crucifer seed (except canola) to be grown as a seed crop. Mertect has a supplemental label for head and stem *Brassica* crops as well as root crucifers including radish. Coronet has a section 3 registration for use on crucifers including canola (supplemental label), but is not currently registered for use on radish, rutabaga or turnip.

Crop group	Crucifer crops	Coronet	Mertect	Rovral
head & stem <i>Brassica</i> crops	broccoli; brussels sprouts; cabbage; cabbage, Chinese (napa); cauliflower; kohlrabi	Yes	Yes	No
leafy <i>Brassica</i> crops	broccoli raab; cabbage, Chinese (bok choy); collards; kale; mizuna; mustard greens; mustard spinach; rape greens	Yes	No	No
root vegetables	radish, rutabaga, turnip	No	Yes	No
crucifer crops grown for seed (no sprouts)	<i>Brassica</i> seed crops including canola, and radish	Yes for crops on label (no root crops)	Yes, except canola	Yes, except canola

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Hot water treatments are typically done on-farm. To hot water treat crucifer seed, first pre-warm seed for 10 minutes in 100°F water, and then transfer seed to a hot water bath (122°F) for 15 to 25 minutes. Recommended time period for hot water treatment are 15 minutes for radish and mustard, 20 minutes for broccoli, cauliflower, collard, kale, kohlrabi, rutabaga, and turnip, and 25 minutes for Brussels sprouts and cabbage. After treatment, place seed in cold water for 5 to 10 minutes to cool, spread the seed out, and dry the seed. This hot water treatment will aid in controlling other fungal and bacterial diseases.

Apply protective, foliar-fungicide sprays beginning in the fall, as rains return, and ideally start applications before leaf spots are first observed. In order to prevent the development of additional acreages of infected residues, fungicide applications will be needed at least monthly throughout winter into spring in conventional seed crops, including winter canola, across western Oregon as long as the weather remains conducive for disease and infected crop residues are present in the Willamette Valley. Protective foliar fungicides applications made every 2- to 3-weeks will aid in preventing disease introduction into fields and reducing disease spread after initial infections occur in a field. Be sure to rotate fungicide chemistries (FRAC groups) for fungicide resistance management, especially in the presence of high ascospores loads in the Willamette Valley. Spring-planted crops may warrant protective sprays if conditions are cool and wet because of continued potential ascospore release and dispersal. The following fungicides are labeled for use as foliar sprays on crucifer crops in Oregon, unless otherwise noted:

FRAC group	Foliar fungicide	Head & stem <i>Brassica</i>	Leafy <i>Brassica</i>	Crucifer root vegetables	Crucifers grown for seed (no sprouts)
2	Rovral 4F	No	No	No	Yes, except canola
3	Proline 480 SC	No	No	No	<i>Brassica</i> seed crops on label
3	Quash	No	No	No	Labeled for canola
3	Tebuconazole formulations (Monsoon, Onset, Orius, Tebustar, Tebu-Crop, Toledo, etc.)	No	On label	No	Yes for vegetable crops on label when grown for seed in Oregon
11	Cabrio EG	On label	On label	On label	Yes, except canola
3 + 9	Inspire Super	On label	On label	No	Yes for vegetable crops on label
3 + 11	Quadris Top	On label	On label	No	Yes for vegetable crops on label when grown for seed in Oregon
7 + 11	Elatus	No	No	No	Labeled for canola
7 + 11	Merivon Xemium	No	No	On label	Yes for vegetable crops on label when grown for seed in Oregon
7 + 11	Priaxor Xemium	On label	On label	No	Yes for vegetable crops on label when grown for seed in Oregon, and canola

- Cabrio EG (pyraclostrobin) is registered for other diseases of *Brassica* and radish and will help control black leg in Oregon; **use only as a tank mix partner** or in fungicide rotations. This fungicide is NOT currently registered for use on canola.

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- Inspire Super (difenoconazole + cyprodinil) is labeled for other diseases on leafy and head and stem brassicas and will aid in controlling black leg and light leaf spot. This fungicide is NOT registered currently on canola, radish/daikon, or *Brassica* root vegetables (rutabaga and turnip).
- Priaxor Xemium and Merivon Xemium (fluxapyroxad + pyraclostrobin) are labeled for black leg control in canola and *Brassica* leafy and head and stem vegetables (Priaxor) as well as for other diseases in root crop crucifers (Merivon).
- Proline 480 SC (prothioconazole) is labeled for use on *Brassica* seed crops including canola to control black leg or *Sclerotinia*, and can be used in Oregon to also control light leaf spot. Not labeled for radish at this time. Be sure to rotate fungicide FRAC groups.
- Quadris Top (azoxystrobin + difenoconazole) is labeled for other fungal diseases on *Brassica* leafy and head and stem vegetables. In Oregon, it should be effective on light leaf spot and will help control black leg.
- Quash (FRAC Group 3; metconazole) is labeled for *Sclerotinia* on canola and can be used in Oregon on canola to help control light leaf spot. Be sure to rotate fungicide FRAC groups.
- Rovral 4F (FRAC Group 2; iprodione) is labeled for use on *Brassica* and *Raphanus* seed crops only in Oregon (SLN OR-130001) for blackleg, light leaf spot, and white leaf spot. Not currently registered for use in canola/rapeseed.
- Tebuconazole formulations (Onset 3.6L, Tebustar formulations, Monsoon, Orius 3.6F, Tebu-Crop 3.6F, Toledo 3.6F, etc.) are labeled for other diseases of leafy *Brassica* crops and can be used in Oregon for management of light leaf spot and black leg. Be sure to rotate fungicide FRAC groups.

References:

- du Toit, L.J., and Derie, M. L. 2005. Evaluation of fungicide seed treatments for control of black leg of cauliflower, 2004. *Fungicide & Nematicide Tests* 60:ST011.
- du Toit, L.J., Derie, M. L, and Brissey, L.M. 2006. Evaluation of fungicide seed treatments for control of black leg of cabbage, 2005. *Fungicide & Nematicide Tests* 61:V041.
- Louisiana State University Ag Center. 2014. Hot water seed treatment. Youtube video at https://www.youtube.com/watch?v=Ie3H_icKWb4
- Miller, S.A. and Lewis Ivey, M.L. Hot water treatment of vegetable seeds to eradicate bacterial plant pathogens in organic production systems. Ohio State University Extension Factsheet HYG-3086-05. Available on-line at <http://onionline.osu.edu/hygfact/3000/pdf/3086.pdf>
- Oregon Dept. of Agriculture Crucifer Black Leg Ruling: <http://www.oregon.gov/ODA/programs/Pesticides/Pages/PesticidesCurrentIssues.aspx> (scroll to “Details about permanent blackleg rule in Oregon” for a PDF file of the ruling)
- PNW Plant Disease Management Handbook website - Seed Crops, Crucifers (*Brassica* and *Raphanus* spp.) – Black Leg: <http://pnwhandbooks.org/plantdisease/seed-crop-crucifers-brassica-and-raphanus-spp-black-leg>

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