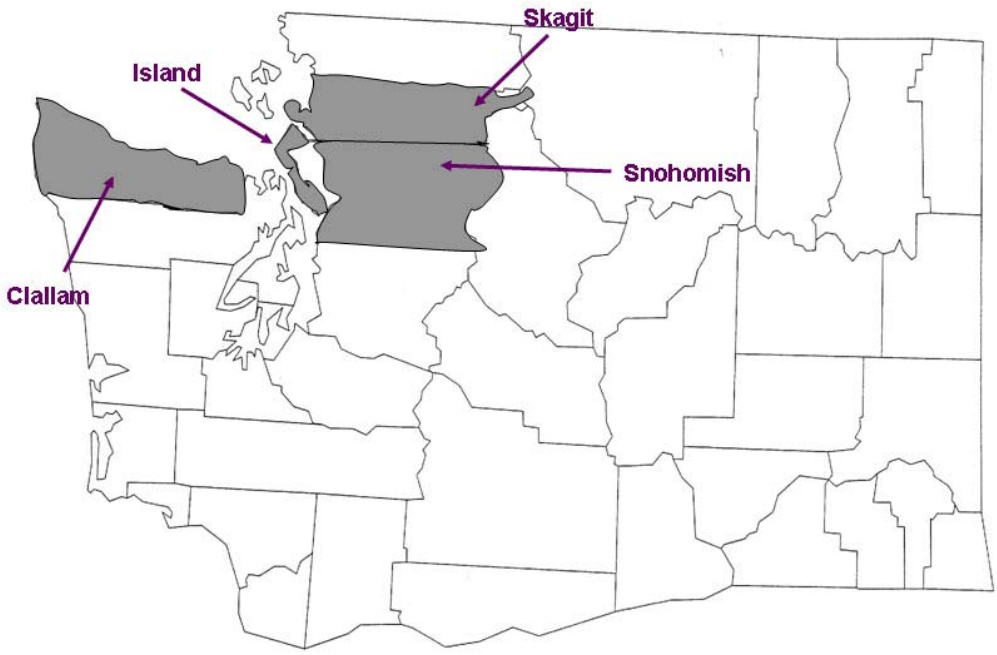
CROP PROFILE FOR CABBAGE SEED IN WASHINGTON

PRODUCTION FACTS

- Washington State supplies approximately 75% of the U.S. production and 25% of the world production of cabbage seed (1).
- 400–500 acres are grown annually in Washington State (350-400 acres of hybrid seed and 50-100 acres of open-pollinated seed) (1).
- Value of market seed sold to commercial growers is $22.4 million (1).
- Grower production costs are $3500/acre for hybrid seed and $1200/acre for open-pollinated cultivars (1).

PRODUCTION REGIONS

Major cabbage seed-producing areas are Skagit, Snohomish, Island, and Clallam counties in western Washington (1).



GENERAL INFORMATION

There is no open market (non-contracted) small-seeded vegetable seed production in Washington. Commercial vegetable seed is produced under

bailment contracts, where the seed companies (bailors) provide growers (bailees) with the stock seed necessary to produce a crop. The seed company retains ownership of the seed, growing crop, and the resulting harvested seed. Growers produce and harvest the crop, and are then paid the contract price for the resulting seed if it meets quality criteria stated in the bailment contracts, typically a 90-92% germination rate and 99.00-99.75% purity for cabbage seed. Weed seeds that are similar in same size/shape as the vegetable seed are difficult to remove at the conditioning plant, and can cause seed companies to reject a seed crop (2). Federal regulations for moving seed into interstate commerce require that seed must be completely free of all noxious weeds (2).

Small-seeded vegetable seed production takes place on approximately 4,500 acres in western Washington annually, contracted by approximately 7 seed companies. The average field size for cabbage seed crops is 5 acres for hybrid seed production and 15 acres for open-pollinated seed production. Rotation periods for cabbage are a minimum of 5 years to mitigate disease problems. Companies control the location of seed crop fields in order to prevent cross-pollination among cultivars of the same crops (within and among cabbage open-pollinated seed and hybrid seed) and of cross-compatible crops (e.g. related crucifer species). Isolation distances vary depending on whether the crops are grown for market or stock seed, and can range from one-quarter mile to 2 miles or more. Cabbage is bee-pollinated. Market seed is produced and used for vegetable production. Stock seed is grown specifically for use in planting seed crops (1,2).

Company representatives meet with county extension educators at the WSU Mount Vernon NWREC each spring in a "pinning" meeting to plot map locations of seed crops planned for that year. With increased urbanization of the Skagit Valley and surrounding areas, and the presence of hobby farmers, it is now more difficult to control pollen flow and ensure the pollen isolation necessary for high quality (“trueness-to-type” genetically) hybrid seed production.

In Washington State, small-seeded vegetable seed crops are considered nonfood and nonfeed sites for pesticide use (2).

Dried cabbage seed

CULTURAL PRACTICES

Cabbage, *Brassica oleracea*, is a biennial crop when grown for seed. Other biennial *Brassica* species include Brussels sprouts, cauliflower, collards, kohlrabi, and kale. Seed is sown in a plant bed or greenhouse. At the 6- to 8-leaf stage, seedlings are transplanted into production fields in early August through mid-September. The crop overwinters in the field, then bolts and flowers in the spring. Bees are used for pollination. Seed development and maturation occurs in June and July. In early August, the crop is cut (hybrid production crops are hand cut, while open-pollinated crops are usually machine-swathed), and then threshed mechanically after curing in the windrow for up to 14 days. Hybrid cabbage seed is sufficiently valuable to require hand-turning to facilitate drying of the seed during field-drying. After harvest, the seed is dried artificially in commercial driers, and cleaned at local conditioning facilities (1).

The cool maritime environment of western Washington is ideal for overwintering *Brassica oleracea* seed production. Winters are generally not cold enough to freeze the crop, yet are cold enough to vernalize the plants properly (initiate flowering or bolting after exposure to an extended cold

period). Summer weather is moderate, providing optimum conditions for plant and seed development.

Cabbage grows well in soils that are well drained, especially during the over-wintering period. Cabbage seed crops often fail on fields with high water tables or that become flooded for extended periods of time during fall/winter or early spring. During the growing season, it is critical that there is sufficient soil moisture during the seed fill period after bloom, or the seed may become shrunken and non-viable or non-marketable because of small size.

Other related *Brassica* crops grown for seed include arugula, broccoli-raab, Chinese cabbage, Chinese kale, Chinese mustard, kale, mustard, pak choi, radish, and turnip. Many of these crops are grown as annuals and are direct-seeded rather than transplanted. *Brassica oleracea* seed crops are very susceptible to certain insects and diseases, requiring extensive control for successful seed production (1). Weeds are primarily problematic during the early growth phase of the crop.

Gravity separator

Drier bins

Seed conditioning area with clean seed bins

Temporary seed storage area

INSECT PESTS

The most serious insect pest of cabbage seed is the cabbage maggot, followed by cabbage aphid, turnip aphid, cabbage seedpod weevil, loopers and cutworms.

Cabbage Maggot
(*Delia radicum*)

Cabbage maggots are the larval stage of a small gray fly that lays its oblong white eggs at the base of plants during the seedling stage. The white larvae dwell in the soil, and feed on roots and underground plant parts. Damage by root maggots weakens, lodges, and kills plants (3). Potential yield loss to growers is 100% if root maggots are not controlled (1).

Chemical controls

Diazinon (Diazinon 14G at 2-3 lbs AI/A). It is used on 100% (500 acres) of the area planted for cabbage seed, and is applied at transplanting (1). Transplant drenches may also be used (Diazinon 4E or 50W at 2-4 oz AI/A). Registrant has requested cancellation of the 14G formulation in 2007.

Chlorpyrifos (Lorsban 4E at 0.05-0.086 lbs AI/1000 linear ft. row, Lorsban 15G at 0.04-0.09 lbs AI/1000 linear ft. row). 30-day PHI. Chlorpyrifos is applied as a drench following transplanting, on 100% (500 acres) of the area planted for cabbage seed (1).

Cabbage Aphid
(*Brevicoryne brassicae*)
Turnip Aphid
(*Hydaphis pseudobrassicae*)

Both aphid species are mealy gray and feed in colonies on the foliage, on heads, or in buds resulting in plant decline (3). Potential yield loss to growers is 50% if aphids are not controlled (1).

Chemical controls

Dimethoate (Dimethoate 4EC at 0.224 pt AI/A or Cheminova Dimethoate 4E at 0.2175-0.435 pt AI/A). 7-day PHI. Dimethoate is applied on up to 25% (100 acres) of the area planted for cabbage seed production, after bloom (1). Registrant has requested cancellation of cabbage use.

Cabbage Seedpod Weevil
(*Ceutorhynchus obstrictus*)

This is a small, dark gray "snout beetle" which congregates on blooms. The larvae feed on seed in the pods resulting in seed loss. Potential yield loss to growers is 25% if weevils are not controlled (1).

Chemical controls

Endosulfan (Thionex 3EC at 1 lb AI/A). (24c, WA-030027). Endosulfan is used on 100% (500 acres) of cabbage seed at bloom (1). Timing of applications is when bees are not active (<50^{o}F). This is a critical use to the industry.

Cabbage Looper
(*Trichoplusia ni*)
Alfalfa Looper
(*Autographa californica*)
Cutworms
(various species including
red-backed cutworm, *Euxoa ochrogaster*)

Cabbage loopers are the pale green larvae of a gray-brown moth that feeds on foliage and other tender, aboveground plant parts, causing plant decline. Alfalfa loopers are similar in appearance and cause similar damage. Cutworms are the variously-colored and -patterned larvae of moths which typically feed on foliage, causing plant decline. They may also completely sever stems of young plants, resulting in plant loss. Potential yield loss to growers is 25% if loopers and cutworms are not controlled (1).

Chemical controls

Permethrin (Ambush at 0.05-0.2 lbs. AI/A). 1-day PHI. Permethrin is used at the time of transplanting on 10% (50 acres) of the area planted to cabbage seed (1). This product is a critical use to the industry.

***Bacillus thuringiensis* (various trade names, at various rates).** It is applied to about 2% (10 acres) of the cabbage seed crop, up to the time of bolting (1).

DISEASES

Sclerotinia soft rot or white mold is the most important disease, causing problems "year in and year out." There has only been one outbreak of black rot within Washington State, but there is zero tolerance for the pathogen in harvested seed lots. Infected seed crops or seed lots must be destroyed, leaving the grower with a total crop loss. Alternaria leaf and pod spot occurs regularly in western Washington, but the severity of infection and losses is dependent on susceptibility of the parent lines and conduciveness of environmental conditions, with low tolerance for the pathogen on harvested seed. Black leg has largely been controlled by fungicide seed treatments, but recent loss of all registrations of the standard fungicide seed treatment has resulted in concern over this disease becoming established again in the brassica seed production area. Club root is only occasionally a problem in cabbage seed crops (1,4,,15).

Sclerotinia Soft Rot = White Mold

(*Sclerotinia sclerotiorum*)

This fungal disease typically occurs on aboveground plant parts, causing a cottony white mold on affected tissues. Small black sclerotia form in the cottony mold, and serve as overwintering structures for the fungus. The sclerotia persist in the soil for many years. In early spring, sclerotia may germinate to produce the sexual stage of the fungus, which releases ascospores that are readily dispersed by air currents and turbulence. Ascospores are probably the most important source of inoculum in the spring. Stem infections in seed crops produce cankers that can girdle the stem and cause severe losses (4,7,11,15). Potential yield loss is up to 100% if white mold is not controlled (1).

Cultural Controls

Crop rotation with non-susceptible crops such as grass or grains is practiced. Where possible, rows are oriented to provide maximum air movement so that relative humidity and durations of leaf wetness are minimized (4).

Chemical Controls

Iprodione (Rovral 4 FL at 1-2 lb AI/A). (24c, WA-960027). Applied with a spreader sticker. When disease pressure is severe, applications are made at 2-week intervals at full bloom, pod set, and before harvest. Applications of Rovral also help control Alternaria leaf spot (4,6,11). Total cabbage seed crop area treated is 80% (400 acres).

Boscalid (Endura EG at 4.2-6.3 oz AI/A). 0-day PHI. Applied with a spreader sticker. Applications are made at early petal fall through pod set, at 7- to 14-day intervals, if conditions are conducive for the disease, for a maximum of 2 applications per season (4,6,11). Total cabbage seed crop area treated is 80% (400 acres).

Cyprodinil + fludioxonil (Switch 62.5WG at 0.328 lb cyprodinil/A + 0.218 lb fludioxonil/A) (24c. WA-020016). A maximum of 4 applications per season, with no more than 2 consecutive applications before switching to a fungicide with a different mode of action. 12-month plant back restriction to crops other than those on the SLN 24c label, strawberries, or onion. Total cabbage seed crop area treated is up to 20% (100 acres) because of the plant back restriction.

Black Rot

(*Xanthomonas campestris* pv. *campestris*)

Black rot is caused by a bacterium that persists in infected plant debris up to two years (8) and may survive in soil for months. It can also survive on seed, and this inoculum is usually the major source of the pathogen in disease outbreaks. Infections through the stomata on the cotyledons of young cabbage seedlings enter the xylem and become systemic. Infections of leaves of older plants can also develop into systemic infections. Black veins develop in yellow lesions along leaf margins, and water uptake may be impaired. All Brassica species and several cruciferous weeds are susceptible to *X. campestris* pv. *campestris*. The pathogen may be spread by water, insects, equipment, and animals (10). Water is required for spread of the disease. Warm temperatures (80 to 86°F) are optimal for disease development (10), which is part of the reason black rot has not become endemic in the mild maritime climate of northwestern Washington (4,7,15).

Cultural Controls

Sanitation and the use of pathogen-free stock seed are the primary cultural controls used to prevent disease establishment. In general, seed companies assay stock seed for the disease before planting. Any suspect seed lots are exposed to hot water treatment at 122°F for 30 minutes. This is the primary method used if the pathogen is detected in stock seed. Practices also include rotating out of crucifers (5 years in fields and 3 years in planting beds), and management of weed hosts and insect pests. A few resistant cultivars are available, but seed growers typically do not get a choice in their contracts of the particular parent lines they are asked to grow for seed (4,7,15).

Chemical Controls

There are no chemical controls for this pathogen, although copper bactericides combined with mancozeb may have some efficacy. This is a critical need of the industry. Infected crops or seed lots are destroyed to prevent spread of the disease.

Alternaria Leaf and Pod Spot = Black spot

(*Alternaria brassicae* and *A. brassicicola*)

Yellow-brown leaf spots that later turn necrotic are the major symptom of infections by these two fungi. Older leaves and pods are more susceptible. Lesions caused by *A. brassicae* tend to be more circular and develop a tan

center as they mature, compared to typical black spots caused by *A. brassicicola*. Under moist conditions, lesions may develop a sooty black mass of spores. Violet to tan or black spots may develop on seed pods. The fungi can spread via infected seed, wind, splashing rain, contaminated soil or equipment. The pathogens typically overwinter in crop debris and residues of cruciferous plants, including weed hosts, or by surviving in infected seed (10). Potential yield loss is estimated at 100% if the disease is not controlled (1). Infection of seed can directly affect seed quality (germination) (4,7,8,15).

Cultural Controls

Growers reduce inoculum levels by using long (5 year) crop rotations out of crucifers, incorporating crop debris into the soil, removing cull piles, managing cruciferous weeds, and using clean seed. Hot water treatment of seed (122°F for 25 to 30 minutes) can clean up seed lots (4,15).

Chemical Controls

Chlorothalonil (Bravo Weather Stik at 1.13 lb AI/A). 7-day PHI. Applications are made at bloom and during the growing season when conditions are favorable for disease, or at 7- to 10-day intervals, often in combination or rotation with fungicides with site-specific modes of action (e.g., pyraclostrobin, azoxystrobin) for preventing fungicide resistance from developing in the pathogen population. Chlorothalonil also has efficacy against downy mildew (4,15). Applications are made to 100% (500 acres) of the total cabbage seed crop (1).

Mancozeb (Manzate 75DF at 1.5 lb AI/A under 24c registration WA-010018A and WA-010018B**, or Dithane DF Rainshield at 1.5 lb AI/A** under 24c registration WA-020028**).** Applied in rotation with fungicides with site-specific modes of action (e.g., pyraclostrobin, azoxystrobin) for preventing fungicide resistance from developing in the pathogen population. Total cabbage seed crop area treated is 100% (500 acres).

Iprodione (Rovral 4 FL at 1-2 lbs AI/A). (24c, WA-960027)). Iprodione is applied with a spreader sticker. When disease pressure is severe, applications are made at full bloom, pod set, and before harvest. Applications of Rovral also help to control white mold (8,11). Total cabbage seed crop area treated is 80% (400 acres) (1). Applications are usually alternated or in combination with a broad spectrum fungicide such as mancozeb (Dithane DF Rainshield or Manzate 75DF). Total cabbage seed crop area treated is 100% (500 acres).

Pyraclostrobin (Cabrio EG at 0.15-0.2 lb AI/A). 0-day PHI. Maximum of 4 applications per season and maximum of 2 sequential applications,

preferably in rotation of combination with a broad-spectrum fungicide like mancozeb or chlorothalonil (6,8). Maximum 64 oz product/acre/season. Total cabbage seed crop area treated is 100% (500 acres).

Azoxystrobin (Amistar or Quadris Flowable at 0.10-0.25 lb AI//A). 0-day PHI. Applications are made during petal fall and pod set at 7-14 day intervals depending on weather conditions, in combination or alternation with a broad-spectrum fungicide like mancozeb or chlorothalonil (6,8). Maximum of 3 applications per acre per season. Total cabbage seed crop area treated is up to 100% (500 acres).

Cyprodinil + fludioxonil (Switch 62.5WG at 0.328 lb cyprodinil/A + 0.218 lb fludioxonil/A) (24c. WA-020016). A maximum of 4 applications per season, with no more than 2 consecutive applications before switching to a fungicide with a different mode of action. 12-month plant back restriction to crops other than those listed on the SLN 24c label, strawberries, or onion. Total cabbage seed crop area treated is up to 20% (100 acres) because of plant back restrictions.

Bacterial Soft Rot

(*Erwinia carotovora* subsp. *carotovora*)

Infection by the soft rot bacterium occurs through wounds caused by insects, other diseases, mechanical damage or through natural plant openings during suitable weather. The disease is also associated with winter injury. Infected areas of the plant appear water-soaked and spread quickly, with rapid collapse of affected plant parts. A foul odor may develop as a result of secondary infection of the decaying tissues by other organisms. Seed stalks are not produced if plants are infected. Disease development is favored by extended periods of moisture from rain or irrigation, and moderate temperatures, all prevalent conditions in western Washington. The pathogen is spread by insects, splashing rain, contaminated tools and clothing, or infected plant material. Soft rot bacteria can survive on plant debris and for several months in the soil (4). Potential yield loss is as much as 50% if this disease is not controlled.

Cultural Controls

Growers orient plant spacing to provide good airflow, and avoid plant injury (e.g., from cultivation) to reduce infection sites during the over wintering stage of cabbage seed production (4).

Chemical Controls

Copper hydroxide (Kocide DF). Applications are made at a rate of 1 to 2 lb product/A beginning when heads are 1.5 inches in diameter. Generally, more than one application is used on a 7- to 10-day interval. Copper may cause a flecking on the outer wrapper leaves. Approximately 20% of the total cabbage seed crop acreage (100 acres) is treated with one of the copper fungicides to control bacterial soft rot (1).

Copper hydroxide (C-O-C-S WDG). Usually more than one application (7- to 10-day intervals) is made at a rate of 3 to 4 lbs. product/A when conditions are favorable for disease. Copper may cause a flecking on the outer wrapper leaves. Approximately 20% of the total cabbage seed crop acreage (100 acres) is treated with one of the copper fungicides to control bacterial soft rot (1).

Damping-Off
(*Pythium* spp., *Fusarium* spp., and *Rhizoctonia solani*)

Pythium spp., *Fusarium* spp. and *Rhizoctonia solani* are soilborne fungi. They can survive in soil indefinitely and attack vulnerable seedlings of many plant species including *Brassica* species. If infection occurs prior to seedling emergence, the germinating seedling is killed. Low seedling numbers can be easily confused with poor seed germination due to a lack of vigor. Young plants can also be attacked during emergence, resulting in plant loss due to damping-off. Damping-off is favored by cool weather, high humidity, and saturated or compacted soils (4,7). Under favorable conditions, seedling death may reach 100% if untreated seed is planted in soils where these fungi are established (1).

Cultural Controls

Soil pasteurization or use of sterilized potting media in greenhouses or seedbeds for production of transplants, as well as excellent sanitation (including removal or decomposition of plant debris) and crop rotation with cereals is practiced to reduce the inoculum level. Crop rotation with cereals may reduce inoculum levels in the soil. Damping-off pathogens are more of a concern when cabbage is direct-seeded, but cabbage seed crops in western Washington are not usually direct-seeded (4,7).

Chemical Controls

Thiram (Thiram 50WP). Seed is treated at a rate of 4 oz AI/100 lb seed. All of the cabbage seed planted for commercial seed production is treated (1). The

seed is planted in greenhouses for transplant production. Seed treatment may reduce germination and/or seed and seedling vigor if treated seed is damaged or weakened.

Fludioxonil (Maxim 4FS). Applied at 0.003-0.005 fl oz/100 lb seed for control of *Fusarium* and *Rhizoctonia* spp. Seed treatment may reduce germination and/or seed and seedling vigor if treated seed is damaged or weakened.

Downy Mildew
(*Peronospora parasitica*)

This fungus can affect nearly all cultivated and weedy plants (including wild mustards) in the Brassicaceae (Cruciferae). Infection can occur at any stage of growth. Seedling plants may become systemically infected following cotyledon infection, so control of this disease in greenhouse transplant production is very important. Infection of leaves causes chlorotic areas on the upper leaf surface, which later turn papery. Infection of lower leaves can result in systemic stem infection. *P. parasitica* overwinters in roots or infected plant debris and may be spread on seeds as a surface contaminant. The disease is favored by high humidity, fog, drizzling rains, and heavy dew, with optimum temperatures for infection at 46-61°F for at least four successive nights and 75°F or lower during the day (4,7). Potential yield loss to growers is 30% if downy mildew is not controlled (1).

Cultural Controls

Growers follow eradication programs for susceptible cruciferous weeds, such as wild mustards, to reduce inoculum. Irrigation schedules can be adjusted to reduce periods of high humidity that favor the pathogen, but most cabbage seed crops in western Washington are not irrigated. Resistant commercial cultivars are under development, but are not yet available, and seed growers usually do not have a choice on the parent lines they are contracted for seed production (4,7,15).

Chemical Controls

Mefenoxam/chlorothalonil (Ridomil Gold Bravo at 1.08 lb AI/A). 7-day PHI. Applications begin prior to infection when conditions are favorable for disease. Additional applications are made at 14-day intervals up to a total of 4 applications per season. Chlorothalonil also provides some protection against *Alternaria* infection. Resistance to Ridomil has been confirmed within

the Pacific Northwest. Fifty percent (250 acres) of the cabbage seed crop is treated (1).

Cymoxanil (Curzate 60 DF at 0.12 lbs. AI/A). (24c, WA-990021). Must be used in combination with products containing mancozeb or chlorothalonil for resistance management. Initial application of 1.92 oz AI/A begins when conditions indicate downy mildew infection is imminent. Additional applications can be made at 5 to 7-day intervals (6). Cymoxanil is applied to 90-100% of the cabbage seed crop acreage (450-500 acres) in western Washington (1).

Chlorothalonil (Bravo Weather Stik at 1.13 lbs AI/A or Echo 720 at 1.125 lb AI/A). 7-day PHI. Applications are made at bloom and during the growing season during periods favorable for disease, at 7- to 10-day intervals. Applications are made to 100% (500 acres) of the cabbage seed crop (1). Applications also provide some control of Alternaria leaf and pod spot (10).

Mancozeb (Manzate 75DF at 1.5 lb AI/A under 24c registration WA-010018A and WA-010018B**, or Dithane DF Rainshield at 1.5 lb AI/A** under 24c registration WA-020028**).** Applied at 7-10 day intervals at first signs of disease. Total cabbage seed crop area treated is 100% (500 acres).

Azoxystrobin (Amistar or Quadris Flowable at 0.10-0.25 lb AI//A). 0-day PHI. Applications are made during petal fall and pod set at 7-14 day intervals depending on weather conditions, in combination or alternation with a broad-spectrum fungicide. Maximum of 3 applications per acre per season. Total cabbage seed crop area treated is up to 100% (500 acres).

Ring Spot
(*Mycosphaerella brassicicola*)

Ring spot is typically observed on the older leaves of cabbage seed crops in mid- to late-winter, in the form of circular lesions with dark concentric rings from black fruiting bodies of the fungus. Lesions have definite margins, often with a yellow zone around the lesion. Spots may coalesce and cause leaves to abscise prematurely. Spores are spread by wind and splashing rain, and development of ring spot is favored by cool (50-70^{o}F) and moist conditions (4,7).

Cultural Controls

Growers typically control ring spot by crop rotations and removing infected crop residues or incorporating infested debris after harvest of the crop. Ring

spot seldom causes severe damage in cabbage seed crops as the disease is usually limited to the older and lower leaves. However, the fungus can be seed borne (4,7).

Chemical Controls

Some of the fungicides used to control Alternaria leaf and pod spot, or white mold, have proven efficacious against ring spot, including chlorothalonil and pyraclostrobin.

Chlorothalonil (Bravo Weather Stik at 1.13 lb AI/A). 7-day PHI. Applications can be made during the winter and spring when conditions are favorable for ring spot. Applications are made on up to 50% (250 acres) of the total cabbage seed crop for this purpose (1).

Pyraclostrobin (Cabrio EG at 0.15-0.2 lb AI/A). 0-day PHI. Maximum of 4 applications per season and maximum of 2 sequential applications, preferably in rotation of combination with a broad-spectrum fungicide like mancozeb or chlorothalonil (6,8,11). Maximum 64 oz product/acre/season. Total cabbage seed crop area treated is 70% (350 acres).

Black Leg

(*Phoma lingam* = asexual stage,
Leptosphaeria maculans = sexual stage)

This fungal pathogen is carried on crucifer seed, and over winters on plant debris and on alternative hosts (including cruciferous weeds). Although the disease generally does not reduce seed crop yields, low levels of seed borne infection combined with favorable weather conditions for disease spread in seedbeds can result in severe losses after transplanting seedlings. The fungus is spread by splashing water, workers, and on equipment. Symptoms appear as pale, irregular spots on leaves. The spots become a gray color and form scattered black dots (fruiting bodies called pycnidia). Lesion can form on the hypocotyl of seedlings at the soil line, resulting in damping-off type symptoms on seedlings. Severely infected plants are stunted and wilted. In seed crops, stem cankers may form and spots may appear on over wintered leaves. However, these leaf symptoms can readily be confused with those caused by ring spot. Symptoms are not typically observed on cabbage seed pods (4,7,15).

Cultural Controls

Growers typically control ring spot by crop rotations and removing infected crop residues or incorporating infested debris after harvest of the crop. Ring spot seldom causes severe damage in cabbage seed crops as the disease is usually limited to the older and lower leaves. However, the fungus can be seed borne (4,7).

Chemical Controls

Black leg was controlled effectively for many years by using benomyl seed treatment. However, recent loss of all registrations of this fungicide has created an urgent need for research to identify effective alternative fungicide seed treatment(s) for control of black leg, with promising results published recently for several fungicides (6,9,10).

Thiabendazole (Mertect 340F). Based on recent seed treatment research (9,10), a Section 18 emergency registration, 06-WA-03 was approved in November 2006 for a single application of thiabendazole at 0.032-0.064 lb AI/100 lb seed to control seed borne *P. lingam*. The Section 18 expires on November 17, 2007.

Iprodione (Rovral 4F). SLN 24c seed treatment registration WA-070001 for treatment of crucifer seed with Rovral 4F at 0.25 lb AI/3 lb seed for a soak treatment for 24 hours at 86°F, or 0.5 lb AI/100 lb seed as a slurry treatment (9,10). This registration is only for crucifer seed to be planted for seed production in Washington, for control of seed borne *P. lingam*. The registration expires on December 31, 2011.

Thiram (Thiram 50WP). Seed is treated at a rate of 4 oz AI/100 lb seed. All of the cabbage seed planted for commercial seed production is treated (1). The seed is planted in greenhouses for transplant production. Seed treatment may reduce germination and/or seed and seedling vigor if treated seed is damaged or weakened. Thiram is moderately effective as a seed treatment for black leg compared with thiabendazole and iprodione.

Fludioxonil (Maxim 4FS). Applied at 0.003-0.005 fl oz AI/100 lb, this seed treatment is less effective against seed borne *P. lingam* than iprodione and thiabendazole (9,10). Seed treatment may reduce germination and/or seed and seedling vigor if treated seed is damaged or weakened.

Club Root
(*Plasmodiophora brassicae*)

This pathogen survives in soils for 18 years or longer after a crucifer crop has become infected. The pathogen is moved by any method that infested soil can be moved, including wind, water, footwear, equipment, and in infected transplants. Cool and wet soils (70-80% water-holding capacity) that are acidic favor development of club root. The main symptoms are abnormal development of the roots, which develop swellings (clubs) that can be as much as 5 to 6 inches wide. Distorted roots have less ability to absorb minerals and water from soil, so infected plants typically wilt in hot weather and may recover at night. Growth may be stunted, leaves yellowed, and plants may bolt prematurely (4,7).

Cultural Controls

Club root is seldom a problem in cabbage seed crops in Washington. Cabbage seed growers control club root by using clean transplants, applying lime to fields into which seedlings are transplanted to raise the soil pH to 7 or higher, using long crop rotations (5 years or longer), controlling wild crucifer weeds or volunteers, and hilling the soil around the base of plants to promote development of adventitious roots for improved yields (4,7).

Botrytis Stem Blight/Gray Mold
(*Botrytis cinerea*)

Botrytis stem blight is occasionally a problem in cabbage seed crops in western Washington. Only certain varieties of cabbage are affected by this pathogen. Non-infected cabbage bolts in early spring (March). In infected seed crops observed in 1999, infected seed stalks broke off or the cabbage head rotted and no seed stalk was formed (4). An estimated 5% of fields were affected in 1999.

WEEDS

Weed competition can significantly reduce the yield and performance of *Brassica* crops planted for seed production. Crop yield loss can be as much as 100% if broadleaf weeds are not controlled, and 50% if annual and seedling perennial grasses are uncontrolled (1). In general, weed control is most important early in the season while the cabbage is small and unable to compete. In later spring (April), the seed crop is able to compete against

seedling annual weeds, ultimately choking them out as the seed crop becomes tall and dense.

More important concerns are that many weed species serve as hosts for diseases and insects that affect the seed crop (10), and that weed seeds can be contaminants of harvested cabbage seed, affecting marketability. Wild mustard, catchweed bedstraw and redstem filaree are particularly problematic as their seeds are the same size as cabbage seed (12). Typical weeds include barnyard grass (*Echinochloa crus-galli*), chickweed (*Stellaria media*), lambsquarters (*Chenopodium* spp.), pigweed (*Amaranthus* spp.), henbit (*Lamium amplexicaule*), common groundsel (*Senecio vulgaris*), mustard (*Brassica* spp.), nightshade (*Solanum* spp.), pale smartweed (*Polygonum lapathifolium*), annual grasses (including annual ryegrass [Italian ryegrass], *Lolium multiflorum* and annual bluegrass, *Poa annua*), seedling perennial grasses (such as perennial ryegrass, *Lolium perenne* and quackgrass, *Elytrigia repens*), Canada thistle (*Cirsium arvense*), wild buckwheat (*Polygonum convolvulus*), vetch (*Vicia* spp.), pineapple-weed (*Matricaria matricariodes*), volunteer grains (such as wheat, *Triticum aestivum* and barley, *Hordeum vulgare*), and catchweed bedstraw (*Galium aparine*) (1,13,14,16).

Cultural Controls

Growers practice crop rotation, primarily to control diseases, which also helps in weed control. Handweeding is the major cultural control employed to prevent weed contamination.

Chemical controls

Simazine (Simazine at 0.8 lb AI/A). (24c, WA-900005 for Simazine 4L). Simazine is applied late fall and early spring to 50% (250 acres) of the area planted to cabbage seed to control barnyard grass, mustard, chickweed, lambsquarters, and pigweed (1). This is the most critical use for the industry.

Trifluralin (Treflan at 0.5-1 lbs AI/A). Trifluralin is applied as pre-plant to 100% (500 acres) of area planted to cabbage seed to control annual bluegrass, barnyard grass, chickweed, lambsquarters, pigweed, and henbit (1). It does not control established weeds. Because it does not control members of the mustard, nightshade or sunflower families, this herbicide cannot stand alone in weed control programs. However, this is still a critical use to the industry.

Oxyfluorfen (Goal at 0.25-0.5 lbs. AI/A). Oxyfluorfen is applied pre-plant to 90% (450 acres) of the area planted to cabbage seed to control

lambsquarters, groundsel, henbit, pigweed, mustard, and barnyard grass (1). This can only be used on transplanted cabbage (12). Because this active ingredient primarily controls broadleaf weeds, it cannot stand alone in a weed control program. However, this is still a critical use to the industry.

Fluazifop-P-butyl (Fusilade DX, 0.19-0.25 lbs AI/A). (24c, WA-040006). It is applied at pre-bloom stage to 35% (175 acres) of the cabbage seed crop to control annual grasses and seedling perennial grasses.

Clopyralid (Stinger at 0.094-0.124 lbs AI/A). (24c, WA-970033). It is applied at pre-bloom stage to 20% (100 acres) of the cabbage seed crop to control wild buckwheat, thistle, pineapple-weed, and vetch (1).

Sethoxydim (Poast at 0.19-0.28 lbs AI/A). It is applied at pre-bloom stage to 10% (50 acres) of the cabbage seed crop to control annual grasses and seedling perennial grasses.

Other control methods

In addition to chemical controls, hand hoeing at the pre-bloom stage of the crop is performed to control any escapes from the chemical controls. Seventy percent (350 acres) of cabbage seed crops are hand-hoed to control weeds such as volunteer grain, catchweed bedstraw, mustards, vetch, thistle, chickweed, henbit, groundsel, and annual ryegrass (1). Labor costs comprise the majority of cabbage seed production costs (16).

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