Alternaria leaf spot of cole crops - *Alternaria japonica*

*Alternaria japonica* is a seed-borne pathogen of plants in the Brassicaceae. No sexual state is known for the fungus, and identification based on conidial and cultural morphology is difficult. The production of chlamydospores, structures which should allow it to survive in soil or plant debris, does distinguish it from similar species. It is known to occur in certain regions on all continents, but is generally a minor pathogen compared to other species on the same hosts. Its major impact consists of reduced germination of contaminated seeds and disease and death of seedlings. It is not listed as being of concern by phytosanitary agencies, but imported seed lots can be and are rejected due to its presence, because once introduced, it can persist and then spread by means of airborne conidia.

**Alternaria japonica** Yoshii 1941

In culture on potato–carrot agar, colonies pale to olive-grey, occasionally becoming darker, mycelium forming a loose, cobweb-like network. Hyphae septate, branched, colorless to pale olive, 2-5(-7) µm diam. Chlamydospores numerous, intercalary, irregular in shape, one-celled at first, becoming multicellular, cells swollen, thick-walled, heavily pigmented, usually in a series in the hypha rather than in a dense cluster, walls becoming ornamented. Conidiophores olive-brown, arising from surface or aerial hyphae, unbranched or sometimes branched, variable in length but usually 4-7 µm diam., slightly enlarged at apical conidiogenous cell. Conidia solitary or in short chains of 2-4, 55-70 µm long, beakless.

On host plants, conidia broadly ellipsoid to ovoid or obclavate, with a bluntly rounded apical cell that may develop through an abrupt transition into a broad, short, 1-2-celled secondary conidiophore; initially smooth-walled, becoming slightly roughened (punctate) at maturity, 80-100 x 20-30 µm. Transverse septa 7-10, longitudinal septa 0-3 per segment. Conidia in culture short- to long-ovoid, beakless, strongly constricted at transverse septa, smooth-walled, mid-brown, only darkening slightly when mature, size and septation variable: some with 2-3 transverse septa and 1-2 longitudinal septa in one or more transverse segments, 35-45 x 20-24 µm, others with 5-7 transverse septa and 1-2 longitudinal septa in the segments, spore body 55-70 x 18-22 µm.

**Distribution:** Reported on all continents, found often in Europe, the Middle East and North America (CABI/EPPO, 2002). Because it is seed-borne, the pathogen may occur wherever the hosts are grown from imported seed. Neergaard (1945) found it in seed produced in several European countries, Japanese seed tested in Finland was found to be infected (Valkonen and Kopenen, 1990), and Agarwal et al. (2002) detected the fungus in one of four shipments of seed from Australia.

**Host range:** Most commonly occurring on radish (*Raphanus sativus*), cabbage and cauliflower (*Brassica oleracea*), Chinese cabbage (*B. chinensis*), *B. rapa* Chinensis Group and *Matthiola incana*. Within *Brassica* there are reports of *A. japonica* on *B. oleracea* (Botrytis and Capitata Groups), *B. napus* (NapoBrassica Group), *B. nigra*, and *B. rapa* (Chinensis, Pekinensis and Raphifera Groups, as well as subsp. *campestris*).

In general, the species seems to be confined to Brassicaceae (Cruciferae) with occasional reports of it on parts of other hosts such as flax seeds (*Linum usitatissimum* L.) (Petrie, 1974), pecan (Huang and Hanlin, 1975), rice (Tai, 1979), tomato (Khulbe and Sati, 1987) and cowpea (Mendes et al., 1998). Whether these are cases of infection from nearby brassicaceous crops or of misidentification is uncertain. There are a few records of *A. japonica* from Araliaceae although these may well be misidentifications of *Alternaria* pathogens specific to that host family, such as *A. panax*.

For additional details, see Tohyama and Tsuda, 1990; Corlett and Corlett, 1999; Simmons, 1995, 2007; Yu, 2001.

**Similarities to other species/conditions**

*Alternaria japonica* was treated by Simmons (1995) as a member of the *Alternaria cheiranthi* group, characterized by generally beakless conidia, and the usually dense pigmentation of the conidial septa. Secondary conidiophores, also known as “false beaks”, are, however, often produced by the conidia. Within this group, *A. japonica* is distinct in producing chains of hyphal chlamydospores. Two possible confusions may have arisen in the past: first, since *A. japonica* and *A. cheiranthi* both occur on hosts in the Brassicaceae, these two species may be mistaken for each other. The hyphal chlamydospores should allow them to be distinguished easily, but, in addition, the conidia of *A. cheiranthi* are typically in longer chains (up to six) which may be branched through production of lateral secondary conidiophores and, further, their septation is more complex. There are reports of *A. japonica* on *Cheiranthus cheiri* (Conners, 1967); Neergaard (1945) was able to obtain infection of the seedlings with some of his isolates. A second confusion, reflected in the reports of *A. japonica* on araliaceous hosts, is
with is with a species that may have different morphology in culture from that on host plants. *Alternaria panax* can be distinguished, apart from its lack of hyphal chlamydospores, in that the conidia generally have a greater range of length, up to 175 µm, particularly in nature (Simmons, 2007). A key to the *A. cheiranthi* group was published by Simmons (1995).

Currently, Simmons (2007) separates *A. cheiranthi* from the other species in what he now calls the *A. radicina* species-group. Again, within the group, only *A. japonica* produces chlamydospores. All the other species are found on plants in the Apiaceae (=Umbelliferae).

Two other species of *Alternaria* also cause black-spotting of crucifers: *A. brassicae* and *A. brassicicola*. Neither produces hyphal chlamydospores. The conidia of *A. brassicae* are much longer, and usually have long true beaks, being produced singly on the conidiophores in nature (Simmons, 2007). Conidia of *A. brassicicola* are similar in length to those of *A. japonica*, but have fewer longitudinal septa, are not constricted at the transverse septa, and are produced in longer chains (Tewari and Buchwaldt, 2007). Both species are more common and more damaging pathogens of crucifers than is *A. japonica*. *A. brassicicola* is more prevalent in warmer climates (Atkinson, 1950; Tewari and Buchwaldt, 2007).

*Alternaria japonica* had been known since the 1890s as *A. brassicae* var. *macrospora* Sacc. (Joly, 1964; Simmons, 1995) the name that Yoshii (1933) used when he first discussed leaf spot of radish (*Raphanus sativus* L.). It was not until the 1940s, however, that the fungus was recognized at species level and then three separate workers did so in quick succession. The earliest species name, *A. japonica* Yoshii, was long ignored except by Joly (1964) in favour of *A. raphani*, published three years after Yoshii’s name. Neergaard (1945) published the name *A. Matthiola* for the fungus occurring both on *Matthiola* and *Raphanus*. It was quickly realised to be a synonym of *A. raphani*, the name by which this fungus is often referred to in the literature. Groves and Skolko (1944) noted that their fungus was the same as Yoshii’s *A. brassicae* var. *macrospora* but were not, apparently, aware of his later publication of another name at species rank. Simmons (1995) demonstrated that *A. japonica* is the correct name for the fungus and resolved the problem of its typification that had been confused in the determination by Tohyama and Tsuda (1990) that the two species reported on *Raphanus*, *A. japonica* and *A. raphani*, could not be distinguished by morphology and pathogenicity.

Within the genus, *A. japonica* has been placed in what is called either the *A. cheiranthi* species-group (Simmons, 1995) or the *A. radicina* species-group (Simmons, 2007) based on morphological criteria. On the other hand, some recent molecular phylogeny studies (Jasalavich et al., 1995; Pryor and Gilbertson, 2000; Berbee et al., 2003; Pryor and Bigelow, 2003; Xue and Zhang, 2007) associate *A. japonica* with *A. brassicicola*, another leafspot pathogen of crucifers in a separate morphological species-group (Simmons, 2007). An earlier analysis involving an *A. raphani* strain did not place it near *A. brassicicola* (Cooke et al., 1998).

Studies examining polymorphisms in the genomes among related fungi do not separate *A. japonica* from other small-spored species in the genus (Sharma and Tewari, 1998; Wang and Zhang, 2003) and, in one, different results were obtained for each of two isolates, only one of them grouping with *A. brassicicola* (Sharma and Tewari, 1998). Hong et al. (2005a) concluded that the position of the species with respect to the *A. brassicicola* species group was not resolved, because analyses of sequences for two different genes did not agree. Nevertheless, their results did not place *A. japonica* close to either *A. cheiranthi* or *A. radicina*. A further study using restriction site mapping of the IGS region of DNA likewise did not yield a firm position for *A. japonica*, although it did put significant distance between that species and both *A. brassicicola* and *A. radicina* (Hong et al., 2005b).

**Quarantine Restrictions**

There are no known quarantine restrictions on *A. japonica*. The distribution of locations where it has been reported (CABI/EPO, 2002), however, indicate that it is capable of infecting plants in many additional temperate and tropical areas. Its common transmission in and on seeds (see Seedborne Aspects) provides a direct route of introduction to populations of susceptible hosts.

**Biology and Ecology**

**Detection and Inspection Methods**

The disease symptoms (see Symptoms) are conspicuous enough to be detected in the field. It appears that the lower leaves are the first parts of the plant to be affected (if infection is from airborne spores) and then spread to the upper leaves, stems and flowers occurs.

Severity of infection in the field can be assessed by a range of methods but the most frequently used is a visual assessment by means of descriptive keys or by standard area diagrams. Verma and Saharan (1994) suggest a number of other possible methods including inoculum-disease intensity relationships and video image analysis. Keys for the assessment of *Alternaria* disease severity on crucifers have been produced by Mayee and Datar (1986) and Saharan (1991); and schematic drawings of infected crucifer
leaves and fruits by Conn et al. (1990).

**Diagnosis**

If the fungus cannot be detected directly on field material, it should produce conidiophores and conidia following incubation of infected plant parts in a damp chamber for up to 24 hours. The fungus can also be isolated into culture from the infected parts. Optimum growth is obtained at 24-28°C and pH 7.1-8.0, with the best standard medium being PDA, although better results were achieved with brassicaceous leaf decoction agar. Sporulation is best achieved by incubating the culture at between 23 and 25°C under near-UV light for 12 hour alternating light/dark periods (Verma and Saharan, 1994).

Schleier et al. (1997) found amplified taxon-specific DNA fragments for *A. japonica* and other fungi which could be used as hybridization probes for the diagnosis of rape-seed pathogens. A number of sequences of the ITS and other regions of DNA are now available in GenBank for comparison (NCBI, 2009).

**Symptoms**

*Alternaria japonica* is known to affect most parts of infected plants depending upon growth stage. There are reports of it on the hypocotyls and cotyledons of seedlings and on the leaves, petioles, stem, inflorescence, fruits (siliquae) and seeds of adult plants. Leaf lesions are small, 1-10 mm diam., black to grey, dry, with a raised margin, and they are often surrounded by a translucent yellow halo (Atkinson, 1950). Similar black spots can be found on the siliquae, which presumably are the means of infection of the seeds; these spots can coalesce to cover the entire pod (McLean, 1947). Neergaard (1945) noted that infection of seeds by *A. japonica* (as *A. matthiolae*) caused seed discoloration from the normal brown to grey. In radish, when the whole fruit is affected, the seeds are small and shrivelled (Atkinson, 1950). Disease developing from infected seeds produced black stripes or dark brown sharp-edged lesions on seedling hypocotyls in *Brassica oleracea* var. *pekinensis*, and some seedlings were killed (Valkonen and Koponen, 1990). There appears to be some variation according to host: on *Raphanus* the lesions are as described above, and initially black in the centre due to sporulation, but later the centre dries up and may drop out. On *Matthiola*, the lesions are pale greyish green with concentric zones, the centre becoming dark brown to black with sporulation (Neergaard, 1945; Atkinson, 1950). Lesions on stems and flowers may have water-soaked margins (Davis et al., 1949).

Su et al. (2005) reported that *A. japonica* infection of harvested radishes in cold storage caused black and brown patches on the skin that were closely associated with skin wounds and damaged root hairs.

**Biology and Ecology**

**Life Cycle**

*Alternaria japonica* grows well between 17 and 29°C (Changsri and Weber, 1963) and these are the optimum temperatures for infection (Degenhardt et al., 1982). The optimum temperature for sporulation is in the middle of this range. Conidia are produced abundantly in wet weather but high humidity restricts dispersal such that air spore concentration shows a distinct diurnal periodicity, with a maximum in the early afternoon and a minimum in the early morning. The conidia germinate in free water on the leaf surface (such as that resulting from dew) and penetrate host tissues through stomata or ordinary healthy tissues. Germination can take between 5 and 8 hours and infection of the host can occur within 24 hours at 15°C or above (Verma and Saharan, 1994).

**Transmission**

Three main sources of inoculum have been identified: infected seeds, diseased plant debris, and conidia spreading from related wild host plants (Verma and Saharan, 1994). *Alternaria japonica* occurs in all parts of radish seed. Its presence in the embryo can result in seed death, but in milder infections it will affect seedlings after germination, causing seedling blight ("damping-off"), both before and after emergence. However, both time and temperature deleteriously affect the fungus: where temperatures are above 35°C, seed can become free of infection. It can survive up to 5 years in soil culture without any loss of viability or virulence, although tests failed to show evidence of survival in unsterilized soil (Atkinson, 1950, 1953). It can also persist as chlamydospores, which are produced on the host plant and can survive prolonged freezing. Once established on a host plant, the fungus will spread through dispersal of conidia in the air or over short distances by rain splash (Verma and Saharan, 1994).

**Epidemiology**

Under field conditions, *A. japonica* infection progresses rapidly at 22-26°C. In the boreal-temperate zones where the affected crops are most commonly grown, the most severe outbreaks are in the summer period. In Canadian canola production, disease severity varies from year to year, depending upon weather conditions. The greatest losses are sustained when there is frequent rain or dew during pod formation (Seidie et al., 1995).
Physiology and Phenology

Atkinson (1950) observed variation in culture growth and pathogenicity to several hosts among single-spore isolates from radish. Based on culture morphology, 312 isolates could be sorted into thirteen groups. In contrast with the nearly uniform virulence of *A. brassicicola* isolates in Japan, isolates of *A. japonica* induced varied reactions in different host plants or plant parts in inoculation tests (Tohyama and Tsuda, 1995).

Notes on Natural Enemies

Tsuneda and Skoropad (1980) showed that *Nectria inventa*, a fungal phylloplane inhabitant of canola, can attack a number of conidial fungi including *A. japonica*. It is able to penetrate and parasitize the hyphae, causing granulation and vacuolation of host cytoplasm. Fungi isolated from crucifer seeds that were able to antagonize or parasitize the pathogen in vitro included *Chaetomium globosum* and species of *Fusarium*, *Myrothecium* and *Trichoderma* (Vannacci and Harman, 1987).

Means of Movement and Dispersal

Natural dispersal: Conidia of the fungus are disseminated primarily by wind and rainsplash (Verma and Saharan, 1994; Tewari and Buchwaldt, 2007). The fungus may also be moved in infested debris and by any natural dispersal of infected seeds. The role of the chlamydospores in survival in the debris or in soil is undetermined.

Vector transmission: None reported

Accidental introduction: The fungus is most likely to be transported in and on seeds (see Seedborne Aspects), although infected seedlings could carry it locally if transplanted.

SEEDBORNE ASPECTS

Incidence

Petrie (1974) isolated *A. japonica* frequently from turnip-rape seeds (*Brassica campestris*) but less from rape (*B. napus*). It was also found in 30% of seed lots of radish and black radish (*Raphanus sativus var. major*) seed in Finland (Tahvonen, 1979). Vannacci and Pecchia (1988) detected the fungus on 80% of seeds in one radish lot. A high rate of occurrence of the pathogen on radish seeds was also reported in Michigan, USA (McLean, 1947). In South Africa and Egypt, the pathogen was isolated from seeds of other brassicaceous plants (Holtzhausen and Knox-Davies, 1974; Michail et al., 1979). Many Japanese seed lots of Chinese cabbage (*B. rapa subsp. pekinensis*) tested in Finland were infected with *A. japonica* (Valkonen and Koponen, 1990).

The fungus was found in all parts of radish seeds, with conidia present on the seed coat. The amount of inoculum decreased with depth in the seed (Vannacci and Pecchia, 1988). Vannacci and Harman (1987) also found that the fungus was present on seeds both internally and externally.

Effect on Seed Quality

Neergaard (1945) stated that infection by *A. japonica* affects the colour of the seed in radish, but this has not been substantiated in more recent literature.

In a Canadian study (Rude et al., 1999), surface-sterilized seed samples of *Brassica rapa subsp. campestris* from Saskatchewan and Alberta were assessed for seed infection by *Alternaria* spp. and for seed germination. Infection by *Alternaria brassicicola* and *A. japonica* significantly reduced seed germination, whereas *A. alternata* had no effect; as many as 30% of seeds in a lot failed to germinate.

Pathogen Transmission

Evidence for transmission of *A. japonica* by seeds is based on germination tests of radish seeds in which the pathogen colonized the growing seedling structures, resulting in infection of all the epicotyl-hypocotyl axes and of most cotyledons. Most seed coats remained adherent to the hypocotyl base, enabling some cotyledons to escape infection. In another test, in which infected radish seeds were planted in soil, a large proportion of diseased seedlings died before emergence (Vannacci and Pecchia, 1988). Petrie (1974), on the other hand, found no relation between levels of *Brassica* seed infestation by *Alternaria* spp. and seedling emergence and survival. Most of the *A. raphani* present was determined to be on the seed surface, since surface sterilization removed 90% of it.

Infection of seeds of *Brassica rapa subsp. pekinensis* (Chinese cabbage) reduced germination in plate tests, produced stripes or sharp-edged lesions on seedling hypocotyls, and killed other seedlings (Valkonen and Koponen, 1990). Germination was reduced by 7% in a seed lot in which 35% of seeds carried the fungus internally and/or externally.

Seed Treatment
Seed dressings with a wide range of different fungicides have been shown to give effective control of *A. japonica* (Mondal et al., 1989; Verma and Saharan, 1994). Champion et al. (1979) found iprodione to be especially effective, but thiram did not control the fungus, which was mostly borne internally (Valkonen and Koponen, 1990). Vannacci and Harman (1987) found that treatment with some antagonistic fungi resulted in an increase in the number of healthy seedlings and in the number of seedlings germinating from infected radish seeds. These fungi were strains of *Chaetomium globosum*, *Trichoderma harzianum*, *T. koningii* and *Fusarium sp.* Several of these were observed to be mycoparasites on the *Alternaria* hyphae. However, it was concluded that treatment with iprodione was more effective than with any of the fungi. Hot water treatment has also been recommended for control of *Alternaria* and other pathogens in brassicaceous vegetable seeds (Tewari and Buchwaldt, 2007).

### Seed Health Tests

**Blotter Test** (Vannacci and Pecchia, 1988)
1. Place untreated seeds on damp blotters.
2. Incubate at 18-20°C under a near UV light 12 h/dark 12 h cycle for 7 days.
3. Examine for brown spots on cotyledons, containing light to dark-brown conidia, with longitudinal and transverse septa.

**Culture Plate** (Vannacci and Pecchia, 1988)
1. Pre-treat the seed in 1% chlorine solution for 10 min.
2. Incubate on PDA at 20°C under a near-UV light 12 h/dark 12 h cycle for 5 days.
3. Examine daily for characteristic dark mycelium and conidia, and possibly chlamydospores, in colonies.

Valkonen and Koponen (1990) preferred use of 4% water agar to slow fungal growth in plate tests.

**PCR** (Iacomi-Vasilescu et al., 2002)

A PCR-based diagnostic technique has been developed for the detection of some seedborne *Alternaria* species. Specific primer pairs were designed from DNA sequences in the internal transcribed spacer (ITS) region of nuclear rDNA and used in PCR reactions containing DNA extracted from seed macerates. After only 2 days of incubation, the assay successfully revealed the presence of *A. brassicicola* and *A. japonica* in seeds of crucifers at levels of infection as low as 10%.

### IMPACTS

#### Economic Impact

Although widespread and occurring on a range of brassicaceous hosts, infections by *A. japonica* are seldom severe, only causing minor damage to established crops (Neergaard, 1945; Petrie, 1985; Petrie et al., 1985). In Canada, the fungus is often found on crops affected by other more serious pathogens, such as *Leptosphaeria maculans*, *Albugo candida* and *Sclerotinia sclerotiorum*. Degenhardt et al. (1974) reported that *A. japonica*, in association with *A. brassicaceae* can cause yield losses in certain rapeseed cultivars (*B. rapa* subsp. *campestris* 'Span' and *B. napus* 'Zephyr') of between 40 and 70%; alone it caused yield losses of 34-42%. Reduction in oil content was noted for 'Span' and reduction in protein content was found in 'Zephyr'. The main economic impacts of *A. japonica* result from the effect on germination and the subsequent seedling blight (Neergaard, 1945). Seed with reduced germination due to infection may not be saleable as certified (Rude et al., 1999). The level of shriveled seed may also reduce the price the grower receives for canola (Seidle et al., 1995). Tohyama et al. (1991) noted that this and other *Alternaria* species can pose a threat to the production of food items such as young seedlings of Chinese radish (*Raphanus sativus var. hortensis*) which is a popular food garnish in Japan. Likewise, in the USA, *Alternaria* spot on the edible leaves, heads and other parts of vegetables can make them unsaleable (Kucharek, 1994).

#### Human Health

*Alternaria japonica* is not known to be pathogenic to humans or animals, but medical species identifications in the genus may be imprecise (de Hoog et al., 2000). *Alternaria* spores are known to be allergenic (Marks and Bush, 2007). Workers in Canadian fields have attributed skin and eye irritation to high spore levels of *A. brassicaceae* spores on plants at harvest (Petrie, 1973). *Alternaria japonica* is not one of the species most frequently found in the air (Infante et al, 1987), but the gene for the alt a allergen has been found in one strain (Hong et al., 2005a).

### MANAGEMENT
Prevention

SPS Measures

Because the fungus is readily transmitted in and on seed, the use of certified fungus-free seed is a necessity to prevent its introduction into new areas and to avoid elsewhere the initiation of a possible serious level of disease starting at seedling emergence. Neergaard (1945) detected *A. japonica* (as *A. matthiolae*) in seed lots from Germany, Hungary and the Netherlands. Many Japanese seed lots of Chinese cabbage (*B. rapa* subsp. *pekinensis*) tested in Finland were infected with *A. japonica* (Valkonen and Koponen, 1990). Recently, one of four seed shipments from Australia to India was determined through phytosanitary inspection to contain the fungus (Agarwal et al, 2002). (See Seed Health Tests for methods of detection.)

Cultural Control and Sanitary Methods

The nature of the main sources of inoculum (infected seeds, infested plant debris, and conidia spreading from related wild host plants) generally preclude effective cultural control. Atkinson (1953) showed that *A. japonica* can survive and reinfect susceptible crops after 5 years in dried soil cultures. Furthermore, it is also known that chlamydospores can withstand severe freezing. This means that once present, the pathogen may be able to survive in the field for a long time. Nevertheless, some cultural methods which have been recommended are crop rotations of several years, eradication of wild and volunteer crucifers, and incorporation of debris into the soil (Tewari and Buchwaldt, 2007) as well as selection of a planting date that avoids favorable conditions for disease at sowing or pod fill, and prompt harvesting to avoid deposits of rain or dew on the pods (Seidle et al., 1995).

Physical/mechanical methods

Because infection can cause canola seeds to be small or shrivelled, Seidle et al. (1995) suggest that vigorous cleaning by various methods, including screening and winnowing, may reduce the infection level in the harvest. Petrie (1974) found that storage of Brassica seeds for six to eight months at 25° C substantially reduced the level of infestation by viable conidia on the seed surface.

Host-Plant Resistance

Although sources of resistance to *Alternaria* infection in some brassicaceous crops have been identified, breeding efforts are at an early stage and few data are available (see Tewari and Buchwaldt, 2007).

Biological Control

Vannacci and Harman (1987) investigated biological control of *A. japonica* using a range of fungi. While isolates of *Chaetomium globosum*, *Trichoderma harzianum*, *T. koningii* and *Fusarium* sp. gave significant improvement in seed germination and numbers of healthy radish seedlings, and reduced disease on pods and the infection of seeds, they were found to be no more effective than iprodione. The lack of complete control by either the fungicide or the fungi is likely due to the deep-seated nature of seed infection by *A. japonica* (Vannacci and Harman, 1987) Tsuneda and Skoropad (1977, 1980) have shown that *Nectria inventa*, a fungal phyloplane inhabitant of canola, can parasitize the hyphae of *A. japonica* and infect the conidia of *A. brassicaceae*. This provides a prospect for natural control of these pathogens on the above-ground parts of cruciferous crops.

Chemical Control

Many fungicides applied as a seed dressing are effective in reducing disease caused by *A. japonica* (Laska and Rod, 1985). There is little evidence that chemical control is necessary, although it is known that benomyl, captan, carbendazim, iprodione, mancozeb, thiophanate-methyl and zineb, are effective against *Alternaria* species on seedlings (Mondal et al., 1989; Dhyani et al., 1990;).

IPM

Kharbanda and Tewari (1996) discussed the value of crop rotation, weed control, and high cutting for integrated management of *Alternaria* pathogens of canola in Canada.

GAPS IN KNOWLEDGE/RESEARCH NEEDS

The precise relationship of strains identified as *A. japonica* and *A. raphani* from different continents, and their relationships to other species within the genus, should be examined by molecular means, using more than one strain of each species and considering more than one region of DNA.

The role of the chlamydospores in the survival of *A. japonica* in crop debris and soil in different climates should be investigated.

The promising studies on biological control of *Alternaria* species on crucifer seeds and plants should be followed up for the possible inclusion of biological agents in integrated control programs.
Efforts to identify sources of resistance and incorporate resistance into usable cultivars should continue. This may necessitate additional exploration of variation within the pathogen, so that resistance can be made durable over time.

References


Use this link to revisit SMML website
Chain of conidia, 400x. CBS 118403: from cornmeal-dextrose agar.

Conidia, 400x. CBS 118403: from cornmeal-dextrose agar.

Chlamydospores, 200x. CBS 118403: from cornmeal-dextrose agar.

Chlamydospores, 200x. CBS 118403: from cornmeal-dextrose agar.