

Crop Profile for Canola in Minnesota

Prepared April, 2000

General Production Information



Canola (*Brassica napus* and *B. rapa*), a member of the mustard family, was developed by Canadian breeders from oilseed rape in the 1970s. These efforts resulted in a lower level of erucic acid in the oil (from the 20-40% found in oilseed rape to less than 2% in canola)

and a reduced level of glucosinolate in the meal remaining after oil extraction (rapeseed meal contains about 1% glucosinolate and canola meal contains less than 0.1% glucosinolate). Canola is grown primarily for the oil extracted from the seed (canola seed contains about 40% oil). The meal remaining after oil extraction is used as a high-protein feed ingredient for livestock. Canola oil sales and demand have increased tremendously in the U.S. since 1985, when the oil was granted Generally Recognized as Safe (GRAS) status, clearing it for use in human foods. Canola is low in saturated fats, and is considered a high quality, all-purpose edible oil. Canola is marketed worldwide, and is grown in Canada, Europe, Australia, and the United States.

Production Information

- Canola production in Minnesota has increased dramatically in the past ten years. In 1990, canola was produced on about 8,000 acres.¹⁹ In 1998, canola was planted on 220,000 acres, and 210,000 acres were harvested, which was over twice that of 1997. Due to poor weather conditions, 1999 acreage did not follow the trend of increasing acreage; seed sales predicted 225,000-250,000 acres, but weather conditions prevented planting, and poor stands resulted on planted acreage due to wet conditions. Thus, in 1999, canola was planted on approximately 115,000 acres and harvested from about 100,000 acres. In the 2000 season, grower feedback indicates a return to 1998 production levels; estimates for 2000 are about 250,000 acres.⁹
- In 1998, Minnesota produced 290 million pounds of canola, ranked second in the US, and accounted for approximately one fifth of the total US canola crop.⁸
- Canola is grown primarily in the northwest region of the state, although limited acreage is also found in

the central and southern regions of Minnesota. ^{8,16}

Cultural Practices

Two species of canola are planted in Minnesota, *Brassica napus* (referred to as Argentine) and *Brassica rapa* (referred to as Polish). Argentine varieties have a higher yield potential, are taller, require a longer growing season, and have higher oil content than Polish varieties. Although the yield is lower, Polish varieties are valuable because they can extend the canola planting season; Polish varieties can be seeded later in the spring and still reach maturity prior to frost. Canola grown in Minnesota is typically the spring annual variety; currently available winter varieties are not well suited to Minnesota and other Northern U.S. states due to their lack of winter hardiness. In Minnesota, planting dates range from late April through early May, and the seed is harvested in August and September.

Canola is best suited for clay-loam soils that do not crust, but can be grown on most soils. Canola is very susceptible to soil crusting. Also, the soil must have a structure which promotes water intake, storage, and movement. Good drainage is critical; canola does not tolerate standing water or water-logged soils ² (hence the very poor performance in the 1999 Minnesota canola crop ⁶). If the soil has poor internal drainage, good surface drainage is essential. ²

Canola should be seeded as early as possible (late April through mid-May) to produce the highest yields. Seedlings are frost tolerant, and the plant is very susceptible to heat and drought stress during flowering; early planting will reduce the potential effects of plant stress. At planting, the seedbed should be firm with soil moisture throughout, since seed and soil moisture contact is critical for rapid emergence. This allows for quick and even emergence of seedlings, which is important for optimal stand establishment. The seedbed should be prepared to avoid wind erosion and soil drift, which can easily damage seedlings. The optimal seeding depth is between ½-1", at rates of between 4-8 lbs in 6-8 inch row spacing. Insecticide- or fungicide- treated seed is often used. Weeds should be controlled early in the season; this is accomplished via preplant incorporated herbicides and/or cultural methods. Harrowing will help to control weeds prior to canola emergence; however, harrowing is not recommended once canola seedlings have emerged. ²

Canola is similar to small grains in its response to fertilizer and levels of soil fertility,² but it requires more sulfur. ¹⁶ Nitrogen and sulfur are the key elements for increasing canola yields. Sulfur is especially critical, and application is recommended at medium to low soil-test results; applications should be made prior to or at planting. Soil samples are used to provide an indication of N, P, K, and micronutrient levels, and to plan fertilization needs. Additionally, plant tissue should be sampled early during the rosette stage to allow time for corrective micronutrient applications. Because canola stressed from nutrient deficiencies will not mature evenly and will increase problems with green seed, adequate (not high) fertility levels for growth and ripening should be maintained. Fields with high fertility levels can be expected to delay maturity in years that are cooler than normal. ²

Green seed (late maturing seed) can present harvest management problems in Minnesota. Quick, even seedling

emergence helps prevent green seed, and is accomplished by preparing a firm seedbed and planting at consistent and optimal depths to ensure good seed-to-soil contact. Green seed can also be avoided by planting in fields with better surface drainage, maintaining adequate fertility, and seeding as early as possible to allow for maximum ripening time. Cool, wet and overcast weather during the growing season promotes a long season for pod set, and thus some late maturing seed.²

Canola harvest should be conducted at the recommended color stage for the weather conditions. Optimally, canola is swathed when the bottom third of the pods are at 20-30 percent moisture, the middle third are at 34-40% moisture, and the top third are at 40-45% moisture. The windrow is then allowed to dry to 8-10% moisture before combining.²⁰

Pest Management In Canola

Minnesota farmers employ a variety of cultural and chemical practices to attain weed, insect and disease control while maintaining a productive crop. In many cases, the practice which controls one pest is also impacts the control of another, or will impact the production system in the long run. Many factors must be considered when a grower determines the appropriate method to prevent and/or manage the impacts of a pest. Criteria which are important in this decision-making process include: impact on all potential and present pests, impact on beneficial organisms, economic benefit, and impact to the crop system and environment as a whole. For instance, crop rotation is a practice which has broad applicability, and is one component in a pest management program. Used with other measures, appropriate crop rotations can aid control of certain insect, weed, and disease pests.

It is counterproductive to isolate control of one pest without considering a holistic approach. The control strategies detailed in this report should be viewed in that light, and should be considered only one part the total decision-making process to employ a specific practice.

Insect Pests

Because canola is a relatively new crop in Minnesota, all the effects which specific insect pests will and do have on the state's canola crop may not yet be fully known. The most commonly encountered insect pests in Minnesota canola fields include flea beetle, Lygus bug, red turnip beetle, diamond back moth, and Bertha armyworm.⁶

These pests and the thresholds for treatment and cultural controls specific to each pest are discussed in detail below. If there are chemical control issues specific to a pest, it is discussed with that pest; general insecticide information is presented in "Chemical Control of Insect Pests".

Flea Beetles

Flea beetles (*Phyllotreta cruciferae*) can be a serious pest of canola in Minnesota.⁶ Flea beetles overwinter as adults, becoming active when temperatures reach 68°F. They then fly to canola fields just as the seedlings emerge. Adults feed on the emerging cotyledon and the first true leaves of the young plant, causing holes or small pits in cotyledons and leaves. Feeding damage can result in plant death and significant stand loss, especially during hot, dry weather. Flea beetles feed most actively when the weather is dry, sunny, and warm. During warm, dry conditions, canola's development is slowed, exacerbating the effects of flea beetle feeding. Because canola grows best in cool, wet weather, the plant may be able to compensate for flea beetle feeding during these conditions. Once plants are beyond the seedling stage and the first true leaves are fully expanded, serious damage usually does not occur. By mid June, adult beetles decrease in number.^{2,4,12}

Flea beetles are primarily a pest of stands as seedlings emerge, when they can inflict the most damage. Newly emerged adults may feed on stems, leaves, in August; this damage does not usually cause serious loss.^{2,12}

Flea Beetle Management:

Thresholds– During the seedling stage, fields should be checked daily for the presence of flea beetles. Treatment thresholds for foliar application are when the injury level is almost 25% and beetles are present.⁴

Cultural control – Early planting may lead to establishment of canola plants before adult flea beetles become active in the spring. Canola is at greatest risk from flea beetle feeding when it is in the cotyledon to 2-leaf stages. Larger plants may outgrow flea beetle feeding injury. If canola plants become established and grow beyond the 2-leaf stage before flea beetles adults enter the fields, most yield loss from feeding can be avoided.⁴

Planting into stubble may also reduce injury due to the cooler micro-environment created by stubble shading of surface soil; cooler temperatures at the soil surface slow down flea beetle activity, reducing damage. Using a higher seeding rate may also help manage flea beetle damage.¹⁵ Canola adapts well to various seeding rates without yield loss; however, increasing seeding rate also increases cost, the incidence of sclerotinia, and may not be sufficient to prevent stand failures in high population years.¹⁶ Early planting in stubble at higher seeding rates will maximize cultural control of flea beetle. In low to medium population years, this management strategy usually results in adequate stands.¹⁵

There is little data regarding the number of growers who adopt these cultural practices. Some growers are utilizing these recommendations in canola production, but adoption depends largely on both the historical flea beetle pressure in a particular growing area and the weather conditions being experienced.⁶

Chemical Control (Seed Treatment) – Seed treated with Gaucho® (Gustafson, imidacloprid) may be used in Minnesota for flea beetle control. This is for use in commercial seed treaters only. Currently, Gaucho is the only fully registered seed treatment insecticide labeled for use in Minnesota. A Section 18 emergency exemption was recently approved for the 2000 growing season for seed treated with Helix (from Novartis, a mixture of the fungicides difenoconazole, fludioxonil, and mefenoxam and the insecticide thiamethoxam). In 2000, up to 50,000 acres may be planted in the northwest corner of the state with seed which has been treated with Helix and imported from Canada.

Chemical Control (Foliar Treatment) – In addition to seed treatments, foliar application of insecticides may

be necessary in some years to control flea beetle and ensure adequate stands. They must be made quickly because flea beetles move rapidly when disturbed and may avoid exposure to the chemical. Foliar insecticides are not always very effective, because of the inability to cover large numbers of acres quickly when feeding pressure is high, and residual protection by the insecticides is short, allowing for reinfestation to occur.⁴

All foliar insecticides registered for use in canola in the state are labeled for control of flea beetle; in addition, a Section 18 registration was in place in 1998-1999 for the use of Warrior (lambda-Cyhalothrin, Zeneca) for foliar use in canola to control flea beetles.¹⁰ Warrior and Capture tended to be chemistries of choice for control of flea beetles in Minnesota, apparently due to their effectiveness, ease of use, and perceived relative safety.⁶ Warrior is not available to Minnesota growers in the 2000 growing season.¹⁰

Lygus Bug

Several species of Lygus bugs (*Lygus spp.*) have become increasingly important insect pests in Minnesota canola production. Weather conditions in the past several years have favored the development of Lygus populations in canola.⁶ Adults are 1/5" long, pale green to reddish brown, with a distinct white triangle or "V" mark on their backs, just behind the head. Nymphs are wingless, pale green in color, have prominent black dots on the forward portions of their backs, and are very active. Adults overwinter under debris in ditch banks, fence lines, and tree lines. Adult Lygus bugs enter canola fields while the plant is in the bud stage to feed and lay eggs. Eggs are laid directly into the stems and leaves of host plants during May, June, and early July. The first nymphs appear in May.^{6,15}

Lygus bugs have piercing-sucking mouthparts and puncture the plant tissue, sucking plant juices. Adult feeding on the bases of canola buds and flowers causes blasting with feeding lesions occurring on the surfaces of stems, buds, flowers, and pods. Lesions on stems and pods are characterized by brown, stippled areas; canola buds and flowers attacked by Lygus bugs turn white within 24 hours and quickly drop from the plant. Nymphs and adults will attack developing pods, puncturing the pods and sucking out the contents of the developing seeds. Seeds attacked by Lygus bugs may have small ruptures in the seed coat or may be completely or partially collapsed. There are at least 2-3 generations per year in Minnesota. Adults remain in fields until late summer when they migrate to overwintering sites.^{6,15}

Lygus Bug Management:

Thresholds - A sweep net should be used to determine the population of Lygus. Before petal fall is complete the threshold is 15 lygus per 10 sweeps. Within 4 or 5 days after petal fall is complete then the threshold is 20 Lygus per 10 sweeps. Fields should be checked weekly for the presence of Lygus Bugs while canola plants are at risk, which is especially during flowering and pod set.⁶

Cultural Controls – No cultural controls are currently available for this pest.⁶

Chemical Control – Capture is registered for control of plant bugs in canola in Minnesota.

Red Turnip Beetle

Red turnip beetle (*Entomoscelis americana*) is a sporadic and localized pest of canola in Minnesota. Most infestations have occurred in Roseau and Lake of the Woods counties, near the Canadian border. This insect overwinters in the soil as eggs and hatches in early May to feed on the foliage of cruciferous plants. Mature grubs are black, $\frac{3}{8}$ " long, with a rough-skinned, segmented body. After feeding they enter the soil to form bright orange pupae which transform into the adult beetles. Adult beetles are $\frac{3}{8}$ "- $\frac{1}{2}$ " long with bright red and black patches on their heads and three distinct black stripes running down their backs. Adult beetles feed until mid July when they burrow into the soil to aestivate. They then emerge in late July or early August, mate and lay eggs. The beetles often congregate in groups throughout canola fields and mate near the tops of maturing plants. Eggs are laid randomly throughout the field. There is one generation per year.⁶

Both larvae and adults feed on canola, but adults cause more damage to the seedling crop. In spring, beetles move into canola fields from neighboring fields sown to canola the previous year. In summer, the adult beetles can move considerable distances to reach a canola or mustard crop. Although they may move through small grains and feed on the cruciferous weeds and volunteer canola in the field, they will not feed on cereals. When established in a field, red turnip beetles move slowly plant-to-plant, completely devouring canola plants as they move inward from the field margins.⁶

Red Turnip Beetle Management:

Cultural Control - Cultivate infested fields in late fall or early spring to bury eggs and reduce larval survival. Cultivating in early spring has the added advantage of removing cruciferous weeds and volunteer canola, the primary food source for emerging larvae. Because of the sporadic nature of the pest status of red turnip beetle it has not been possible to test the effectiveness of adopting these recommendations in Minnesota.⁶

Chemical Control -There is currently no insecticide registered for use in canola against red turnip beetle.

Diamondback Moth

Diamondback moths (*Plutella xylostella*) migrate to Minnesota annually from the southern parts of the North Central Region of the U.S. in late spring and early summer. Once established, new generations occur about every thirty days, and generations will overlap. Adults are drab brown, about $\frac{1}{2}$ " long, and forewings of the males form three diamonds when the moth is at rest. Adults do not feed on plants. The first eggs are laid on the lower leaves; moths of later generations lay eggs higher on the plant. The small, greenish larvae feed first by mining leaves; about a week later they exit leaves and feed externally, making tiny, irregular holes in the leaves.¹⁵ Later, larvae move to buds, flowers, and developing seedpods.⁴ Because diamondback moth does not overwinter in Minnesota and populations are re-established annually by adults immigrating from southern states, weather events (such as storm fronts moving from the south) have the greatest influence on initial population densities.⁶

Foliar damage by diamondback moth larvae is unsightly, but significant yield losses are not common. Damage is

much worse when plants are under drought or heat stress.⁴ Diamondback moths are considered a sporadic pest of canola in Minnesota.⁶

Diamondback Moth Management:

Thresholds – If there is significant evidence of damage to flowers and/or pods, treat when larval counts are about 20 per square foot at the pod stage; at the early flowering stage, treatment may be required at larval densities of 10-15 per square plant.^{4,15}

Cultural Control – Tillage can be used to reduce food sources such as cruciferous weeds and volunteer canola host plants; this will prevent the first generation larvae from establishing. Rainfall can also decrease populations, knocking young larvae from plants. Consequently, threshold counts should be made after rainfall events. Cool, cloudy weather during the egg-laying period reduces moth flight activity and decreases the number of eggs laid.⁶

Chemical Control – All foliar insecticides registered for use on canola in Minnesota are registered for control of diamondback moth larvae.¹⁰ However, Warrior (when available, as in 1998-1999) and Capture appeared to be more desirable to growers than the others, apparently due to their effectiveness, ease of use, and perceived relative safety.⁶

Bertha Armyworms

The Bertha armyworm (*Mamestra configurata*) attacks canola and many other species of broad leaf plants, including flax and beans.¹⁵ Although not a major insect pest of canola in Minnesota, it has been an infrequent, localized problem in certain fields.⁶ Newly-hatched larvae are pale green and feed on the leaves. Older larvae grow to about ¾-1 inch long; they are velvety brown to black and have a yellowish band along each side of the body. These larvae feed on leaves, and as leaves dry, they begin feeding on seeds and flowers which are more succulent.¹⁵

The greatest risk of crop injury occurs in August as the worms approach full growth. In Canada, where this insect is a more frequent pest, early seeded canola often has been swathed prior to the occurrence of significant feeding injury.¹⁵

Bertha Armyworm Management:

Thresholds - 18 to 22 larvae per square yard, as long as leaf feeding is the extent of the damage observed. If feeding damage is evident on seed pods, thresholds may be adjusted lower.¹⁵

Cultural Control – Although Bertha armyworm outbreaks in Minnesota are so sporadic that control techniques have not been researched and established in the state, many of the cultural techniques used in Canadian canola production would likely function well here. Bertha armyworm pupae can be killed by mechanical cultivation and by reducing the amount of snow trapped on a field by removing or flattening stubble, thus exposing pupae to sub-zero temperatures over the winter. Because adult moths are strong flyers and can easily move to adjacent fields

this technique must be practiced at regional levels to decrease Bertha armyworm populations. Fall cultivation should not be used on a light-textured soils susceptible to erosion. It is not clear to what extent Minnesota growers are using these techniques.⁶

Chemical Control – Capture is the only insecticide registered on canola in the state which is labeled for use against armyworms.

Chemical Control of Insect Pests

Canola should be scouted for insects daily during the seedling stage and weekly thereafter, checking for signs of feeding damage on various parts of the plant. Local district agricultural representatives or district agriculturists should be consulted to ensure that pests have been correctly identified. An accurate representation of the population in the entire field is necessary; many canola insect pests, particularly flea beetles, will have populations that are denser on the field edges than in the field interior. Canola crops can compensate for some insect damage, especially early in the season during cooler periods (which favor canola growth), so chemical application should be avoided unless insect populations exceed thresholds.⁶

Seed treatments are important in canola. Imidicloprid (Gaucho 480 and Gaucho 75 ST, from Gustafson, a commercial seed treatment) is the only fully registered insecticide seed treatment available to Minnesota canola growers. Flea beetle is the canola insect pest targeted by both Gaucho and Helix (a seed treatment for which a Section 18 is approved for the 2000 season).

Foliar treatments may be necessary in some years to ensure adequate stand establishment; foliar insecticides are also sometimes necessary later in the season. Currently, bifenthrin, ethyl-methyl parathion, and methyl parathion are registered as foliar insecticides in canola in Minnesota. In addition, a Section 18 registration was in place in 1998-1999 (this is not available in 2000) for Warrior (lambda-Cyhalothrin, Zeneca).¹⁰

Although ethyl-methyl parathion and methyl parathion were registered in 1999 for use as foliar insecticides in canola, Warrior (when available under Section 18) and Capture (bifenthrin) tended to be the chemistries of choice for canola growers. Apparently, their effectiveness, ease of use, and perceived relative safety made them a more desirable choice for insect control.⁶

In 1996, the Northeast region of North Dakota (which is the region most similar to Minnesota's main canola-producing region) treated about 7% of canola acreage with insecticides.²³ Information from the North Dakota survey for percent acres treated by a specific active ingredient will not be cited in this report; the insecticides available to our growers have changed since that survey was taken. We are not aware of any recent surveys done in Minnesota to collect insecticide use and usage data for canola. The only canola pesticide usage data available is obtained by the Minnesota Department of Agriculture in support of Section 18 registrations; this information indicated that about 1% of Minnesota's canola acreage was treated with Warrior in 1999.

Insecticides Used on Canola:

Active Ingredient	Product(s)	Registration Status	Rate	% Acres Treated	Notes
bifenthrin	Capture 2EC	Section 3	0.033-0.04 lb. AI/acre	no data	RUP. Max 0.08 lb.AI/acre per season. Do not reapply within 14 days. 24 hour REI. 35 day PHI.
ethyl-methyl parathion	Parathion 8EC	Section 3	0.125 lb. AI/acre	no data	RUP. 20 day PHI, 3 day REI.
imidicloprid	Gaucho 75, Gaucho 480 FL	Section 3	0.5-1.0 lb.AI/cwt. seed	no data	Commercial seed treatment only. Only fully-registered insecticide seed treatment for canola.
methyl-parathion	Ethyl – Methyl Parathion 6-3EC	Section 3	0.125 lb. AI/acre	no data	RUP. 20 day PHI, 3 day REI. Max 2 applications/season.
lambda-cyhalothrin	Warrior	'99 Sec. 18; <i>not avail. in 2000</i>	0.02 lb. AI/acre*	1.0%*	RUP. Not available in 2000.

* Data obtained by the Minnesota Department of Agriculture in support of Section 18 registrations. Percent acreage treated may be over-represented; multiple applications to the same acreage are totaled separately. It should be noted that pesticide use in 1999 was affected by excessive spring rain. Percent acreage treated is based on 1999 harvested acreage of 102,000.

Potential Section 18 Insecticides for 2000

For the 2000 growing season, seed treated with a second product, Helix (Novartis) is available through a Section 18 registration. (Seed may be treated in Canada and imported, it may not be treated in the U.S.) Helix is a combination of the insecticide thiamethoxam and three fungicides (difenoconazole, fludioxonil, and mefenoxam). Up to 50,000 acres in the northwest corner of Minnesota may be planted with seed treated with Helix in the 2000 growing season under this Section 18 label.¹⁰

Diseases

As with weed control, disease control in canola requires integrated management, including management of crop rotations. Plant diseases can be serious problem in canola production and rotations must be carefully planned to keep disease incidence low. Cruciferous weeds and volunteer canola are hosts to many canola diseases; these weeds should be managed throughout the crop rotation cycle.

Some of the commonly found diseases in canola are Alternaria Black Spot, Aster Yellows, Blackleg, Root Rot Complex, Sclerotinia Stem Rot, Seedling Disease Complex, and White Leaf Spot & Grey Stem. Sclerotinia Stem Rot and Blackleg are the most important diseases in the state. Cultural and biological controls specific to a disease are discussed in the following sections. Fungicides are discussed following the section detailing specific diseases.

Alternaria Black Spot:

Alternaria black spot is caused by the fungi *Alternaria brassicae* and *A. raphani*. The disease begins when plants grow from infected seed, spores are produced on infected crop residue, or spores are produced on infected cruciferous weeds. The spores germinate, penetrate plant tissue and cause lesions within a few days. The lesions develop and produce wind-borne spores which may cause more infection on the same or neighboring plants. Lesions on leaves are black or grey spots, with or without a purplish or black border. Severely infected leaves wither and drop. Stem and pod lesions are small brown or black spots which may develop into conspicuous spots or larger irregular lesions. These larger spots/lesions are entirely black or are dark-bordered with a greyish white center. Severely spotted pods may split or contain shrunken, infected seed. Alternaria black spot survives and overwinters on infected crop residue, seed and cruciferous weeds. If seed is infected, the disease may cause seed to rot in the ground or it may produce infected seedlings the following year. Warm and humid conditions favor the disease.³

This is a widespread disease, but usually causes minor yield loss. Approximately, each 1 percent of pod and stem surface affected by black spot represents a 1 percent yield loss. Severe infection may cause yield loss from pod splitting and shriveled seed. If severe infection occurs early, it may kill plants.³

Alternaria Management:

A crop rotation with at least three years of non-cruciferous crops between canola crops will reduce air-borne spores from crop residue. Cruciferous weeds and volunteer canola should be controlled during the rotation. Diseased stubble should be incorporated into the soil if canola is to be grown on an adjacent field the following year. Use only clean seed (free of small, shrunken seed) to reduce seed-borne inoculum. Seed treatment only suppresses infection. Early swathing may reduce shattering and seed loss.³

Aster Yellows:

Aster Yellows is caused by a phytoplasma vectored by the Aster Leafhopper (also known as the Six-Spotted

Leafhopper), *Macrosteles quadrilineatus*. In canola, aster yellows causes discoloration, aborted flowers, aborted pods and bladdering of pods.^{3,6} In stressed plants, aster yellows can cause decreased seed set, early maturation of seed, or germination of seed still in the pod. The aster yellows organism overwinters in perennial host plants.^{3,21}

The prevalence of aster yellows varies with the abundance of the aster leafhopper. Once infected, the leafhopper can spread the disease continuously as long as it lives.³ This disease, in combination with weather conditions, was responsible for decreased production in many canola production areas in 1999.^{6,21}

Aster Yellows Management:

There is no treatment for Aster Yellows and vector treatment is not effective or cost efficient.^{6,21}

Blackleg:

Blackleg is a fungal disease caused by *Leptosphaeria maculans*. There are two strains of the disease, a mild, or weakly virulent, strain, and an aggressive, or virulent strain. The virulent strain attacks early in the season. The fungus attacks cotyledons, leaves, stems, and pods. Lesions on cotyledons and leaves are dirty white to buff in color, round to irregular in shape, and dotted with numerous pin-head sized black fruiting bodies called pycnidia. Under moist conditions, pycnidia ooze spores in pink masses; pycnidia spores may infect and cause lesions or cankers on all the above-ground parts of the plant. Stem lesions are whitish-grey, may have a dark border, and later turn dark gray to black. Over time, lesions become sunken and may girdle the stem. Early infection causes premature plant death and lodging. Less severely affected plants have reduced moisture and nutrient flow and ripen prematurely. Infected pods split open resulting in seed loss. Seed produced in infected pods is shriveled and gray in color. The mild strain usually attacks as the plant nears maturity, typically causing only stem lesions which do not girdle the stem.³

The disease overwinters in hard black perithecia in seed and on diseased plant residue. Where virulent blackleg is already well established, infected seed is of little importance to disease development. However, once an area is infected, it can continue year after year until all stubble completely decomposes. In these areas and in nearby fields, ascospores released from the previous year's stubble usually cause the initial infection in the spring. The airborne ascospores may blow in from distances from one to three miles, and rarely up to five miles. Seed provides a method of long distance spread and introduction of the fungus into areas where it does not occur. Pycnidia formed in primary lesions release ascospores which are spread by rain splash, and cause localized infection within the crop.³

Dry conditions slow the spread of the disease, whereas prolonged moist conditions favor rapid disease development and spread.³ Temperatures in the 70s F favor infection; disease development is inhibited by temperatures above 86 F or below 50 F. Plant injury from insects, hail or herbicides increases incidence and severity of blackleg.¹¹ In years following blackleg infections, decomposition of crop residue is more rapid in wet years than in dry years.³

The mild strain seldom causes yield loss. The virulent strain will cause yield loss. A 1989 survey in Saskatchewan detected yield loss estimates from blackleg of more than 50 percent.³

Blackleg Management:

In areas where blackleg is not present, it is critical to prevent introduction of blackleg. Certified seed which is treated with benlate will help prevent introduction of the disease.^{2,3,11} Benlate is the only seed treatment which provides good control of blackleg.¹³ Seed treatment and certified seed will not prevent introduction of blackleg from ascospores originating from stubble in the region. Thus, following the management practices detailed below may also be helpful to prevent infection.³

In areas where blackleg is already established, cultural controls and crop rotations can be somewhat effective in managing the disease. In these areas, canola crop residue is the primary source of inoculum. Management of crop residue and crop rotation are essential to blackleg management in these areas. Canola and susceptible crops should not be planted in or near severely infested fields, especially in the first and second years following a canola crop, but also in the third and (depending on conditions) the fourth years, since ascospores may blow in from one to three miles (rarely up to five miles) away. Control of weed hosts throughout the rotation is important; both wild mustard and volunteer canola are hosts to blackleg. Canola residue should be buried by moldboard plowing or by deep tillage shortly after harvest or early the next spring to speed the decomposition and prevent the release of ascospores in following years. Minimum shallow tillage or direct seeding of cereals in the two following years will help reduce risk by leaving canola residue buried. A small amount of diseased woody tissue may persist for four or five years, especially if these years have been drier. While tissue remaining after five years is unlikely to lead to immediate economic yield losses, it may be sufficient to continue the disease cycle.³

There are several varieties which provide moderate or good resistance; in Minnesota, this information is available in the Minnesota varietal Trials Results annual publication (available through the University of Minnesota Extension Service).¹⁹

Root Rot Complex:

This complex is caused primarily by *Rhizoctonia solani*, although *Fusarium* and *Pythium* species may also be involved. The different symptoms of this complex are brown girdling root rot, foot rot, and late root rot / root rot. Only the brown girdling root rot is of major economic importance.³

Brown Girdling Root Rot: Initially, light brown lesions with irregular margins about 3 inches below the surface appear on the taproot or main lateral roots; this occurs during and after flowering. Later, lesions may appear anywhere on the taproot. Lesions grow together, become sunken, and eventually girdle the taproot. Sunken lesions become dark brown. Roots below the girdling rot off; root tissues above the infected part become swollen. The lesion continues to develop upwards, sometimes to the soil surface, but never moves into the stem. In moist conditions, the whole taproot may be destroyed up to the soil surface. In dry soil, a taproot stub remains that is sound; taproot stubs that retain a few roots are sometimes capable of regenerating main laterals and fibrous roots. In dry conditions, plants wilt and dry up, even though soil moisture may be adequate for plants with normal root systems. In moist topsoil, plants may survive and set some seed if they are not uprooted or blown over. Yield losses will depend on the amount of root system lost by girdling. Losses are a result of increased pod sterility, low seed weight, seed shriveling, and plant death. Girdled plants that survive ripen prematurely and tend to be pulled out of the ground rather than cut during swathing, thus increasing shattering. Damage from disease is usually greatest when wet soil conditions during first flowering permit extensive root rot development, followed by high temperatures and dry windy conditions. Brown girdling root rot is

unpredictable; it can be severe where canola has never been grown previously and even on freshly broken land. Several cruciferous weeds, including stinkweed, shepherd's-purse and ball mustard also suffer from root rot.³

Foot Rot: Hard, brown, distinct lesions which may have a black border occur near the stem bases. The tap root may be discolored above the lateral roots. In humid weather, pink spore masses may develop on diseased roots. In severe cases, the stem is girdled and the plant dies. Yield loss may occur when the stem is one-half girdled. If lesions occur late in the season, yield loss is usually light. Affected plants may ripen prematurely.³

Root Rot: The symptoms are variable in color and shape, but can be grouped into four general types: light grey oval lesions of the upper taproot; dark grey discoloration (later turning black) of the lower taproot and internal tissue; soft, light brown, indistinct taproot lesions; and/or sunken, dark brown, distinct taproot lesions.³

Root Rot Complex Management:

Cultural Control: There should be at least three years between canola crops, and volunteer canola and cruciferous weeds should be controlled throughout the rotation. The management practices outlined for the seedling disease complex should be implemented to establish a vigorous, uniform crop.³

Chemical Control: No chemical controls are available.³

Sclerotinia Stem Rot:

Sclerotinia stem rot is caused by the fungus *Sclerotinia sclerotiorum*, which has a host range of over 350 plant/weed species, most of which are broadleaves. The fungus produces overwintering bodies called sclerotia which survive in soil, in stubble at the soil surface, and with seed. Sclerotia produce apothecia, which are the primary source of spores. Most infections in canola result from air-borne spores produced by apothecia at the soil surface. Only sclerotia in the top few centimetres of soil will produce functional apothecia. Deeply buried sclerotia can remain dormant for more than five years; if they are later brought near the surface by cultivation, they may germinate. The critical period for damaging infections to occur is when the crop is in bloom. Spores are carried by air and land on flower petals which provide the food necessary for germination. Spores cannot infect the leaves and stems directly, but must first grow in dead petals adhering to leaves and stems. Petals eventually fall onto leaves, and the growing mycelium invades the plant tissue. Contact moisture is required for successful infection. Spores germinate during prolonged periods (10+ days) of moist conditions and moderate temperatures, but can remain alive for up to 21 days.³

Two to three weeks after infection, soft, watery lesions or areas of tan discoloration appear on leaves, stems and branches. Lesions expand, become grayish white in color, and may have faint concentric markings. Plants with girdled stems wilt, ripen prematurely, and become straw-colored in a crop which is otherwise still green. Infected stems tend to shred and break. Infected plants may produce fewer pods per plant, fewer seeds per pod, or small shriveled seeds. Severely infected crops frequently lodge, shatter at swathing, and are difficult to swath. The extent of damage depends on whether the main stem or a branch is infected, and at what stage during flowering infection occurs.³

Low, wet areas and dense crops provide better conditions for sclerotia to germinate. Even low levels of germinated sclerotia in a canola field or an adjacent cereal field may cause severe infection when conditions are

especially favorable for disease development. Heavy canola crops are more prone to infection because a dense canopy provides better conditions for symptom development, heavy stands tend to lodge, and the disease will spread from plant to plant by direct contact. Spread will also occur in wet swaths.³

Sclerotinia is the most serious disease of canola in the state. In 1999, surveys showed that the average incidence of the disease in Minnesota canola was 15%, with one county reaching 26%-incidence. In 1997 the state's average incidence was 19%, and in 1998, the average incidence was 11%. These annual surveys indicate that the disease is worse in areas with longer histories of canola production.¹⁴

The severity of stem rot varies from year to year, and even from field to field within a region. With the right combination of crop density and weather conditions or irrigation, heavy infections can develop almost anywhere. When conditions for the disease are favorable and infections occur throughout the flowering period, yield loss per infected plant can equal 50%. For example, if 25% of the plants in a crop are infected, and the yield potential is 40 bushels per acre, the bushel loss would be $0.5 \times 0.25 \times 40 = 5$ bushels per acre. If infections are delayed until late bloom or if dry weather sets in after early bloom, yield reduction per infected plant may be reduced to as little as 10%.³

Sclerotinia Management:

Cultural Control: The recommended management strategy is crop rotation with a four-year break between susceptible crops (beans, sunflowers, peas, lentils, alfalfa, clover, carrot, and potato). Cereals and grasses should be used in the rotation, control weeds and volunteers should be controlled throughout the rotation. However, crop rotation can reduce risk only within a particular field and does not protect against air-borne inoculum from nearby fields. Management of stubble and crop residue of all susceptible crops is important. No resistant varieties are available. Canola should not be planted adjacent to a field in which a heavily infected crop was present the previous year, and only clean seed should be used.³

Chemical Control: Foliar fungicide treatments can be effective if applied with precise timing. Protection of the crop is necessary only during flowering because of the critical role petals play in infection. It is essential to spray before symptoms are visible in the crop. The use of fungicides increases yields and reduces dockage due to contamination of the seed and small, shriveled seed.³ First-year results of the newly-registered fungicide Quadris show variable results.¹⁴

Seedling Disease Complex:

Seedling disease complex is caused primarily *Rhizoctonia solani*, although *Fusarium* and *Pythium* species may also be present. These fungi are usually weak pathogens, able to infect only young roots and hypocotyl tissue. Seedling disease complex results in canola emergence and establishment problems. The seedling disease complex pathogens exist in the soil; seed-borne fungi are rarely significant in canola emergence problems. The complex exhibits several symptoms called seed decay, pre- and post-emergence damping-off, seedling blight, and seedling root rot. The disease complex is most often a problem during prolonged periods of low soil temperatures.³

Symptoms appear during the four weeks following seeding, or up to the fourth leaf stage. Stands may be thin, fail to emerge, or appear patchy. Symptoms appear as any of the following:³

- Seeds fail to germinate and decay.
- Developing seedlings decay and fail to emerge.
- Seedlings emerge and appear normal, but either the roots decay or the hypocotyl may be partially or completely girdled with decay and shrivel at any point, causing the emerged part of the seedling to topple over, wilt and die when the decay reaches the soil surface.
- The hypocotyl appears constricted or shriveled and may be reddish brown. The plant may persist for a while, but in dry windy conditions, the whole seedling disappears.
- Seedlings emerge, then stagnate in the two to four leaf stage even when growing conditions appear favorable (effects of root pruning).
- Effects of seedling root rot and partial girdling of the hypocotyl may be less apparent, causing plants to stagnate for a while, then grow and mature in the usual way. The fungi may persist, however, reducing the efficiency of the root system and stress tolerance, resulting in poor vigor and reduced yield.

Flea beetle damage may occur together with the disease complex. Flea beetles do not cause the hypocotyl to rot-off or constrict; however, they do eat portions out of the hypocotyl at, or below, the soil line.³

Seeds are vulnerable to seedling disease complex as soon as they take up water prior to germination. Fungi present in the soil grow with favorable conditions, or are stimulated by secretions from germinating seeds or roots of host plants. Fungi invade plant tissue and multiply, causing decay. The fungi form dormant bodies within, or on the surface of, infected tissue, until another host is available. At the two to four leaf stage, the below ground parts of the plant become sufficiently woody to withstand further infections. Vigorous, fast-growing seedlings reach this stage quickly, reducing the susceptible period, and withstanding infection better.³

Seedling disease complex accounts for most of the failure of viable seeds to emerge as seedlings and may result in partial to complete loss of the stand. Recommended seeding rates usually compensate for part of the loss, however, on some fields, reseeding is required.³

Seedling Disease Complex Management:

Cultural Control: Most critical to management of seedling disease complex is to promote quick germination and emergence. Certified seed should be planted ½ - 1 inch deep in firm, moist, adequately fertilized soil when the temperature is above 10°C. The greatest loss comes from seeding early into cold soils and from deep seeding. Canola should not be planted in a poor seedbed or one with harmful herbicide residues. Excessive fertilizer should not be placed with the seed, but adequate, balanced nutrition should be provided for the crop.³

Chemical Control: Treated seed is available and should be used. Results may be unpredictable because no single fungicide is effective against all three fungi. Captan and thiram protect the seed but are nonsystemic and cannot protect the seedling. Benomyl is systemic and effective against *Rhizoctonia* but ineffective against *Pythium*. Combinations of fungicide may be more effective than one used alone. Fungicide-insecticide combination seed treatments (Helix, available for limited use under a Section 18 registration for 2000) also provide early protection against flea beetle injury.³

White Leaf Spot and Grey Stem:

This disease is caused by the fungus *Pseudocercospora capsellae*. White leaf spots and large purple to grey

specked stem lesions appear as the crop ripens. Infected plants appear purplish or grey. Severe infection can cause leaf loss. The disease may develop earlier and be more severe in plants weakened by stress. The disease has a wide host range among cruciferous weeds.³

The fungus overwinters on crop residue as thick-walled mycelium. In spring, it produces wind-borne spores which infect canola. Following infection, white to buff-colored spots develop on lower leaves. These lesions produce wind-borne spores which cause the rapid spread of the disease in the ripening crop.³

White Leaf Spot and Grey Stem Management:

Crop rotation and control of volunteer canola and cruciferous weeds throughout the rotation will help reduce inoculum. Good crop production practices including weed control and proper fertilization will reduce plant stress and help delay disease development.³

Chemical Control of Diseases

Chemical control of disease in canola consists of seed treatment and/or foliar treatment. Fully registered seed treatments include benomyl, captan, fludioxonil, and thiram. Benomyl is the only seed treatment which provides control of the seed-borne phase of blackleg, and it is highly recommended for all canola seed planted in areas not yet infected with the severe strain of blackleg. The only fully registered foliar treatment is azoxystrobin. Section 18 label is approved for the 2000 growing season Helix (Novartis), and a Section 18 label is pending for the fungicide Ronilan (BASF).

North Dakota pesticide use surveys indicate that seed treatments are used on about 80% of planted fields in Northeast North Dakota (this region is similar to the main canola-producing region in Minnesota).²³ Quadris (azoxystrobin) is newly registered in the state, and use patterns have not yet been established. Minnesota has conducted no surveys on fungicide usage on canola.

Experts think that at the current time, Sclerotinia may be a primary driver of azoxystrobin applications. Most acreage is treated only once per season. There are no data for efficacy of Quadris in Minnesota.⁷

Fungicides Used on Canola

Active Ingredient	Product(s)	Registration Status	Rate	Notes
benomyl	Benlate, Benlate SP	Section 3	0.50 lb. AI/cwt.	Slurry seed treatment, the only fungicide seed treatment effective against seed-borne blackleg ¹³

captan	Captan 4000, 30DD, & 400	Section 3	0.03–0.06 lb. AI/cwt.	Seed treatment for some protection against seedling diseases ¹³ Not for use on ag. establishments.
fludioxonil	Maxim 4 FS	Section 3	0.0025-0.005 lb. AI/cwt.	Seed treatment for seed- and soil-borne fungi ¹³ Commercial use.
thiram	42-S Thiram, Thiram 50WP Dyed	Section 3	0.20 lb. AI/cwt.	Seed treatment for some protection against seedling diseases ¹³ Commercial use, slurry treatment.
azoxystrobin	Quadris	Section 3, newly available in 1999	0.1-0.25 lb.AI/acre	Foliar spray for Alternaria, blackleg, and Sclerotinia. Max 0.45 lb.AI/acre/season in max of 2 applications. For blackleg, use low rate at 2-4-leaf stage. For Alternaria and Sclerotinia apply up to the max rate at 10-25% bloom. For Alternaria only may be applied at pod stage (95% petal fall). Do not apply after 95% petal fall. New in 1999; usage patterns not yet established.

Potential Section 18 Fungicides for 2000

For the 2000 growing season, a maximum of 50,000 acres in Northwest MN may be planted with Helix-treated seed; treated seed is available via an approved Section 18. This seed treatment from Novartis contains the fungicides difenoconazole, fludioxonil, mefenoxam, and the insecticide thiamethoxam. Also for the 2000 growing season, a Section 18 is being pursued for the fungicide Ronilan. This fungicide from BASF contains the active ingredient vinclozolin, and is needed for control of white mold.¹⁰

Weeds

Once established, canola is a good competitor with many weeds. However, if uncontrolled, heavy weed infestations can cause 50% loss in canola yield, reduced seed quality, and increased dockage. Effective weed control programs should include crop rotation, tillage, cultural practices, and herbicide use. It is also important to integrate weed control in canola with weed control in the rotation crops. Weed control early in the season is

critical.⁵ Canola seedlings are very susceptible to early competition from weeds.^{2,22}

Common weeds of canola are discussed in the following categories: annual grass weeds, annual broadleaf weeds, and perennial weeds. Notes about the efficacy of cultural and chemical controls specific to a weed species are discussed under the heading for that species. Cultural controls with application to many weed pests are discussed in the section titled "Cultural Control of Weeds"; general chemical control information is presented last.

Annual Grass Weeds

Barnyardgrass, green foxtail, yellow foxtail, wild oats, and volunteer cereals are common annual grasses which infest canola in Minnesota. The postemergence herbicides quizalofop and sethoxydim generally provide good control of these grasses. Glyphosate also provides good control. Preplant-incorporated trifluralin provides good control of these weeds, with the important exception of wild oats, where it provides poor control in Minnesota, and the volunteer cereals, for which it provides poor to fair control.⁵

Barnyardgrass:

Echinochloa crus-galli is an annual grass with stems which are flattened near the base and grow along the ground before growing upward.^{17,18} Leaves are 2-20 inches long, flat or v-shaped, keeled below, and smooth to somewhat rough above. Plants produce about 7200 seeds per plant on compound spikes. Barnyardgrass prefers warm, moist soils.¹⁸

Barnyardgrass is susceptible to shading, and thus is usually not a severe problem if it emerges after the establishment of a tall, vigorous crop.¹⁸

Barnyardgrass Management:

Cultural Control: Because of its ability to root at the nodes and re-establish after light cultivation, barnyardgrass may not be controlled by tillage in minimum tillage programs.¹⁸

Chemical Control: Trifluralin, quizalofop, sethoxydim, and glyphosate may provide good control of barnyardgrass.⁵

Green foxtail:

Setaria viridis is an annual grass 8-24 inches tall, with an erect stem which branches at the base. Leaves of green foxtail are flat, hairless, and rough. It reproduces by seed. It produces about 34,000 seeds per plant; seeds are viable for about 3 years, and will not germinate if they are buried deeper than three inches.¹⁸ Green foxtail's floral structure is a dense spike with green to purplish bristles.¹⁷ The weed's root system is shallow. Green foxtail germinates slowly in most springs, at temperatures from 68-77 F, but grows quickly. This weed grows more vigorously in high temperatures.¹⁸

Because it is slow to germinate in cool spring weather, and because it is a poor competitor unless it grows in dense stands, green foxtail is not typically a strong competitor with canola. If spring weather is warm and wet, however, the weed becomes more competitive. ¹⁸

Green foxtail has little effect on canola yields. Densities as high as 100 plants per square yard reduce canola yields by less than 5%. Yield losses are more severe during seasons that start with hot spring temperatures. ¹⁸

Green foxtail Management:

Cultural Control: Because this weed is a poor competitor, it can be controlled by strong crop stands produced by early seeding and good fertilization. Canola competes well with this weed. ¹⁸

Chemical Control: Quizalofop, sethoxydim, trifluralin, glufosinate, and glyphosate may provide good control of green foxtail. ⁵ Under hot conditions, green foxtail grows quickly, potentially escaping the window for herbicide application. ¹⁸

Volunteer Cereals (barley and wheat):

Volunteer barley is a weed pest in canola sown into barley stubble. Barley seeds have no innate dormancy; infestations are rare in fields two to three years after barley is grown. Barley is an annual which reproduces by seeds. Plants tiller, producing smooth stems and wide smooth leaf blades. Large whitish auricles are present at the collar and clasp the stem. Flowers are borne on spikes; seeds are tapered at the ends, white to yellowish, and approximately 8 mm long by 4 mm wide. ¹⁸

Volunteer wheat is an annual which reproduces by seeds. The plant tillers to produce erect, smooth stems with wide, glabrous leaf blades. Flowers occur on spikes, and produce seeds which are reddish, oblong, and approximately 5-8 mm long by 3 mm wide. Seeds survive only 1-3 years in soil. ¹⁸

Both wheat and barley are highly competitive, and infestations reduce the yields of many economically important crops. Yield losses of up to 10-30% have been reported due to volunteer barley in rapeseed with weed densities of 30 plants per square yard. ¹⁸

Volunteer Cereals (barley and wheat) Management:

Chemical Control: Quizalofop, sethoxydim, glyphosate may provide good control of volunteer cereals. ⁵

Wild oats:

Avena fatua is an annual grass; the mature plant has smooth, erect stems up to four feet tall. Seeds have a hairy base, and are borne on open panicles which each contain up to 250 seeds. ¹⁸ Most seeds germinate within two years, but they can remain dormant for 7-12 years. ^{1,18} Seeds must be buried to germinate, and shatter from the plant when they mature. ¹ The weed prefers cool weather and moist soil. ^{1,18}

Wild oats is primarily a weed in spring-seeded small grains. Wild oats has become a major weed in the canola cropping system because spring-seeded grains are predominant crops in rotation, and because of the long seed dormancy of wild oats.¹²

Wild oats compete for light, moisture and nutrients, resulting in crop yield losses. A vigorous canola stand is strong competition for wild oats. Yield loss depends on the density of wild oats and the growth stage of wild oats vs. growth stage of canola. Left unchecked, 10 wild oat plants per square yard can reduce canola yields by 10%.¹⁸

Wild oats Management:

Cultural Control: Time of emergence of the crop relative to wild oats is critical in limiting the amount of yield loss wild oats will cause.^{1,18} Yield losses are greater when wild oats emerge prior to the crop, when wild oats grows more vigorously than the crop, or with increased density of wild oats.¹ However, established canola is competitive with wild oats; thus, a strong canola stand, in combination with practices that give the crop a jump on weeds (shallow seeding, good seedbed preparation, proper fertility, herbicide burnoff or tillage timed close to crop emergence or seeding), will limit the yield loss caused by wild oats.¹⁸

Chemical Control: Post-emergence treatment with sethoxydim and quizalofop gives good control of wild oats, as does glyphosate. Pre-plant incorporated trifluralin provides poor control of this species in Minnesota.⁵ (In Montana and North Dakota experiments, pre-plant incorporated trifluralin gave excellent control of wild oats.¹² However, the majority of studies, including those in Minnesota, have indicated that trifluralin gives poor to fair control of wild oats.^{5,16}) Herbicide resistance can be a problem with wild oats.¹⁸

Yellow Foxtail:

Setaria glauca is an annual weed which reproduces by seeds. The base tillers heavily, producing erect stems up to 3 feet tall. Leaves are smooth, up to 12 inches long, with long hairs at the base and margin surface. The leaf sheath is smooth, keeled and hairless. Flowers are borne on dense panicles with yellow bristles 1-4 inches in length. It generally prefers warmer regions.¹⁸

Yellow Foxtail Management:

Chemical Control: Quizalofop, sethoxydim, and glyphosate may provide good control of yellow foxtail.⁵

Annual Broadleaf Weeds

The most serious annual broadleaf weeds which commonly infest canola in the Northern Plains Region of the U. S. are redroot pigweed, Russian thistle, wild buckwheat, and wild mustard.¹² Smartweed is a localized problem in Minnesota. Other common weeds include cocklebur, kochia, lambsquarters, venice mallow, Eastern black nightshade, hairy nightshade, common ragweed, giant ragweed, wild sunflower, and marshelder.⁵

Redroot pigweed:

Amaranthus retroflexus is a common annual weed of the family Amaranthaceae which reproduces by seed. The plant has a pink to reddish taproot. The weed's 1-3 foot high stems are erect, light green, stout, branched, rough, and angular. Leaves are alternate, dull green, rough, ovate, and about 3-4 inches long. Small green flowers are borne on dense spikes in leaf axils; a large terminal spike is also produced. The seeds require temperatures of 70-85 F to germinate, and will germinate throughout summer if moisture is available. Redroot pigweed thrives on high temperatures and rich soils, but will grow almost anywhere. ¹⁸

Redroot Pigweed Management:

Cultural Control: Crops established before soils warm and hot weather sets in are very competitive with redroot pigweed. ¹⁸ No-till systems may favor redroot pigweed occurrence in canola. ¹²

Chemical Control: Good control may occur with pre-plant incorporated trifluralin, and with glufosinate and glyphosate. ⁵ Under hot conditions, redroot pigweed can advance through its growth stages quickly, potentially escaping the window for herbicide application. ¹⁸

Russian thistle:

Salsola kali is an annual weed of the Goosefoot family which reproduces by seed. Stems are up to 4 feet tall and are red-stripped. The plant may spread as much horizontally as vertically. Dark green leaves are narrow, fleshy, alternate, and about 1-2 inches long; later leaves are shorter and broader, with spines at the tips. Small (2mm), inconspicuous, green or pinkish flowers are borne in the upper leaf axils. Flowers produce brown to grey cone-shaped seed which is 2mm in diameter. ¹⁸ One plant may produce up to 200,000 seeds ¹⁸ which germinate rapidly, even after little precipitation. ¹² Russian thistle is a more severe problem in dryer areas and in no-till systems. ¹²

Russian thistle Management:

Chemical Control: Trifluralin and glufosinate may provide good control. Glyphosate may provide fair to good control. ⁵

Smartweed:

Polygonum pennsylvanicum is an annual weed which reproduces by seed. Stems are branched, 30 inches tall, and smooth. Leaves have a petiole with a papery sheath surrounding the stem. Leaves are up to 3 inches long and ½ inch wide, and are tapered at both ends. Some leaves may have a reddish thumbprint; lower leaves are hairless. Flowers are usually green, and are borne on dense terminal clusters and on short stalks in upper leaf axils. Each plant produces about 3,000 seeds. ¹⁸ Smartweed prefers moist soils. ^{12,18} This weed presents localized problems in Minnesota. ^{6,16}

Canola is typically a strong competitor against smartweed. Densities of 15-20 plants per square yard in canola will reduce yields by 4-5%. If densities reach 100-200 plants per square yard, yields may be reduced by 25-50%.

Smartweed Management:

Chemical Control: Herbicide 273 (Elf Atochem) provides control ¹⁶ and had a section 18 for 1999, but will not be available in 2000. ¹⁰ Glufosinate and glyphosate both may provide good control of smartweed. ⁵

Wild buckwheat:

Polygonum convolvulus is an annual weed which reproduces by seed. Stems are angular, 1-3 feet long, and branch at the base. The stems trail on the ground or twine on other plants. Leaves are heart-shaped, alternate, smooth, and about ½ - 2 inches long. Small greenish-white flowers are borne in leaf axils or are terminal. Each plant produces about 1200 seeds. Wild buckwheat thrives in most soil conditions. ¹⁸ Wild buckwheat becomes more prevalent when dicotyledons are introduced into the crop rotation. Buckwheat is less competitive than wild oats in canola, however, it is still an important weed pest. ¹²

Wild buckwheat Management:

Chemical Control: Wild Buckwheat is most sensitive to herbicides in its early stages. ¹⁸ Trifluralin, although labeled for control of some small-seeded broadleaf weeds, gives poor control of wild buckwheat. Pre-plant incorporated trifluralin provided fair to good control of wild buckwheat in Montana; however, this is the exception rather than the rule. With the exception of Section 18 labels of clopyralid on canola, which was available in 1999 and may be in 2000, no registered herbicide controls wild buckwheat. Clopyralid gives fair to good control of wild buckwheat. Glufosinate may provide good control. ⁵

Wild mustard:

Brassica kaber is an annual or winter annual of the Mustard family and is closely related to canola. Wild mustard reproduces by seed. ^{12,18} Stems are branched, erect, about 3 feet tall, and have with short, stiff, downward-pointing hairs, particularly on the lower part of the stem. As the plant matures it develops purple coloring down the stem and near the leaf nodes. Leaves are alternate, coarsely-toothed, and upper leaves have petioles. Flowers are bright yellow. Each plant produces 2,000-3,500 brown to black seeds which are similar in size and shape to canola seed. Early season dry conditions will help keep wild mustard populations low; this weed thrives in cool, moist conditions. ¹⁸ Wild mustard seed can remain dormant in the soil for many years. ¹²

The threshold for wild mustard in canola is 3 plants per square yard. ¹⁸ Wild mustard seed can be a serious contaminant of canola seed. ^{12,18} Because it is so similar to canola seed, it is impossible to separate by conventional methods. Densities as low as 20 plants per square yard in canola may result in wild mustard accounting for up to 5% of the harvested seed, which is the maximum tolerance of wild mustard in any grade of canola. ¹⁸

Wild mustard Management:

Under cool, moist conditions, wild mustard grows quickly and can quickly escape the window for herbicide application.¹⁸ No chemical is available for control for general production, but a Section 18 will be available in 2000 for seed production fields only. There is very little canola grown for seed production in Minnesota.^{10,16}

Other Annual Broadleaf Weeds:

Other annual broadleaf weeds which infest canola in Minnesota are cocklebur, kochia, lambsquarters, venice mallow, Eastern black nightshade, hairy nightshade, common ragweed, giant ragweed, wild sunflower, and marshelder.⁵

Perennial Weeds

The important perennial weeds which infest canola in Minnesota are Canada thistle, quackgrass and sowthistle.⁵

Canada thistle:

Cirsium arvense is a perennial weed in the Composite family which reproduces both by seed and vegetatively via its deep, extensive root system. Plants will emerge along horizontal roots, creating patches of infestations. Purple, pink or white flowers in branched clusters at the ends of stems produce seeds with attached white hairs which aid in seed dispersal. Canada thistle produces about 700 seeds per plant.¹⁸ Flowering begins in mid-June.¹

Canada thistle is a strong competitor, approximately 3-4 times more aggressive than wild oats.¹² At one plant per square foot, the weed can cause yield losses in canola of 16%; this increases to nearly 60% yield loss at five plants per square foot.¹

Canada thistle Management:

Control of Canada thistle requires an integrated control strategy planned and implemented over several years. This may include tillage, patch mowing, in-crop herbicides, and pre-harvest and post-harvest herbicides, and proper crop rotation (avoiding crops with poor competitive ability and no in-crop herbicide options). Recognizing the problem and being persistent with control measures are critical to success.¹⁸

Cultural Control: Tillage alone will not control Canada thistle, but it may increase the effectiveness of a total management strategy which would include use of herbicides. Tillage in late fall gives mixed results, and can either increase or decrease an infestation. It may reduce the number of shoots, and may delay emergence the following spring of many shoots by about 1 month (this delay in emergence can give the crop a competitive advantage). However, tillage can also aggravate a thistle problem. Small fragments of Canada thistle often survive adverse conditions and regrow to spread and expand the infestation. Under favorable conditions, even a ½ inch length of root can generate new growth.¹⁸ Cutting roots through

sporadic tillage without additional chemical control measures increases patch size and establishment. ¹²

Chemical Control: Although top growth could be controlled by spraying broadleaf herbicides, this is not an effective control measure. Canada thistle has a massive capacity to produce roots and shoots; thus, killing the top-growth will not control Canada thistle, as the plant will regrow and reproduce vigorously from its root system. The only way to completely control Canada thistle is use of a herbicide that translocates deeply into the roots. ¹⁸

Clopyralid, which had a Section 18 in 1999, gives good control of Canada thistle if applied when Canada thistle plants are 6-8 inches tall or wide, and are before bud stage. ^{5,16} A second good control option may be treatment in the fall with glyphosate or clopyralid plus 2-4D, prior to the season when canola is grown. ¹⁶ There are no other acceptable chemical controls available. ¹⁰

Quackgrass:

Agropyron repens is a perennial grass reproducing by seeds and by rhizomes. Stems are smooth and 1-4.5 feet tall, with flat leaves which are somewhat hairy on the upper surface. Yellow or white seed is borne on flattened spikelets which are attached in two parallel rows to the flower stalk; seeds are viable for more than one year. Quackgrass reproduces and spreads primarily via rhizome formation. Compounding the negative effects of and infestation, quackgrass is allelopathic. Quackgrass grows most vigorously in cool, moist conditions. ¹⁸ Quackgrass is about as competitive as wild oats. ¹²

Quackgrass Management:

As with Canada thistle, a multi-year integrated control plan must be used for control of quackgrass. The economic threshold in canola is about 20-25 shoots per square yard. ¹⁸

Cultural Control: Broken or cut rhizomes remain viable, therefore mechanical control is difficult. ¹² Tillage may decrease quackgrass density or may spread the rhizomes, which then will spread the weed. Quackgrass patches should be tilled into the center of the patch to limit the spread of the rhizomes. ¹⁸

Chemical Control: Quizalofop will suppress quackgrass if used with a crop oil concentrate or a nonionic surfactant (with the exception of vegetable oil additives). Sethoxydim provides only fair control, even at the high labeled rates. Preplant incorporated trifluralin provides poor control of quackgrass. ⁵ Glyphosate applied pre-seeding or post-harvest will control quackgrass, but pre-harvest applications are the most effective. ¹⁸ Use of Liberty-Link canola with glufosinate will not manage quackgrass. ⁵

Perennial Sowthistle:

Sonchus arvensis is a perennial weed that reproduces both by seed and by its horizontal, underground roots which can penetrate 5-10 feet. Stems are erect, smooth, hollow, 2-4 ft. high, and branch at the top. Stems exude a milky sap when cut. Leaves are 6-12 inches long, alternate, and toothed; lower leaves have deeply-cut, backwards-pointed side lobes, and upper leaves are slightly-toothed and smaller. Yellow flowers are produced at the ends of branched stems. Flowers mature into fluffy white seed heads

containing brown seeds with white hairs attached; seeds are dispersed by wind. Sowthistle prefers moist, fertile soils and typically occurs in patches.¹⁸ Sowthistle is commonly found with Canada thistle.¹

Yield losses in canola in Minnesota are not available, but in Saskatchewan, perennial sow-thistle densities of 10 shoots per square meter reduced rapeseed yields by 18%.¹

Perennial Sowthistle Management:

Control measures must employ a multi-year integrated control plan similar to that for Canada thistle.

Cultural Control: Mechanical control may increase or decrease infestations. Tillage may increase infestations by moving weeds to new areas of the field or by breaking dormancy of underground buds, resulting in new shoot growth. Tillage during cool, wet conditions provides little control.¹⁸ In order to be effective, tillage should be frequent and deep, a practice which may not be economic and may increase soil erosion.¹

Chemical Control: Pre-harvest applications of clopyralid may provide fair to good control of perennial sow thistle. Glyphosate provides better control.⁵

Cultural Control of Weeds

Because of the limited number of herbicides available for use in canola, a weed management program must involve integrated weed management, including mechanical and cultural controls, crop rotations, and herbicides.⁵

Early-season tillage (prior to canola seedling emergence) can provide some control of annual weeds which have germinated. If annuals are controlled adequately in the first weeks of the season, good season-long control should result, since canola, once established, will compete well with these weeds. However, tillage has little effect on annual weeds which have not yet germinated. Early-season tillage may also be useful for suppression of biennial and perennial weeds. Additionally, tillage and/or herbicide application in the previous fall, following harvest of the preceding crop, will help manage perennials and will reduce the number of weeds which go to seed (thereby reducing the weed seed in the soil).⁵

Preplant incorporation of Trifluralin is strongly recommended. It provides good control of most annual grasses, pigweed, and common lambsquarters early in the season, allowing canola to become established and thus gaining a competitive edge over some weeds. Postemergence herbicides may still be needed to control specific weeds.⁵

Canola should be seeded at the optimal rate indicated, since recent data suggests that seeding rate affects canola's ability to compete with weeds. It is important to establish a vigorous and uniform stand of canola to optimize its competitive ability.⁵ Herbicide-resistant varieties may be considered.

Good control of perennials requires consistent management throughout all crops in the crop rotation system. Good weed management in crops preceding canola in rotation should also be used to reduce the

amount of viable weed seed in the soil. If land has heavy infestations of weeds which cannot be controlled with herbicides registered on canola, a different crop should be planted.⁵ In the crop rotation, cereals should follow canola to allow the use of broadleaf phenoxy herbicides to control volunteer canola and other broadleaf weeds.¹⁶

Chemical Control of Weeds

Because canola is a relatively new crop in Minnesota, herbicide usage is not well established. Data for selected chemicals is gathered to maintain Section 18 registrations, which change from year to year. No pesticide use surveys have been done for canola in the state. Thus, we do not have information specific to Minnesota for some of the herbicides which are used in the state. Please refer to text about specific weeds or weed classes in the section above for information about efficacy of chemical products against particular weed pests.

There are three herbicide resistant canola varieties available which, when used, provide the grower with effective options for weed control. These varieties are Liberty-Link (for use with Liberty (glufosinate-ammonium)), Roundup Ready (allows use of Roundup (glyphosate) in the crop), and Imi-tolerant (allows for use of Raptor (imazamox) in the crop). The herbicides associated with these resistant varieties should only be used as a postemergence herbicide on the variety intended. Roundup is registered for use in 2000, a Section 18 registration is approved for Raptor, and a Section 18 is pending for Liberty.

Herbicide application is typically done by the grower, via ground. In 1996, the Northeast region of North Dakota (which is the region most similar to Minnesota's main canola-producing region) treated about 75% of canola acreage with herbicides (this may be artificially high because multiple treatments to the same acreage were totaled as separate values).²³

Herbicides Used on Canola

Active Ingredient	Product(s)	Registration Status	% Acres Treated
glyphosate	Roundup	Section 3	0.2*
quizalofop-ethyl	Assure II	Section 3	3.6*
sethoxydim	Poast	Section 3	44.8*
trifluralin	Treflan	Section 3	35.2*
clopyralid	Stinger	1999 Sec. 18, 2000 Sec. 18 approved	2.14**
ethalfluralin	Sonalan	1999 Sec. 18, 2000 Sec. 18 pending	2.45**
glufosinate-ammonium	Liberty	1999 Sec. 18, 2000 Sec. 18 pending	4.26**

imazamox	Raptor	1999 Sec. 18, 2000 Sec. 18 approved	9.8**
endothall	Herbicide 273	1999 Sec. 18, <i>not available in 2000</i>	4.71-7.06**
ethametsulfuron methyl	Muster	1999 Sec. 18, <i>not available in 2000;</i> for seed fields only	2.35**

* Data obtained from North Dakota's 1996 Pesticide Use and Pest Management Practices for Major Crops in North Dakota.²³ Percent acreage treated may be over-represented; multiple applications to the same acreage are totaled separately.

** Data obtained by the Minnesota Department of Agriculture in support of Section 18 registrations.¹⁰ Percent acreage treated may be over-represented; multiple applications to the same acreage are totaled separately. It should be noted that pesticide use in 1999 was affected by reduced planting caused by excessive spring rain. Percent acreage treated is based on 1999 harvested acreage of 102,000.

Potential Section 18 Herbicides for 2000

For the 2000 growing season, Section 18 registration for Raptor (imazamox, for use on IMI canola), Liberty (glufosinate-ammonium, for use on Liberty-Link canola), Sonalan (ethalfluralin, for control of kochia), and Stinger (clopyralid, for control of thistle) are being pursued.¹⁰

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