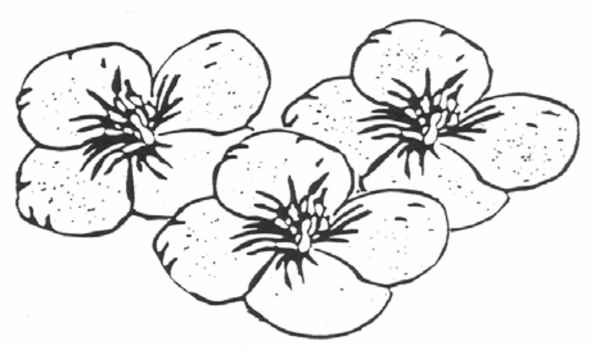
U.S. Canola Association

Canola Growers' Manual



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DISCLAIMER

All insecticides, herbicides, pesticides and fungicides are poisonous and must be handled with care to protect the operator, adjacent crops, livestock and property. This document offers recommendations based on the best available information at this time. Users must read and follow label directions of all chemical products. Although trade names are mentioned, no endorsement of named products is intended, nor is criticism implied of similar products not mentioned.

GLOSSARY OF TERMS AND CROP DESCRIPTIONS

Distinguishing between different Brassicaceae oilseed crops and between the end use oil and seed products can often be confusing. For the purposes of this publication, the following terms will be used throughout:

- **Rapeseed oil** refers to the industrial form of oil derived from *Brassica* or *Sinapis* species. **Rapeseed cultivars** have high concentrations of erucic acid, a 22-carbon, single double-bond fatty acid, in the seed oil. Older rapeseed cultivars can have high glucosinolate content in the seed meal, although all newer cultivars have low glucosinolate content (i.e., comparable to canola, less than 30μmoles of total glucosinolate per gram of defatted seed meal). Rapeseed lines are often referred to as high-erucic acid rapeseed (HEAR) cultivars.
- **Canola oil** refers to the edible form of oil produced by *Brassica napus, B. rapa* (synonymous with *B. campestris*) and more recently from *B. juncea*. This definition is in compliance with the Canadian standard where the oil must contain less than 2 percent erucic acid and where the residual meal contains less than 30 μmoles of total aliphatic glucosinolate per gram of defatted meal. **Canola cultivars** are often referred to as low-erucic acid rapeseed (LEAR) cultivars. In the past few years, another mustard species (*Sinapis alba*) has been modified to produce the same oil profile and meal quality as canola and it is hoped that in the future, these also may be considered as canola species.
- **Specialty oil canola cultivars** have been introduced in recent years. Specialty oil canola cultivars are either low-linolenic (LOWLIN) or high-oleic, low-linolenic (HOLL) cultivars. Both LOWLIN and HOLL have high fry quality and a long shelf life without hydrogenation.

Canola oil is used primarily as an edible oil product for a range of cooking applications, margarine, salad dressings and shortenings.

Rapeseed oil is used for industrial purposes (e.g., high quality lubricants, hydraulic fluid, slip agents, foam suppressants, surfactants, transmission fluids, cutting fluids, plastics, and high quality polymers). Rapeseed oil can also, however, be used in food processing (e.g., candy bars or as an emulsifier in peanut butter).

Both canola and rapeseed oils can be used to produce automotive biodiesel fuel, lubricants, surfactants, cutting agents, plastics and printing inks. However, one should note that higher quality non-food products will derive from feed stock oils with specific characteristics. For example, biodiesel made from oils with low saturated fat have improved cold flow properties, while those with low polyunsaturated fats have lower nitrous oxide (NO_x) emissions. Similarly, oils high in erucic acid have significantly higher lubricity compared to other vegetable oils.

INTRODUCTION

Demand for canola oil in the U.S. has increased dramatically since the U.S. Food and Drug Administration (FDA) granted "Generally Recognized as Safe" (GRAS) status to the crop in 1985. Since then, canola products have been rapidly accepted in the U.S. A key factor driving U.S. demand for canola oil is its potential health benefits. According to data from the National Center for Health Statistics, the leading cause of death in the U.S. is coronary heart disease (CHD). Health studies have implicated several risk factors for CHD, one of which is a diet high in saturated fats. Additional studies have shown that a diet low in saturated fat and high in monounsaturated fat can play a major role in decreasing the risk of CHD by lowering low-density lipoprotein cholesterol levels and serum cholesterol levels. Canola oil fills this niche, having the lowest level of saturated fat of all edible oils and the second-highest level of monounsaturated fat (Figure 1.1).

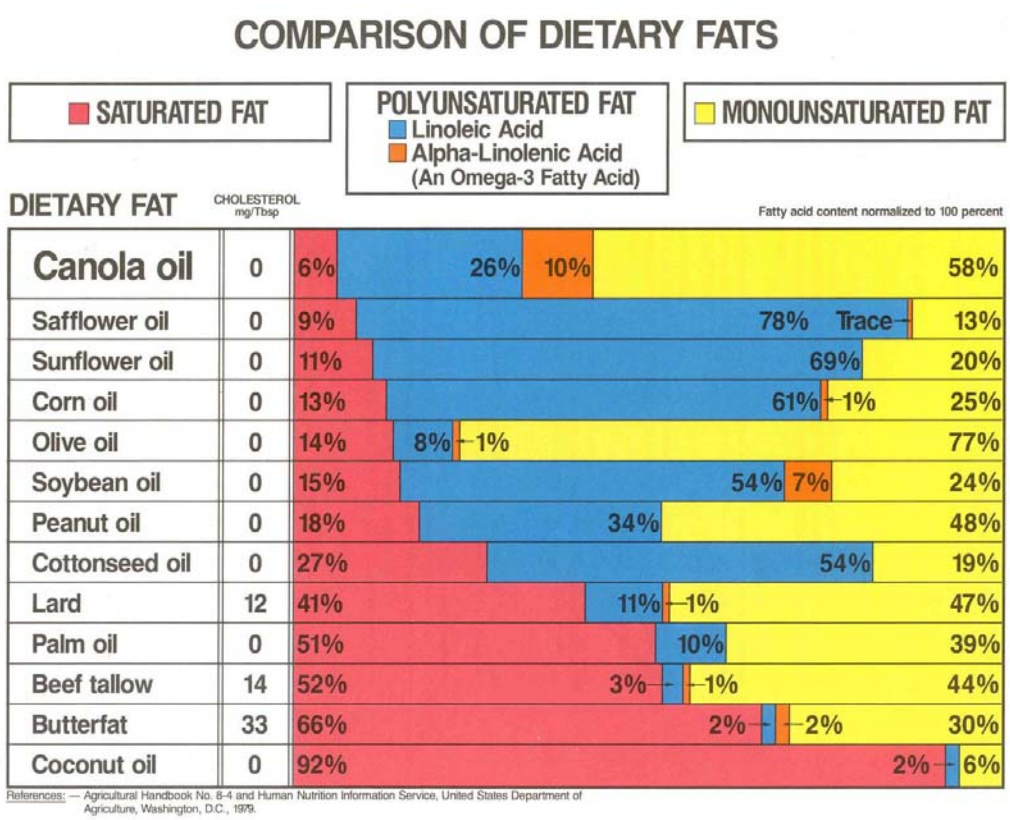


Figure 1.1. *Dietary fats (fatty acid profile) of major edible oils.*

More recent medical research has proven that hydrogenated fats, which contain *trans* fatty acids, have adverse effects on human health. The FDA now requires *trans*-fat content to be listed on all food products. Traditional canola oil, although low in saturated fat, is usually hydrogenated to avoid off-flavors in high-temperature frying and to increase shelf life of the oil products. Rancidity and off-flavors in canola oil are caused by oxidation of alpha-linolenic acid, and hence, products made from traditional hydrogenated canola oil are relatively high in *trans* fats. This has lead to several breeding groups to develop cultivars low in polyunsaturated fats (i.e., alpha-linolenic acid) or high in monounsaturated fats (i.e., increased oleic acid over reduced linoleic and alpha-linolenic acids). These cultivars produce oils that show higher thermal stability, lower levels of oxidation products and increased shelf life with minimal hydrogenation and hence can be use in *trans*-fat free products.

Compared to other sources of vegetable oil (e.g., soybean, cottonseed, peanut, etc.) rapeseed oil (industrial oil types of canola) is unique in having fatty acid chains longer than 18 carbons (e.g. ecosenoic, 20:1; erucic, 22:1; and nervonic, 24:1). High concentrations of these long-chain fatty acids give the oil unique properties in stability, lubricity and viscosity that make this vegetable oil highly suitable for industrial applications. Therefore, there is a high probability that demand for industrial vegetable oil will increase greatly over the next two decades. The industrial oil of choice for many of the potential uses (e.g. lubricants, cutting fluids, surfactants, paints, hydraulic fluid, transmission fluid, and others) is very likely to be from rapeseed crops.

Similarly, interest in biodiesel has increased over the past five years due to environmental concerns of using fossil-based fuels combined with rising costs of traditional diesel fuel. Some believed that biodiesel could be made with equal quality from all feed-stocks, and that the cost of raw feed-stocks was the limiting factor. Experience has shown that a high proportion of saturated fat in a feed-stock results in biodiesel which will gel at relatively high temperatures. Soy oil has 15 percent saturated fat and soy biodiesel will gel at 30 ^{o}F. In contrast, rapeseed oil has 4 percent saturated fat and does not gel until temperatures are below 10 ^{o}F. Although particulate matter, carbon monoxide (CO) and carbon dioxide (CO_2)are significantly reduced in all biodiesel fuels compared to fossil diesel, biodiesel has higher levels of NO_x, a principal contributor to acid rain, than traditional diesel. It has been shown that NO_x emissions are directly related to polyunsaturated fats in a feed-stock oil. Soy with 65 percent polyunsaturated fats has significantly higher NO_x emissions compared to rapeseed with 10 percent polyunsaturated fats.

Relative to canola oil consumption, U.S. canola production has been comparatively low. Small grain cereals (winter and spring wheat and spring barley) are the predominant crops grown in the dryland U.S. regions of agriculture. Corn and soybean represent the major crops for the Midwest region with wheat as the principal winter crop. Recent changes in agricultural policy and an increased awareness of the risks associated with monoculture agriculture have prompted a desire to have more crop options for rotation with small grain cereals. Therefore, while farmers might profit from growing cereal in the short term, dependency on one or two crops in the long term leaves farmers vulnerable to many production problems and market price volatility. However, very few non-cereal crops, with the exception of canola, have shown any adaptability for commercialization in these regions. Canola crops fit well into rotations with other small grain crops. In Europe, canola crops have been recognized for their value in crop rotations with small grain cereals. Compared to continuous cereal production, 17 percent to 20 percent yield increases have been found when canola crops are included in rotation. Canola rotations dramatically reduce pathogens in soil and straw residue. In the U.S., wheat following canola has significantly less sub-crown internode damage and crown blackening, caused by take-all disease, than wheat planted after plowed or burned cereal stubble. When canola is incorporated in small grain rotations, disease incidence on cereal crops decreased and quality increased.

The reasons for the advantageous rotational benefits of canola and rapeseed crops are not fully understood. However, most non-seed plant parts of these plants contain glucosinolates. These organic compounds break down in the soil into toxic compounds that have been proven to have insecticidal, nematicidal and fungicidal properties. In addition, growing canola crops improves the physical soil structure and increases soil fertility. These crops all have a long taproot that can improve soil structure and utilize nitrates deep in the soil. An average canola crop will provide as much residue as a normal cereal crop. For example, a canola crop yielding 2,000 kilograms per hectare of seed will also produce approximately 3,000 to 4,000 kilograms per hectare of dry plant residue, which increases the organic matter content of the soil.

Concern over soil erosion, soil physical properties and sustainability of farming has stimulated growers to adopt direct-seeding practices. In addition, greater interest in reducing input costs has accelerated interest in these one-pass planting systems. Direct-seeding systems have the potential to reduce soil erosion, increase water-use efficiency, reduce weed problems and increase profitability. Greater acreage of direct seeded crops has highlighted the need to have suitable crop rotations that reduce weed and disease pressures. For expansion and increased adoption of conservation farming technologies, growers need non-cereal rotation crops, and canola crops are the most reasonable candidates to fill this niche. Furthermore, canola can be planted and harvested using small grain equipment, so little capital investment is needed to grow this crop.

High demand for canola products resulted in a rapid increase in canola imports into the U.S. In 1988, consumption of canola in the U.S. was less than 12,000 metric tons, while in 1993, U.S. consumption was 500,000 metric tons. Similarly, in 1994, 162,000 metric tons of canola seed and 395,000 metric tons of canola oil were imported to the U.S. (mainly from Canada) at an estimated cost (at that time) of $3 million and $206 million in seed and oil imports, respectively. It has been estimated that the health advantages of canola oil will mean that demand for it in the U.S. will exceed 900,000 metric tons in the near future.

Increased demand for canola oil has resulted in an increased canola acreage. In 1991, only 147,000 acres of canola were harvested in the U.S., while over 1 million acres were harvested in the U.S. in 1998 (Figure 1.2). U.S. canola production peaked in 2000 when almost 1.5 million acres were harvested. The vast majority of the U.S. canola acreage has been from North Dakota and, to a lesser extent, Minnesota (Figure 1.3). The acreage in all regions has shown considerable fluctuation over the past 10 years and each follow a similar trend. Other U.S. states have never collectively harvested more than 123,000 acres of canola in any one year. However, in recent years, acreage in other production states has increased due to growing demand for canola oil for both food and biodiesel.

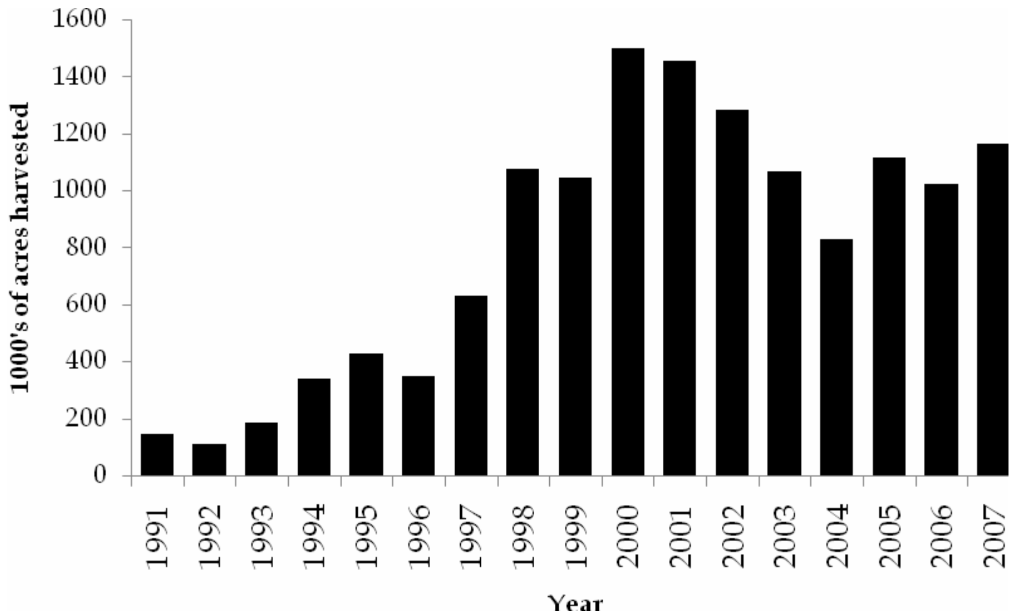


Figure 1.2 *Total acres of canola harvested in the U.S. 1991 to 2007.*

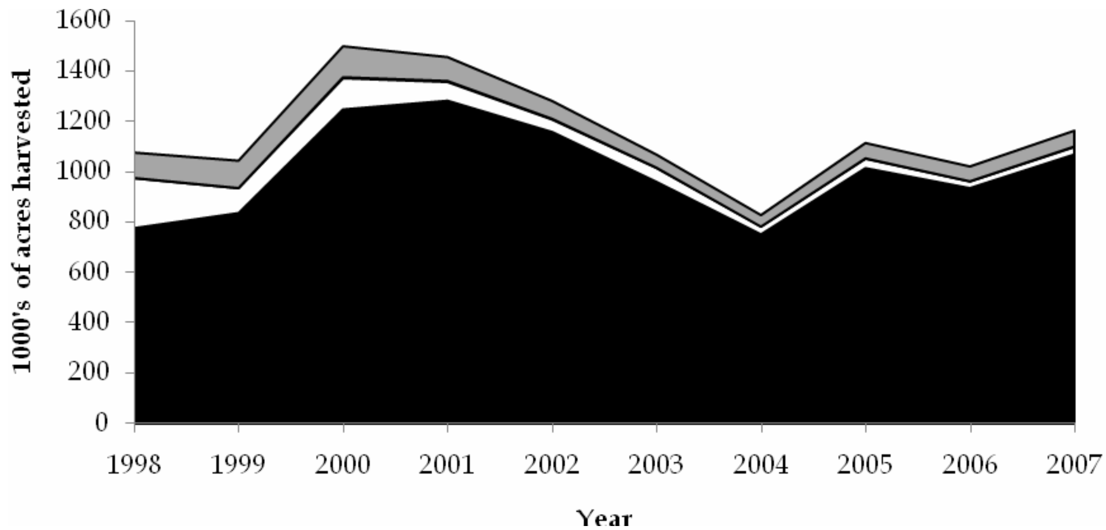


Figure 1.3. *Acreage of canola harvested in the North Dakota (solid black area), Minnesota (white area) and other U.S. states combined (grey, top, area) from 1998 to 2007.*

Many growing regions of the U.S. benefit significantly by adding canola crops to their rotation. The demand for canola products, whether oil or seed meal, is currently very high in the U.S. and imports continue to rise. Therefore, it is critical to increase U.S. canola acreage. To achieve this, growers need:

- Information about canola cultivars that are highly adapted to specific growing regions and high-end use quality; and

- Access to information on the most appropriate agronomic practices to maximize cultivar potential, reduce growing costs, and hence, optimize grower profitability.

This grower guide aims to address these issues.

BOTANICAL DESCRIPTION OF CANOLA

The major canola (and rapeseed) species include *Brassica napus*, *B. rapa*, and more recently *B. juncea*. *B. napus* and *B. juncea* are both hybrids developed through natural hybridization between *B. rapa* x *B. oleracea*, and *B. rapa* x *B. nigra*, respectively. The relationship between these, and other *Brassica* species, is shown in Figure 1.4 (commonly called the Triangle of U, after the famous *Brassica* researcher Dr. U (U, 1936)). Shown within circles in the triangle are the different species involved. Each species has its own specific genome (uppercase italicized letters, i.e., *AA* for *B. rapa*), and chromosome number (i.e., *n* =10, for *B. rapa*).

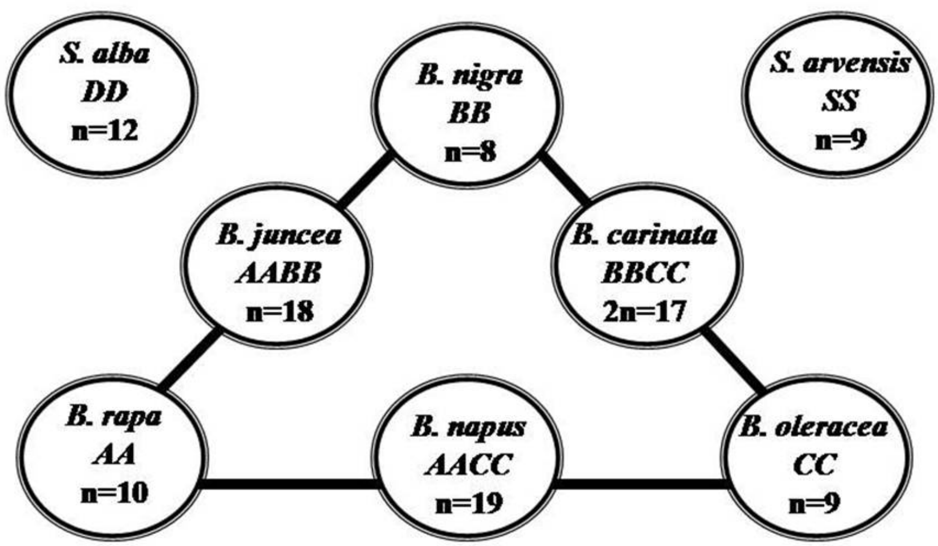


Figure 1.4 *Cross-pollination relationship between Brassica and Sinapis species commonly referred to as the Triangle of U (U, 1936).*

In the Triangle of U, three *Brassica* species are diploid; *B. rapa* (*A* genome), *B. nigra* (*B* genome), and *B. oleracea* (*C* genome), and three other species are believed to have resulted from natural crossing of these diploids; *B. napus* (*AC* genome; *B. rapa* x *B. oleracea*), *B. juncea* (*AB* genome; *B. rapa* x *B. nigra*), and *B. carinata* (*BC* genome; *B. nigra* x *B. oleracea*). *B. napus* is the predominant canola species grown in the U.S. Note also that the two *Sinapis* species (*S. alba* and *S. arvensis*) are often shown in the Triangle of U diagram, but they are not considered to be cross compatible with the *Brassica* species.

Canola plants are relatively tall, ranging from 120-180 centimeters, and have a long and slender taproot. Plant stems are branched, with each branch terminating in an elongated spike. Flowers are mainly yellow with four distinct sepals and petals, six stamens and one carpel. Canola belongs to the family *Brassicaceae*, which is derived from the Latin word crux, meaning cross, a reference to the arrangement of the flowers with four petals diagonally opposite each other. Plants have dark bluish-green foliage that is waxy and smooth.

Although reports of cross-fertilization between canola plants through insect pollination has been reported to exceed 30 percent of seed set, the majority of canola (*B. napus* and *B. juncea*) seeds are set through set pollination because the self-incompatibility from their diploid ancestors is overcome as a result of polyploidy (containing more than two sets of chromosomes). Therefore, canola is primarily self-pollinating and can produce high yields without insect pollination. *B. rapa* canola, however, is a diploid species with a strong self-incompatible system which can result in over 95 percent cross-pollination.

Canola is a cool season crop with both spring and winter varieties (*B. napus* and *B. rapa*) that require rich soil and a moist environment. *B. juncea* canola cultivars are all spring types. These types require an average of 100-125 days from seeding to harvesting. *B. juncea* and *B. juncea* canola species are generally 10-14 days earlier than *B. napus* types. Crops grow best when temperatures are between 54 ^{o}F and 86 ^{o}F (12 ºC and 30 ºC), with optimal temperature for maximum growth and development being 68 ^{o}F (20 ºC).

HISTORY OF CANOLA

The earliest records of rapeseed (canola) have been found in ancient Sanskrit writings of 2000-1500 B.C. in Asia. Japanese literature discusses cultivation of rapeseed in Korea and China 3,000 years ago. However, these ancient records lack sufficient information to be conclusive and modern authors speculate that rapeseed has multiple areas of origin. *B. napus* and *B. rapa* rapeseed are believed to have originated in the Mediterranean and *B. juncea* probably originated in northern India. These crops are currently grown commercially as oilseeds in regions of China, Canada, Europe, India, Pakistan, Australia and more recently, in the U.S.

Europe and northern Africa have records of growing rapeseed because of an inability to cultivate olive or poppy seed oil. By the 13th Century, Northern Europe was growing rapeseed for lamp oil and by the 17th century, Germany and Spain also began cultivation of rapeseed, primarily as a lubricant for the large number of steam engines being used in the Industrial Revolution. In the 19th Century, fossil oil was discovered, resulting in a decrease of rapeseed production in many regions of Europe.

Rapeseed was not widely cultivated in the Americas until the 1920s. During the Second World War, the allied navies required vast quantities of lubricating oil for their fleets of steamships. Rapeseed oil, high in erucic acid was the oil of choice since it is very stable at high temperatures in the presence of water or steam. At this time, Canada was growing oats on several millions of acres to feed horses which were used to work the land. The introduction of tractors in the 1930s and 1940s significantly reduced the number of horses on farms and the demand for oat feed. War time demand, combined with Canadian farmer needs to rotate from oats, caused Canada to produce rapeseed on a much larger scale. By 1945, canola crops had replaced a high proportion of the Canadian oat acreage.

However, the end of World War II saw a dramatic reduction in the number of steamships. In addition, steam-powered ships were replaced with diesel and later nuclear power, and the demand for industrial grade rapeseed oil dropped. A major disadvantage of using rapeseed for human consumption is that the oil contains high concentrations of erucic acid. The Canadian growers had a well-adapted crop but no demand for the industrial oil produced. At this point, the history of canola was dramatically altered by the breeding efforts of two Canadian scientists, Dr. Keith Downey and Dr. Baldur Stefansson, who made two important genetic modifications to rapeseed. First, a two-gene modification was identified that affected fatty acid elongation and reduced the proportion of the long erucic acid carbon chains while increasing oleic acid. The first low-erucic acid cultivar ('Oro') was commercially released in 1966. Secondly, at that time, all rapeseed cultivars had relatively high concentrations of glucosinolates in the seed meal. Breakdown compounds from glucosinolates greatly reduced the feed value of the meal. Drs. Downey and Stefansson identified low-glucosinolate characteristics in a Polish cultivar called 'Bronowski' and this trait was introduced into adapted germplasm and the first '00' cultivar (double-low, low-erucic acid and low glucosinolates) was released in 1974 ('Tower').

Because most cultivars of rapeseed originally contained high concentrations of erucic acid in the seed oil and were not considered edible quality, a new name was needed for the newly developed cultivars (and oil products) with lower concentrations of erucic acid. In 1978, the Rapeseed Association of Canada (later to become the Canola Council of Canada) chose the word "canola" to become the registered trademark for edible rapeseed oil with less than 2 percent erucic acid in the seed oils and less than 30 µmol of aliphatic glucosinolates per gram of oil-free seed meal. Canola cultivars became popular in the late 1970s, and are now grown worldwide for edible oil.

In 1985, the U.S. Food and Drug Administration granted GRAS status to canola oil containing less than 2 percent erucic acid for human consumption, and to canola seed meal with less than 30 µmol per gram of aliphatic glucosinolates suitable for live stock feed. GRAS status greatly increased the edible canola oil market in the U.S. In 1983, canola and rapeseed became the most widely grown non-cereal crops in North America.

CULTIVAR TYPE

The first decision that any canola grower needs to consider before embarking on choosing to grow a canola crop is the type of cultivar which will perform better in their region and in their cropping system. There are generally three types of canola crops that can be grown in the U.S., which include:

- Winter canola, which is planted in the fall, overwinters and requires vernilization over the winter months to produce flowers. It is harvested the following summer. This vernilizing crop is generally produced in the Pacific Northwest, Great Plains and Midwest regions of the U.S.
- Winter canola, which is planted in the fall, overwinters but does not require vernilization to produce flowers. It is harvested the following summer. These crops are produced only in the southeast region of the U.S.
- Spring canola, which is planted in the early spring, requires no vernilization to flower, and is harvested in late summer. These crops are grown mainly in the northern states, including North and South Dakota, Minnesota, Montana, Idaho, and Washington.

Although all the above crop types are available from the species *B. napus* and *B. rapa, B. juncea* is only a spring-planted crop. Winter and spring canola require different agronomic practices and can be effected by different pests and diseases. Hence, growing practices will be considered for each crop type separately.

WINTER CANOLA

Land Choice

Canola can be grown on a wide range of different soil types. However, highest seed yields are usually obtained with well-drained silt loam soils that do not crust. Winter canola is very susceptible to saturated soils and canola should not be planted in fields with poorly drained soils, standing water, or in fields that have a history of flooding. Ideal soil pH for growing canola is between 6.0 and 7.0. Canola should not be grown in soils with a pH less than 5.5 as seed yields will be adversely affected.

Growers should not replant canola the year after a previous canola crop to avoid a buildup of soil-borne diseases like Sclerotinia stem rot, blackleg, or club root. Canola crops should be planted only once every four years. Similarly, growers should avoid planting canola after other crops like legumes (pea, lentil, chickpea, soybean, field or dry bean) or sunflowers which are susceptible to *Sclerotinia*, *Rhizoctonia* and *Fusarium* root rots. Canola is most commonly grown following small grain cereals (winter or spring wheat, barley, corn or sorghum).

Canola crops are highly sensitive to herbicide carryover in the soil, and it is essential to know the herbicide use history of any field before planting canola. Soil residual herbicides can cause severe yield loss and crop failure. Many herbicides used in cereal production have some plant back restrictions for canola (Table 2.1). Some herbicides, for example, Buctril (bromoxynil) have only a 30-day plant back restriction; however, Pursuit (imazethapyr) has a labeled plant back restriction of 40 months, and the label requires a field bioassay to be carried out (where a soil sample is taken and canola seeds planted into it, often in a greenhouse, to determine whether plants are showing herbicide damage symptoms) before planting a canola crop. Indeed, Pursuit, used commonly on legume crops in the Pacific Northwest, has shown damage symptoms on canola crops planted six years after the last Pursuit application, so soil type, rainfall and a number of other environmental conditions will have an effect on plant back restrictions.

Growers can avoid some of the plant back restrictions by growing herbicide resistant cultivars. For example, Clearfield (or other imidazolinone-resistant) cultivars can be planted the season after Pursuit is applied. Similarly, the standard plant back restriction after Liberty (glufosinate) application is 120 days, but there is no plant back restriction if LibertyLink® cultivars are planted. Finally, there is an 18-month plant back restriction after atrazine application but an atrazine-resistant canola cultivar has no restriction.

Land Preparation

The greatest difficulty in winter canola production is stand establishment. Crops that have poor fall stand establishment are more likely to suffer winter kill and offer less competition to weeds. Seed to soil contact is critical for good fall crop establishment. Winter canola can be planted into soils that are conventionally tilled, conservation or minimum tilled, or direct-seeded into standing straw stubble. However, fine and firm seedbed conditions allow for good seed germination, uniform emergence and full-cover establishment producing the best yields and allowing for lower growing inputs. Although some straw residue from the previous crop is desired for erosion control, canola seeds are small and heavy straw residue can make achieving good seed to soil contact difficult, often resulting in straw hair-pinning (where seeds are held between bent straw and have poor seed to soil contact) and poor emergence.

Table 2.1 Herbicide plant back restrictions for canola.

Trade Name	Common Name	Plant back Restrictions	Comments
Achieve	Tralkoxydim	106 days	
Aim	Carfentrazone	12 months	
Ally	Metsulfuron	10 or 22 months	Soil pH 6.8 or lower and greater than 18 inches total precipitation; soil pH 6.9 to 7.9 and greater than 18 inches of total precipitation 34 months and greater than 28 inches total precipitation for mustard.
Amber	Triasulfuron	4 months	Plus field bioassay
Assert	Imazamethabenz	15 months	Clearfield varieties may be planted the next season.
Assure II	Quizalofop	No plant back restrictions	120 days for mustard

Atrazine		18 month	Usually described as second fall season after application.
Avenge	Difenzoquat	Next season	
Axial	Pinoxaden	120 days	
Axiom	Flufenacet + Metribuzin	12 months	Listed as other crop
Basagran	Bentazon	No plant back restrictions	
Beyond/Raptor	Imazamox	26 months	No restrictions for Clearfield varieties
Buctril	Bromoxynil	30 days	
Clarity	Dicamba	120 days	180 days for rates above 24 fl oz/A and annual precipitation below 30 inches; see individual producer labels.
Cleanwave	Aminopyralid + Fluroxypyr	9 months	
Discover	Clodinafop	30 days	
Dual II Magnum	Metolachlor	Time restriction not listed	
ET	Pyraflufen	30 days	
Everest	Flucarbazone	9 months	24 months for mustard
Express	Tribenuron	60 days	45 days for mustard
Far-Go	Triallate	12 months	
Finess		14-18 months	Label not specific
Glean	Chlorsulfuron	No restriction listed	Field bioassay recommended
Gramoxone Inteon	Paraquat	No plant back restrictions	
Harmony GT	Thifensulfuron	45 days	
Harmony Extra	Thifensulfuron	60 days	
Hoelon	Diclofop	No plant back restrictions	
Huskie	Pyrasulfotole + Bromoxynil	9 months	
Karmex	Diuron	12 months	
Liberty	Glufosinate	120 days	No plant back restrictions for LibertyLink canola varieties.
Linex/Lorax	Linuron	12 months	Listed as any other crop
Maverick	Sulfosulfuron	22 months	For soil pH less than 7.5 and more than 24 inches total precipitation; field bioassay for soil pH greater than 7.4 or less than 24 inches total precipitation. Field bioassay for mustard under all conditions.
MCPA Product	MCPA	3 months	See individual product labels.
Olympus	Propoxycarbazone	22 months	22 months and 24 inches total precipitation; field bioassay for mustard and when precipitation is less than 24 inches.

Olympus Flex	Propoxycarbazone + Mesosulfuron	12 months	12 months and 24 inches total precipitation; field bioassay for mustard and when precipitation is less than 24 inches.
Orion	Florasulam + MCPA	9 months	12 months for mustard
Osprey	Mesosulfuron	10 months	Listed as other crops
Outlook	Dimethenamid	No plant back restrictions	
Paramount	Quinclurac	10 months	
Peak	Prosulfuron	10 months	Soil pH 7.2 or lower and applied before June 15 of previous year; field bioassay for all other situations.
Poast	Sethoxydim	No plant back restrictions	120 days for mustard
Powerflex	Pyroxulam	9 months	
Prowl	Pendimethalin	Next season	
Puma	Fenoxyprop	No plant back restrictions	
Pursuit	Imazethapyr	40 months plus bioassay	Clearfield (or other Imazethapyr resistant) varieties may be planted the next season.
Roundup	Glyphosate	No plant back restrictions	
Select	Clethodim	No plant back restrictions	
Sencor	Metribuzin	12 months	
Sonalan	Ethalfluralin	No plant back restrictions	
Spartan	Sulfentrazone	24 months	Minimum 12 months for crops not listed on the label; mustard not listed.
Starane	Fluroxypyr	120 days	
Stinger	Clopyralid	No plant back restrictions	12 months for mustard
Thistrol	MCPB	No plant back restrictions	
Tordon	Picloram	36 months or field bioassay	
Treflan	Trifluralin	No plant back restrictions	
2,4-D Products	2,4-D	3 months	See individual product labels.

Cultivation prior to planting helps to control weeds and volunteers from the previous crop. However, seedbeds should not be overworked as this will result in moisture loss and results in greater possibility of soil crusting before seedling emergence. In minimum tillage and direct seed situations, pre-plant, broad-spectrum herbicides should be applied to reduce weed competition. A winter canola crop that establishes well will compete with most weed species, so good crop establishment is a major component of weed management.

In all studies examined, seed yield from direct-seeded winter canola were significantly lower than crops planted into finely cultivated conventional seedbeds. Direct seeding into standing straw stubble in the Pacific Northwest can slow seedling development as straw reflects sunlight and soils are colder compared to black earth situations, resulting from more conventional tillage (Figure 2.1). However, in regions with limited fall rainfall and low soil moisture, direct seeding may be preferred to conserve water. Similarly, in high erodible soils or steep hillsides, direct seeding or conservation tillage would be preferred over conventional tillage.

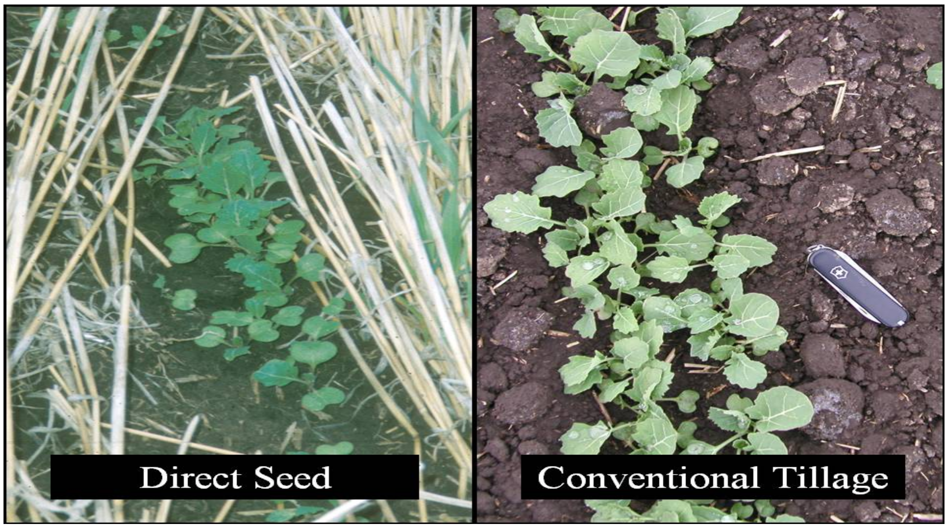


Figure 2.1. *Canola seedlings in standing straw are more shades from sunlight and soil is cooler resulting in smaller plants.*

Seeding Date

Appropriate planting dates for winter canola are important to allow plants to grow sufficiently before the onset of winter and hence, have less winter damage. Generally, winter canola should be planted six weeks before the first killing frost in most states and four weeks before the first killing frost in the southern states. Most U.S. regions with good potential for growing winter canola crops currently grow winter wheat. In the colder northern states, winter canola should be planted five to six weeks prior to optimum winter wheat planting, and two to three weeks before optimum winter wheat planting in southern states (i.e. south Texas). The aim is to have at least 45 days of growth before the onset of winter conditions or to have plants with four to six fully opened leaves (in a rosette stage of growth) before winter.

Cultivars do have differential winter-hardiness at the full rosette and juvenile (four- to six- leaf) stages, so cultivar choice is important especially in regions with severe winters (see Cultivar Choice below).

Planting too early will increase the risk of insect infestation (mainly flea beetles and aphids) and may require seed insecticide treatments or insecticide sprays. Early planting can result in crop failure as overly large plants deplete the soil moisture. Planting too early may result in plants flowering in the fall, which makes them more susceptible to winter kill.

However, planting too late will result in seedlings that are too small to survive winter conditions, which will not compete well with weeds in the spring if the crop does survive.

Planting at the appropriate date allows canola crops to avoid hot summer temperatures in the following spring which can be detrimental to flower and pod development. Planting should be completed such that the crop achieves full ground cover before November to ensure suitable winter hardiness. Winter canola can be planted into summer fallow in the Pacific Northwest from early August to the second week of September; however, optimum yields are obtained from planting from Aug. 14 to 24. In the Pacific Northwest, later planting is possible in regions with less severe winter conditions. In the mild winter region of the Willamette Valley in Oregon, planting is possible up to the first week of November.

Recommended planting dates in the Great Plains and Midwest vary according to latitude. Optimum planting dates in Nebraska are from Aug. 22 through Sept. 12, Aug. 26 to Sept. 25 in Kansas and Missouri, Aug. 20 to Sept. 21 in Oklahoma and Arkansas, Aug. 20 to Sept. 28 in northern Texas, and Sept. 10 to Oct. 25 (winter types) in Alabama and Georgia.

Plants that are better established in the fall have significantly less winter kill compared to later planted, less established seedlings. If possible, canola plants need to have started to develop to the rosette stage and be approximately six to eight inches across, with four to six well-developed leaves (as those planted Sept. 1 in Figure 2.2). Plants planted 2 weeks later (Sept. 15) in this region, are significantly smaller and plants of this stage have only a 50 percent chance of surviving the Pacific Northwest winter. Plants that go into the winter smaller than this (i.e. compared to those planted Sept. 30) have little chance of surviving winter.

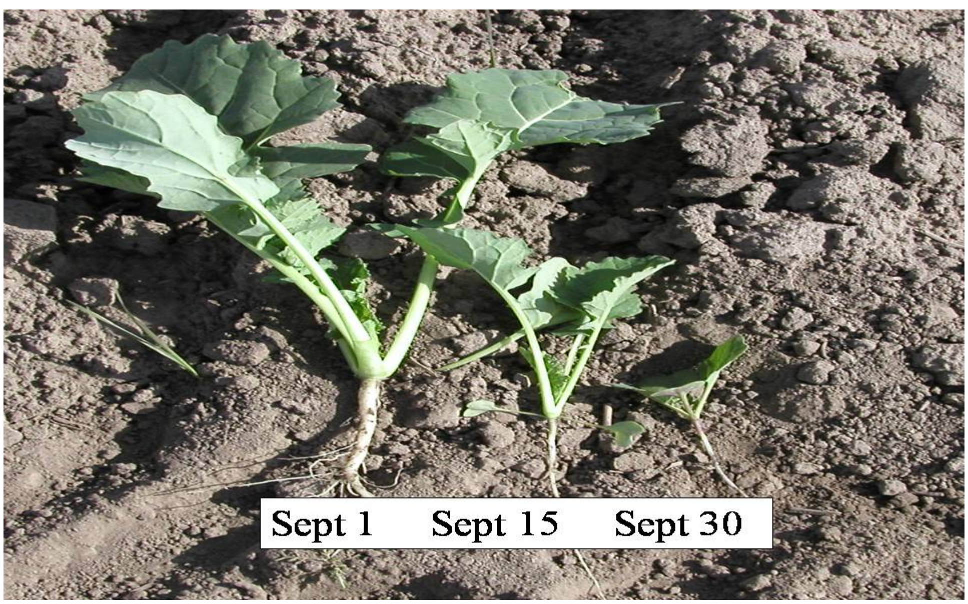


Figure 2.2. *Different stage of seedling development when planted with two week intervals in the Pacific Northwest region.*

Despite cultivar variability for winter hardiness, winter canola needs a specific number of degree days above 4 ^{o}C to accumulate sufficient dry matter to survive winter conditions. The accumulated degree days (ADD) necessary for winter survival is dependent on the severity of the winter conditions expected. Experimentation in Idaho has suggested that a minimum of 6,000 ADD above 4 ^{o}C are necessary for germination, seedling emergence and to establish four to five leaves on winter canola seedlings, which is the minimum seedling stage that will survive a Pacific Northwest winter.

Seeding Rates and Depth

Always plant certified seed that is free from seed-borne blackleg (*Phoma lingum*), Sclerotinia stem rot (*Sclerotinia sclerotinium*), and *Alternaria* black spot (*Alternaria* species). Blackleg is not a problem in most U.S. canola growing regions (the Southeast being the exception) fortunately, as introduction of blackleg into some regions will greatly limit the potential for growing canola. In many regions, it is economically beneficial to use seed treatments containing insecticides and fungicides (i.e., Helix XTra® or Prospor 400®) to prevent damping off and flea beetle damage, particularly when planting very early in the fall. These seed treatments also include a fungicide which offers some control of seed-borne blackleg and *Sclerotinia* stem rot.

Most seed drills that have been used to plant small grain cereals or alfalfa can be used to plant canola. Double-disk opener drills provide best results when planting winter canola into well-cultivated seedbeds. However, shank, single-disk and air-drills have all been used successfully to plant winter canola. Use of press wheel rollers/packers behind the openers improves seed-soil contact, and hence, seed germination, emergence and stand establishment. Always check the drill calibration prior to planting. Many older small grain cereal seed drills do not allow planting very small seeds or low seeding rates. In these cases, seeder modifications may be necessary or seed will need to be mixed with a filler. Winter canola also can be broadcast-seeded, in which case, the seeding rate should be increased 25 to 30 percent compared to drill planting.

Canola seeds are small and round with approximately 90,000 to 115,000 seeds per pound (or ~200 to 250 seeds per graham). With 115,000 seeds per pound and planting 1 pound of seed per acre will result in planting approximately 2.6 seeds per square foot with 7.5 inch row spacing. With larger seeds, 90,000 seeds per pound and planting 1 lb of seed per acre will result in planting approximately 2.0 seeds per square foot with 7.5 inch row spacing. Certified seed bags label the number of seeds per pound and seed germination percentage. Use this information to help calibrate an appropriate seeding rate.

Winter canola crops have been successfully planted using seeding rates that range from less than 2 pounds per acre to more than 12 pounds per acre. Planting a seeding rate which is too low will result in poor crop establishment and most likely, increased weediness. Planting too high a seeding rate will result in high plant populations with thin-stemmed plants, high intra-crop competition and crop lodging at maturity.

The aim is to use a seeding rate that results in 10 to 16 seedlings per square foot, which will hopefully relate to a plant stand count at harvest of 5 to 10 plants per square foot. Studies have shown that winter canola seed yields are not significantly reduced unless plant stand counts at harvest are less than four plants per square foot or greater than 15 plants per square foot.

Achieving such plant stands will require a five to six pounds per acre seeding rate, which is the rate most recommended with seven to eight inches of row spacing. Higher seeding rates should be used if planting is later than optimum, and lower seeding rates should be used when planting is earlier than optimum. Similarly, planting into soil and seedbeds that are less than optimal will require increased seeding rates to compensate for poor seedling emergence. For example, direct seeding into standing wheat straw requires a 25 percent increase in seeding rate to achieve the same plant stands as seeding into a well cultivated and firm seed bed.

Poor fall establishment or winterkill often can result in poor plant stands in the spring and growers often have to question whether to leave a winter canola crop in place or re-plant with another crop. In general, winter canola crops have a wonderful ability to compensate for poor plant stands and high seed yields are often obtained from a relatively poor plant stand in the spring. One caution is that this is only true in the absence of severe weed infestation, which is often associated with poor spring plant stands. So if spring stand counts are low (less than three plants per square foot) growers may consider re-planting another crop if weeds cannot be economically controlled by herbicides. However, spring plant stands of one to two plants per square foot can result in acceptable seed yields, given proper nutrient management (see below). Spring stands of one to two plants per square foot can produce between 70 and 80 percent of the yield obtained from a more optimum spring plant stand of four to 10 plants per square foot.

Seeding depth should be *as shallow as allows the seed to be covered*. Seeding recommendations are to plant ¼- to one-inch deep. However, seed must be placed into moisture. Seeding too shallow can result in irregular germination and emergence and patchy plant stands as soil around the seed zone dries. Planting too deep can delay seedling emergence, resulting in poor plant vigor and increasing the potential for non-emergence as a result of soil crusting.

Winter canola can be planted on row spacing from six to 20 inches, and may depend on what seeder is available. Wider row spacing will require lower seeding rates. For example, plant five pounds per acre when using a 7-inch row spacing and plant 3 pounds per acre with a 15-inch spacing. Wider row spacing will cause less intra-crop competition so plants can be closer together within a row. Planting on narrower row spacing will achieve quicker ground cover, which will likely result in fewer weeds compared to planting on wider rows. Many direct seed planters use a wider row spacing to allow for difficulties in handling high straw residues. Some use a paired row system, whereby two rows are planted close together, and these are separated from the adjacent pair with a wider spacing. Some of these seed drills have mechanisms to remove some or all of the residual straw over the planted row. Wider row spacing, say in an organic system, may allow for mechanical post emergence weed control.

Nutrients

High yield with high end-use quality of winter canola can only be obtained through effective nutrient management. As with any agricultural crop, appropriate soil sample analyses are essential. Take these samples one to two weeks prior to the target planting date to allow sufficient time for the analyses to be completed and the results returned.

Nitrogen

All plants, including winter canola, assimilates nitrogen (N) to form major plant components, primarily amino acids, which are the building blocks of plant proteins. Suitable levels of nitrogen must be available for uptake by the plant at or before the times of fastest growing. Figure 2.3 shows the rate of nitrogen uptake of a winter canola crop from planting through harvest (based on a 3,000-pound-per-acre crop). Also shown is the dry matter accumulation of the crop over that same period.

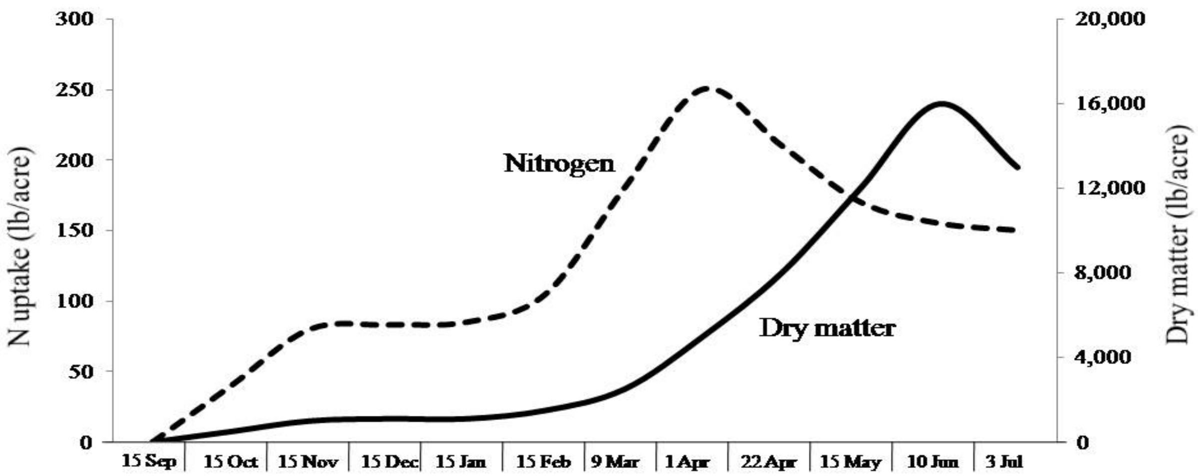


Figure 2.3 *Rate of nitrogen uptake and of dry matter accumulation of a winter canola crop from planting to harvest.*

After planting in the fall, nitrogen uptake rises rapidly and an associated increase of dry matter accumulation occurs as seedlings emerge and plants develop leaves up until the rosette stage. At the onset of winter, nitrogen uptake is significantly reduced as plant growth stops over winter. The rate of nitrogen uptake increases significantly in early spring just prior to the rapid accumulation of plant dry matter as plants move from a vegetative state to a reproductive stage. Plant stems begin to elongate (bolt) in early March and flower buds develop. Winter canola flowers open around the middle of April, opening from the base of each primary and secondary branches (racemes). One to three flowers open per raceme each day depending on temperature. The duration of the flowering period depends on temperature, but flowering lasts from one to four weeks, by which time, developing pods are visible on the first opened flower positions. After flowering seeds develop, they eventually dry down due to plant senescence and become mature before harvest.

Note that almost half of the nitrogen uptake is completed while the plant is in the pre-bolt rosette stage, while most of the remaining nitrogen uptake occurs between the rosette stage and early flowering. Total plant nitrogen declines after flowering because of loss of blooms and leaves. Prior to plant senescence, nitrogen uptake and plant dry matter accumulation decreases as the crop approaches maturity and tissue loss occurs due to leaf drop.

Obviously, the graphs of nitrogen uptake and dry matter accumulation are of a similar shape, with the nitrogen uptake occurring earlier than dry matter accumulation. This illustrates that:

- Nitrogen uptake precedes dry matter accumulation.

- Plant dry matter accumulation (which to a large extent is related to seed yield) is highly dependent on nitrogen uptake, which is related to nitrogen availability.

- Only half of the total plant dry matter accumulates at the time of maximum nitrogen uptake.

  Therefore, not only does the availability of nitrogen relate to dry matter accumulation and seed yield, timing of that availability is key for good crop development. Winter canola can benefit from a split fall-spring nitrogen application to ensure sufficient available nitrogen prior to the onset of the rapid dry matter accumulation in the spring.

Nitrogen is the most limiting of all plant nutrients in winter canola, and making sure that sufficient nitrogen is available to the plant at each growth stage is critical. When available nitrogen levels are high in the fall, winter hardiness is reduced and canola becomes more susceptible to winter kill. Split nitrogen application is recommended with 25 percent to 33 percent of nitrogen applied pre-planting and the remainder top-dressed in early spring.

To determine the appropriate rate of nitrogen necessary requires the following:

- Estimate the expected yield of the crop. This will be determined by previous crops, rainfall potential, soil type and depth, and planting date. Examining the crop in the spring just prior to nutrient application can also help to determine the yield potential. In the Pacific Northwest, winter canola yield potential can be estimated by considering the history of winter wheat yields, as winter wheat yield (bushels per acre) multiplied by 40 estimates winter canola yield (pounds per acre) from the same land.
  For example, winter wheat yields of 40, 50, 60, 70 and 80 bushels per acre, would relate to winter canola yields of 1,600, 2,000, 2,400, 2,800, and 3,200 pounds per acre, respectively.

  Determine the required nitrogen availability to attain this seed yield. In general terms, nitrogen required is between 6.5 (low canola yield), 7.0 (moderate canola yield), and 7.5 (high canola yield) units of nitrogen for each 100 pounds per acre of harvested seed. For example, nitrogen required for winter canola seed yield on 1,500, 2,500, and 3,500 are shown in Table 2.2.

Table 2.2. *Nitrogen requirement for winter canola with different seed yield potential.*

Expected Seed Yield		Multiplier per 100 lb of canola seed harvested	Nitrogen required -- lb N/acre--
Low	1,500	x 6.5	98
Moderate	2,500	x 7.0	175
High	3,500	x 7.5	263

Different U.S. regions have found similar, but slightly different relationships between canola seed yield and nitrogen availability. The above multipliers were derived from studies in Idaho, although recommendations from Oregon are pounds of N per acre = 100 lb seed yield x 6.5 (low), to pounds of N per acre = 100 pounds of seed yield x 7.5 (high). In the Southern Great Plains is pounds of N per acre = 100 pounds of seed yield x 5, and from Georgia is pounds of N per acre = 100 pounds of seed yield x 6. These nitrogen recommendations have been tabulated for different potential winter canola seed yield in Table 2.3.

Table 2.3 *Recommended nitrogen availability according to winter canola seed yield*

Region	Winter canola seed yield (lb/acre)				
	1,500	2,000	2,500	3,000	3,500
	-------------------- lb N/acre----------------				
Oregon	97-112	130-150	162-187	195-225	227-262
Washington	90-120	120-160	150-200	180-240	150-280
Southern Great Plains	75	100	125	150	175
High Great Plains	80-110	-	140-160	-	180-215
Georgia	90	120	150	180	210

- Collect appropriate soil samples from the top 2 feet (irrigated soils) or 3 feet (dryland soils) in 1-foot increments and complete nitrate-nitrogen (NO_3-N) analyses. Also, estimate ammonium nitrate (NH_4-N) from the top foot of soils and add the available soil nitrogen from the different soil depths.

  Note that parts per million (ppm) of nitrogen can be converted to pounds N per acre by multiplying by 3.5. For example of there is 5, 6 and 8 ppm NO_3-N in the first second and third foot of soil and 1 ppm NH_4-N in the first foot total would be 5+6+8+1=20 ppm x 3.5 = 70 pounds per acre.

- In convention tillage systems, determine soil organic matter and from this, determine mineralizable nitrogen release. Soils with less than 2 percent, 2 to 3 percent, 3 to 4 percent, and greater than 4 percent organic matter will have 25, 35, 45, and 55 pounds of mineralizable nitrogen released per acre, respectively.

- Determine immobilized, or tied up, nitrogen in previous crop residue. Immobilization can cause problems in situations where large amounts of wheat straw or corn stalk residue are present and tie up available nitrogen. Increase applied nitrogen by 60, 45, 60, and 40 pounds per acre, when planting winter canola after winter wheat, spring wheat, corn and barley, respectively.

- Finally, add soil available nitrogen to minerizable nitrogen, then subtract from the total required nitrogen and immobilized nitrogen to determine applied nitrogen.

Sulfur

Sulfur (S) is often the second most limiting nutrient for successful winter canola production. Sulfur is required to attain high yield and good seed quality. Winter canola sulfur deficiencies result in pale yellow plants with poor plant growth. Canola crops require 1 pound of sulfur for each expected 100 pounds per acre of seed yield. Heavy precipitation over winter can move sulfate-sulfur (SO_4-S) deep into the soil profile away from winter canola roots. Apply sulfur according to appropriate soil tests. For zero to 5 ppm SO_4-S, apply 20 to 40 pounds S per acre; four 6 to 10 ppm SO_4-S, apply 10 to 20 pounds S per acre; and for over 10 ppm SO_4-S, apply 0 to 10 pounds S per acre.

It should be noted that some recommendations for sulfur application are limited to no more than 25 pounds S per acre since it is highly prone to leaching in the soil. However, others recommend application of higher rates, particularly with field history of higher yield potential and hence to apply 1 pound S per acre for every 100 pounds of expected seed per acre harvested, irrespective of the application rate.

Phosphorus

Winter canola has a moderate requirement for phosphorus (P) although deficiency symptoms (plants remain green but are stunted) can be difficult to detect visually. However, phosphorus application will increase seed yields when soil test levels are less than 5 ppm, using the sodium bicarbonate determination (Table 2.4). Phosphorus is not mobile in the soil so it should be applied in the fall, either banded with the seed at planting or incorporated into the soil before planting.

Table 2.4. *Recommended phosphorus fertilizer rates for winter canola based on soil test results.*

Soil test P (0 to 12 inches)[1]			Application rate[2,3]	
NaOAc (ppm)	Bray 1 (ppm)	$NaHCO_3$ (ppm)	P_2O_5 (lb/acre)	P (lb/acre)
0 to 2	0 to 20	0 to 8	60	26
2 to 3	20 to 30	8 to 10	40	18
3 to 4	30 to 40	10 to 12	20	9
Over 4	over 40	over 12	none	none

Reproduced from Northern Idaho Fertilizer Guide, Winter Canola. By Robert L. Mahler, University of Idaho.
[1] Soil test P can be determined by three different procedures: sodium acetate (NaOAc), Bray 1 method or sodium bicarbonate ($NaHCO^3$). The latter which should not be used on soils with pH values less than 6.2.

[2] P_2O_5 x 0.44 = P or P = 2.29 P_2O_5
[3] Under reduced tillage, apply up to 20 pounds P_2O_5 per acre on soils testing in excess of 4 ppm on the NaOAc test.

Potassium

Many U.S. soils are sufficient in potassium (K) so application of it is only recommended if a soil test deems it necessary (Table 2.5). Potassium can be banded along with the seed, below the seed or alongside the seed at planting.

Table 2.5. *Recommended potassium fertilizer rates for winter canola based on soil test results.*

Soil test potassium (K) (0 to 12 inches)[1]	Application rate[2]	
	K_2O	K
(ppm)	(lb/acre)	(lb/acre)
0 to 50	80	66
51 to 75	60	50
Over 75	0	0

Reproduced from the Northern Idaho Fertilizer Guide, Winter Canola. By Robert L. Mahler, University of Idaho.
[1] Sodium acetate extractable K. [2] K_2O x 0.83 = K, or K = 1.20 K_2O

Boron

Winter canola requires more boron than most other crops. Broadcast 1 to 2 pounds of boron if soil tests show less than 0.5 ppm boron. Boron should be applied before or at seeding in the fall. Never band boron as it can often cause toxicity.

Micronutrients

Although extensive studies have not been completed, winter canola has not been shown to respond to applications of chlorine, copper, iron, manganese, molybdenum or zinc. Do not apply any of these micronutrients without first establishing suitable guidelines because of the greater chance of creating toxicity problems than correcting any micronutrient deficiencies that might exist.

Lime Application

The pH requirements of winter canola are similar to those for winter or spring wheat. Optimal plant growth occurs at a soil pH between 6.0 and 7.0. Lime application is recommended for a soil pH less than 5.8. Lime recommendations using the Shoemaker, McLean and Pratt (SMP) Buffer are shown in Table 2.6.

Table 2.6. *Recommended lime application rates.*

Buffer pH	Target pH = 6.8 (lb ECC $acre^{-1}$) †	Target pH = 6.0 (lb ECC $acre^{-1}$) †
7.2	750	375
6.8	3,000	1,500

6.4	6,250	3,125
6.0	10,250 ‡	5,125
5.6	15,250 ‡	7,625

Reproduced from the Great Plains Canola Production Handout. By Mark Boyles (Oklahoma State University), Thomas Peeper (Oklahoma State University) and Michael Stamm (Kansas State University).

† When using a continuous no-till production system, apply only one-third to half the recommended rate.

‡ When lime recommendations exceed 10,000 ECC per acre, apply at half rate, incorporate and retest after 12 to 18 months.

Cultivar Choice

In regions where winter canola and spring canola can be grown, winter canola will usually produce significant yield increases over spring crops. In the Pacific Northwest, for example, winter canola crops can produce double the seed yield of spring crops. Winter crops also tend to have larger seed and higher seed oil content than spring crops.

Breeding efforts at Kansas State University (KSU), University of Arkansas (UA), Virginia State University (VSU) and the University of Idaho (UI) have resulted in a number of cultivars being released over the past five to 10 years that are a marked improvement over those previously available. In addition, breeding and seed companies from around the world began testing cultivars in U.S. regions for adaptability and several of these cultivars have shown high yield potential.

The National Winter Canola Variety Trial (primarily organized by KSU) is planted in three U.S. regions including the Southeast (Alabama, Arkansas, Virginia and Georgia), Midwest (Illinois, Kentucky, Michigan, Minnesota, Ohio and Pennsylvania,) and the Great Plains (Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas and Missouri). The Pacific Northwest Canola Variety Trial (organized by the University of Idaho) is planted in Oregon, Washington, and Idaho.

Trial yields from around the U.S. have shown that winter canola has very high seed yield potential compared to that of spring canola. Average seed yield data from 2004 to 2007 collected from all U.S. states shows that the highest winter canola seed yields are obtained in the Pacific Northwest (Figure 2.4).

Highest seed yield was obtained from Washington (3,870 pounds per acre) and Idaho (3,366pounds per acre), although all Washington data were collected from irrigated fields, while most of the Idaho trials were planted on dryland summer fallow, rather than continually cropped systems. Average seed yields from Arkansas, Illinois, Kentucky, Montana, Ohio, and Oregon all exceeded 2,500-pound-per-acre yields, while average seed yields from Nebraska, Pennsylvania and Virginia exceeded 2,000 pounds per acre.

These winter canola seed yields can be compared to these obtained from spring crops. Seed yield from U.S. spring canola from 1991 to 2007 has been as high as 1,416 pounds per acre (1998), but has been as low as 1,250 pounds per acre in 2007. Therefore, all the above mentioned states have winter canola yield potential markedly higher than spring crops. Average winter canola yields from Minnesota were less than 1,000 pounds per acre, which is why spring canola types are usually grown in this state. Low yield potential of winter canola has been shown in Mississippi and Missouri, although only one trial has been reported in Mississippi and only four trials in Missouri.

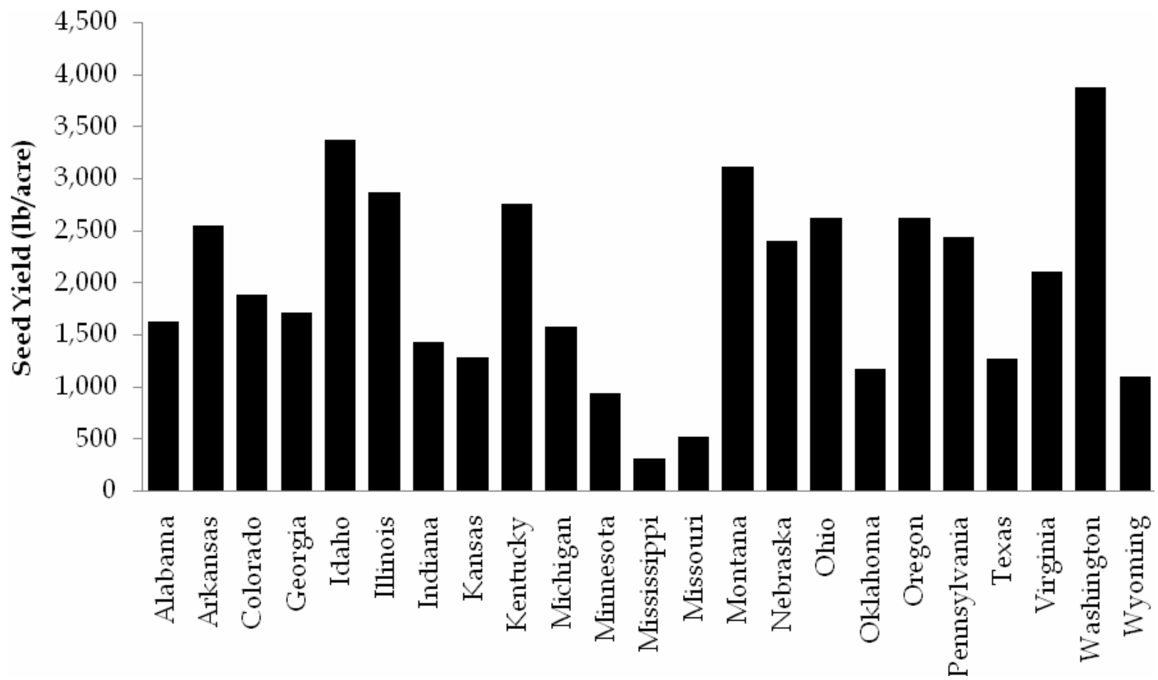


Figure 2.4 *Average seed yield of winter canola (lb/ acre) from plot yield trials in different mainland states between 2004 and 2007.*

Environmental conditions change considerably in the different winter canola growing regions of the U.S. Not surprisingly, different cultivars are more or less adapted to different regions of the country. Evaluation trials in close proximity are more likely to show similar results. To address this, performance of cultivars is considered within each of the four growing regions.

Pacific Northwest Cultivars

Several cultivars have shown good yield potential and adaptability to growing conditions in the Pacific Northwest region (Washington, Oregon and Idaho). The past three years of yield data from these trials are presented in Table 2.7. However, cultivar evaluation trials in this region have been grown under quite contrastingly different environments. Some of these trials were irrigated, some planted on summer fallow, while others were direct seeded into standing cereal straw. Growers should examine data from individual trials: www.ag.uidaho.edu/pses/brassica/.

Average seed yield of all cultivars in all three years was 3,302 pounds per acre. Averaged over three years, the highest seed yield was from 06UIWH.5.1 (3,839 pounds per acre), while lowest yield was still a very respectable 2,151 pounds per acre from the *Brassica rapa* cultivar 'Salut.' Note that *B. rapa* winter canola cultivars have adapted to the very dry crop-fallow regions of Washington, but they lack yield potential in the other Pacific Northwest states.

The two most common cultivars grown in the Pacific Northwest over the past five years have been ‘Baldur’ and ‘Athena.’ Athena was developed for the region by the University of Idaho and is open-pollinated. Baldur was developed in Germany and is currently sold in the region by Croplan Genetics. Baldur is a later-maturing cultivar compared to Athena and does particularly well in longer, cooler summers. Athena matures five to 10 days earlier than Baldur and can avoid severe summer heat in a warm season.

Very few of the winter canola cultivars grown in this region have been herbicide-resistant. However, DEKALB/Monsanto has been evaluating two new Roundup Ready® cultivars, DKW.13.62 RR and DKW.13.86 RR in the region for three years and will complete a fourth year of testing in 2008. Both of these cultivars were grown commercially on reasonably large acreage in 2007. In addition, SW Seed completed the first year of testing four new Roundup Ready® winter canola breeding lines in 2007. Availability of these herbicide-resistant cultivars will offer growers in the region more opportunities in crop rotation and weed management.

The earliest cultivar to be grown commercially in the region is ‘Ericka,’ which flowers and matures at least one week earlier than the other cultivars. ‘Ericka’ is short and determinant in stature and can do well under irrigation situations where water is limited (or expensive). ‘Ericka’ uses less irrigation water than other later cultivars.

A new UI cultivar, ‘Amanda,’ was released this year and will move into commercial production. ‘Amanda’ has consistently produced very high yield of seed with high oil content.

Traditionally, the Pacific Northwest has been an industrial rapeseed production area, where rapeseed has been grown commercially for over 100 years. Very few industrial winter rapeseed cultivars are available for growers to plant. The traditional standby is ‘Dwarf Essex.’ This cultivar has very acceptable seed yield but only moderate levels of erucic acid (40 to 45 percent) in the seed oil and average oil content (38 to 40 percent). A further negative factor of ‘Dwarf Essex’ is that it has high (125 µmol per gram of defatted seed meal) glucosinolates in the seed meal which lowers its value as a livestock feed.

In 1986, the UI Rapeseed Breeding Program released a short stature, higher erucic acid content, high oil content cultivar called ‘Bridger’ and later a similar rapeseed cultivar called ‘LEI III.’ However, neither of these cultivars had sufficient winter-hardiness to consistently survive Pacific Northwest winters. The UI Rapeseed Breeding Program has continued to develop new winter industrial oilseed cultivars. This year, it will release another rapeseed cultivar, ‘06UIWH.5.1’ (yet to be formally named), which is a significant improvement over ‘Dwarf Essex’ in yield potential, has 56 percent erucic acid content in the seed oil and high seed oil content, combined with very low total glucosinolates in the seed meal.

Table 2.7 *Average seed yield over sites of cultivars grown in the Pacific Northwest (extracted from the 2005, 2006, and 2007 Pacific Northwest Winter Canola Variety Trial Results) plot trials 2005 to 2007.*

	Average Yield	Yield Rank	Site/ Years	Year 2,007	2,006	2,005
	lb/acre					
Amanda[1]	3,814	2	25	3,761	3,543	4,139
Athena[1]	3,289	11	25	3,431	3,056	3,379
Baldur[2]	3,696	3	19	3,914	3,097	4,077
D.Essex[†]	3,387	8	25	3,637	3,033	3,490
DKW.13.62.RR[3]	2,872	17	14	2,980	2,763	*
DKW.13.86.RR[3]	3,069	14	14	3,230	2,908	*
Ericka[1]	2,941	16	25	3,054	2,866	2,902
Exp.3269.RR[3]	3,212	12	14	3,212	*	*
Salute[‡]	2,151	18	25	2,216	1,880	2,358
SW.013154.RR[4]	3,354	10	8	3,354	*	*
SW.023168.RR[4]	3,110	13	8	3,110	*	*
SW.023181.RR[4]	3,601	6	8	3,601	*	*
SW.023344.RR[4]	3,499	7	8	3,499	*	*
SW.Falstaff[4]	3,609	5	8	3,609	*	*
Virginia[2]	2,956	15	8	2,956	*	*
06UIWC.1[1]	3,670	4	25	3,863	3,385	3,763
06UIWH.3[†1]	3,362	9	25	3,602	3,207	3,277
06UIWH.5.1[†1]	3,839	1	25	4,141	3,279	4,096
Average	3,302		17	3,398	3,002	3,498

[†] High-erucic acid rapeseed cultivars (HEAR); all other cultivars are edible canola (LEAR).
[‡] *Brassica rapa* cultivar; all other cultivars are *B. napus.*
[1] University of Idaho; [2] Croplan Genetics; [3] DEKALB/Monsanto; [4] Svalöv Weibull (SW Seed).

Great Plains Cultivars

Several cultivars have shown good yield potential and adaptability to growing conditions in the Great Plains region (Colorado, Kansas, Missouri, Nebraska, Oklahoma, Texas and Wyoming). The past three years of yield data from the Great Plains test locations of the 2005, 2006 and 2007 National Winter Canola Variety Trials (Report of Progress 954, 973 and 990, respectively, KSU Agricultural Experimental Station and Cooperative Extension Service) are presented in Table 2.8. However, these cultivar evaluation trials in this region have been grown under quite contrastingly different environments.

Average seed yield over all cultivars in the trials over the three years was 1,347 pounds per acre, while average yield within the test entries over the three years was 1,553 pounds per acre with lowest three year average yields being 1,049 pounds per acre. Highest average seed yield was obtained in 2005 (1,740 pounds per acre) and the lowest year's yields were in 2006 (1,027 pounds per acre).

Table 2.8 *Average seed yield over sites of cultivars grown in the Great Plains (extracted from the 2005, 2006, and 2007 National Canola Variety Trial Reports) plot trials 2005 to 2007.*

	Average Yield	Yield Rank	Site/ Years	Year 2007	2006	2005
	----------	----------	----------	lb acre^{-1}	----------	----------
Abilene[1]	1,453	7	27	1,377	1,068	1,914
ARC 2180-1[2]	1,427	9	20	1,533	943	1,806
ARC 97018[2]	1,265	19	13	1,527	1,004	*
ARC 97019[2]	1,292	18	13	1,578	1,006	*
ARC 98007[2]	1,234	21	13	1,433	1,035	*
ARC 98015[2]	1,179	24	13	1,390	967	*
Baldur[3]	1,463	5	20	1,473	1,037	1,880
Baros[3]	1,463	6	12	1,298	*	1,628
Casino[6]	1,215	23	21	1,127	832	1,685
Ceres[3]	1,321	17	26	1,570	840	1,554
DKW 13-62[4]	1,049	25	26	1,179	742	1,227
DKW 13-86[4]	1,244	20	28	1,292	978	1,460
Jetton[3]	1,471	4	21	1,646	952	1,816
Kronos[3]	1,553	1	14	1,468	1,068	2,124
KS 3018[1]	1,418	10	13	1,506	939	1,809
KS 3074[1]	1,364	14	27	1,642	1,086	*
KS 3254[1]	1,364	15	22	1,614	1,114	*
KS 7436[1]	1,435	8	27	1,492	1,035	1,776
KS 9135[1]	1,507	2	27	1,571	1,085	1,866
Plainsman[1]	1,223	22	26	1,307	808	1,554
Rasmus[3]	1,378	13	22	1,467	828	1,840
Sumner[1]	1,348	16	13	1,413	966	1,666
Viking[3]	1,406	11	13	1,406	*	
Virginia[5]	1,404	12	20	1,494	943	1,776
Wichita[1]	1,478	3	21	1,476	1,043	1,917
Average	1,347		20	1,478	1,027	1,740

[1] Kansas State University; [2] University of Arkansas; [3] Norddeutche Pflanzenzucht; [4] DEKALB/Monsanto; [5] Virginia State University; [6] Svalöv Weibull (SW Seed).

Cultivars entered into these trials were developed by KSU, UA, Norddeutch Pflanzenzucht (NPZ) and DEKALB/Monsanto, VSU and Svalöv Weibull (SW Seed). Highest yielding named cultivars in the trials were 'Kronos,' 'Jetton,' 'Baros' and 'Baldur' from NPZ and 'Wichita' from KSU. Both university breeding programs had numbered breeding lines in the trial that show very good potential as future releases.

Most of the entries in the Great Plains trials were not herbicide tolerant. However, DEKALB/Monsanto has evaluated two new Roundup Ready® cultivars, 'DKW.13.62 RR' and 'DKW.13.86 RR' in the region for three years. Both Roundup Ready® cultivars lagged behind the others in the trials with regard to seed yield, but the Roundup Ready® trait will offer growers more flexibility in crop management and weed control. Surely, more winter Roundup Ready® cultivars will be released with better adaptability in the future.

Midwest Cultivars

Several cultivars have shown good yield potential and adaptability to growing conditions in the Midwest region (Illinois, Kentucky, Michigan, Minnesota, Ohio and Pennsylvania). The past three years of yield data from the Midwest test locations of the 2005, 2006 and 2007 National Winter Canola Variety Trials (Report of Progress 954, 973 and 990, respectively, KSU Agricultural Experimental Station and Cooperative Extension Service) are presented in Table 2.9.

Table 2.9 *Average seed yield over sites of cultivars grown in the Midwest (extracted from the 2005, 2006, and 2007 National Canola Variety Trial Reports) plot trials 2005 to 2007.*

	Average Yield	Yield Rank	Site/ Years	Year 2007	2006	2005
	------------	------------	------------	lb/acre	------------	------------
Abilene[1]	2,149	11	27	1,474	2,708	2,265
ARC 2180-1[2]	2,038	18	20	1,411	2,648	2,055
ARC 97018[2]	2,207	9	13	1,633	2,780	*
ARC 97019[2]	2,244	5	13	1,623	2,866	*
ARC 98007[2]	2,062	16	13	1,485	2,639	*
ARC 98015[2]	2,069	15	13	1,484	2,654	*
Baldur[3]	2,214	8	20	1,813	2,851	1,980
Baros[3]	1,739	22	12	1,436	*	2,041
Casino[4]	1,857	19	21	866	2,690	2,016
Ceres[3]	1,838	20	26	1,823	2,266	1,424
Jetton[3]	2,273	4	26	1,907	2,811	2,100
Kronos[3]	2,241	6	28	1,655	2,885	2,183
KS 3018[1]	2,127	13	21	1,840	2,705	1,835
KS 3074[1]	2,444	2	14	1,901	2,988	*
KS 3254[1]	2,486	1	13	2,060	2,912	*
KS 7436[1]	2,097	14	27	1,843	2,640	1,808
KS 9135[1]	2,341	3	27	1,956	2,819	2,249
Plainsman[1]	1,821	21	27	1,337	2,408	1,718
Rasmus[3]	2,127	12	26	1,589	2,737	2,055
Sumner[1]	2,058	17	22	1,614	2,657	1,905
Viking[3]	1,459	23	13	1,459	*	*
Virginia[5]	2,230	7	20	1,734	2,809	2,149
Wichita[1]	2,194	10	27	1,765	2,795	2,021

Mean	2,125	20	1,657	2,685	1,981

[1] Kansas State University; [2] University of Arkansas; [3] Norddeutche Pflanzenzucht; [4] Svalöv Weibull (SW Seed); [5] Virginia State University.

Averaged over years and cultivars, mean seed yield over the trials was 2,125 pounds per acre. Averaged over all cultivars tested, the highest seed yield was obtained in 2006 with 2,685 pounds per acre, while the lowest yields were obtained in 2007, when average seed yield was only 1,657 pounds per acre.

Cultivars entered into these trials were developed by KSU, UA, VSU, Norddeutch Pflanzenzucht (NPZ) and Svalöv Weibull (SW Seeds). All of the entries in the trial were commodity canola cultivars and none of the trial entries were herbicide resistant.

Averaged over years, the highest yielding cultivars were the KSU numbered lines ('KS 3254' with 2,486 pounds per acre; KS 3074 with 2,444 pounds per acre, and KS 9131 with 2,341 pounds per acre). The highest yielding NPZ cultivars, 'Jetton' (2,273 pounds per acre) and 'Kronos' (2,241 pounds per acre), ranked 4th and 6th highest, respectively. The UA numbered line, 'ARC 97019' (2,244 pounds per acre), ranked 5th highest. VSU and SW Seed each had only one entry in the trial, 'Virginia' and 'Casino', respectively. 'Virginia' (2,230 pounds per acre) ranked 7th highest and 'Casino' (1,857 pounds per acre) was ranked 20th overall.

Southeast Cultivars

Several cultivars have shown good yield potential and adaptability to growing conditions in the Southeast region (Alabama, Arkansas, Georgia, and Virginia). The past three years of yield data from the Southeast test locations of the 2005, 2006, and 2007 National Winter Canola Variety Trials (Report of Progress 954, 973 and 990, respectively, KSU Agricultural Experimental Station and Cooperative Extension Service) are presented in Table 2.10.

Averaged over years and cultivars, mean seed yield over the trials was 1,764 pounds per acre. The highest seed yields over cultivars was obtained in 2005 with 2,137 pounds per acre, while lowest yields were obtained in 2006, when average seed yield was only 1,555 pounds per acre.

Cultivars entered into these trials were developed by KSU, UA, VSU, NPZ and SW Seed. All of the entries in the trial were commodity canola cultivars and none of the trial entries were herbicide resistant.

The highest and most consistent yielding cultivar in the Southeast trials was the KSU cultivar 'Wichita' with an average seed yield of 1,994 pounds per acre, followed by the Norddeutch Pflanzenzucht (NPZ) cultivars 'Baldur' (1,978 pounds per acre), 'Kronos' (1,938 pounds per acre) and 'Jetton' (1,850 pounds per acre). VSU cultivar 'Virginia' (1,840 lb acre^{-1}) ranked as 6th highest yielding, while the Svalöv Weibull (SW Seed) cultivar 'Casino' (1,560 pounds per acre) ranked 16th.

Table 2.10. *Average seed yield over sites of cultivars grown in the Southeast (extracted from the 2005, 2006, and 2007 National Canola Variety Trial Reports) plot trials 2005 to 2007.*

	Average Yield	Yield Rank	Site/ Years	Year 2007	2006	2005
	-----	-----	-----	lb/acre	-----	-----
Abilene[1]	1,747	9	22	1,544	1,487	2,209
ARC 2180-1[2]	1,687	13	16	1,582	1,367	2,114
Baldur[3]	1,978	2	16	1,645	1,655	2,636
Baros[3]	1,699	11	10	1,153	.	2,245
Casino[4]	1,560	16	12	.	1,560	.
Ceres[3]	1,518	19	22	1,713	1,139	1,703
Jetton[3]	1,850	5	22	1,605	1,565	2,379
Kronos[3]	1,938	3	22	1,753	1,710	2,351
KS 3018[1]	1,658	14	16	1,584	1,345	2,044
KS 3074[1]	1,763	8	12	1,888	1,638	.
KS 3254[1]	1,799	7	12	1,904	1,694	.
KS 7436[1]	1,698	12	22	1,863	1,300	1,932
KS 9135[1]	1,895	4	22	1,871	1,660	2,154
Plainsman[1]	1,421	19	22	1,549	1,399	1,315
Rasmus[2]	1,622	15	22	1,427	1,428	2,011
Sumner[1]	1,730	10	16	1,558	1,457	2,174
Viking[3]	1,487	18	12	1,487	.	.
Virginia[5]	1,840	6	16	1,560	1,882	2,078
Wichita[1]	1,994	1	22	1,707	1,701	2,574
Mean	1,764		17	1,653	1,555	2,137

[1] Kansas State University; [2] University of Arkansas; [3] Norddeutche Pflanzenzucht; [4] Svalöv Weibull; [5] Virginia State University.

SPRING CANOLA

Land choice

Spring canola can be grown on a wide range of soil types. However, the highest seed yields are usually obtained with well-drained, silt loam soils that do not crust. Soil crusting prior to seedling emergence is usually more problematic in spring canola than in winter canola. Crusting with spring canola can result in variable crop establishment and, when severe, may result in having to re-seed. Spring canola is very susceptible to saturated soils, and canola should not be planted in fields with poorly drained soils, standing water or in fields that have a history of flooding. Ideal soil pH for growing canola is between 6.0 and 7.0. Spring canola should not be grown in soils with a pH less than 5.5 as seed yields will be adversely affected.

Canola is most commonly grown following small grain cereals (winter or spring wheat, barley, corn or sorghum). To avoid a buildup of soil-borne diseases like Sclerotinia stem rot, blackleg or club root, growers should not plant spring canola the year after a previous spring or winter canola crop was grown in the same field. Canola crops should be planted only once every four years. Similarly, growers should avoid planting canola after other crops like legumes (peas, lentils, chickpeas, soybeans, field or dry beans) or sunflower that are susceptible to Sclerotinia stem rot, or Rhizoctonia and Fusarium root rots.

All canola crops are highly sensitive to herbicide carryover in the soil, and knowing the herbicide history of any field before planting canola is essential. Soil residual herbicides can cause severe yield loss or crop failure. Many herbicides used in cereal production have some plant back restrictions for canola (Table 2.1). Some herbicides - for example, Buctril (bromoxynil) - have only a 30-day plant back restriction; however, Pursuit (imazethapyr) has a plant back restriction of 40 months, and the label requires a season-long field bioassay to be carried out before planting a canola crop. Indeed, Pursuit, used commonly on legume crops in the Pacific Northwest, has shown damage symptoms on canola crops planted six years after the last Pursuit (imazethapyr) application, so soil type, rainfall and a number of other environmental conditions will have an effect on herbicide breakdown and the effects on subsequent crops.

Growers can avoid some plant back restrictions by growing herbicide-resistant cultivars. For example, Clearfield® (or other imidazolinone resistant) cultivars can be planted the season after Pursuit is applied. Similarly, the standard plant back restriction after Liberty (glufosinate) application is 120 days, but there is no plant back restriction if Liberty Link® cultivars are planted. Finally, there is an 18-month plant back restriction after atrazine application, but an atrazine resistant canola cultivar has no restriction.

Land preparation

When growing any crop, growers need to adopt an appropriate tillage system. This system should maintain an appropriate supply of organic matter in the soil (4-8 percent). A proper supply and balance of nutrients must also be maintained. Tillage operations that will minimize soil pollution, maintain proper soil pH., and minimize soil erosion while reducing general soil degradation should be selected.

Spring canola can be planted into soils that are conventionally tilled, conservation or minimum tilled or direct seeded into standing straw stubble. No matter which system is used, the best results are obtained when canola crops emerge and establish quickly; hence, when they compete better with weed populations. Seedbed preparation is critical to achieving good seedling emergence and establishment and should provide a fine, firm seedbed for good seed germination, uniform emergence and full cover establishment. This will produce the best yields and allow for lower inputs. Although some straw residue from the previous crop is desired for erosion control, heavy straw residue can make achieving good seed-to-soil contact difficult and can result in straw hair-pinning (where seeds are held between bent straw) and poor emergence. This effect is usually less in spring canola than in winter canola, since cereal straw has usually decomposed to some degree during the previous winter months.

Cultivation prior to planting helps control weeds and volunteers from the previous crop. However, seedbeds should not be overworked as this will result in moisture loss and an increased chance of soil crusting before seedling emergence. In minimum tillage and direct seed situations, pre-plant broad-spectrum herbicides should be applied to reduce weed competition. A spring canola crop that establishes well competes well with most weed species, so good crop establishment is a major component of weed management.

Conventional tillage

Farmers have been utilizing plows from the onset of agriculture and many growers use conventional tillage practices involving primary tillage where the topsoil is plowed to a depth of six to 14 inches (15-36 centimeters). The goal of primary tillage is to remove (usually by inversion) crop stubble and control weeds. Timing of primary tillage is dependent on soil type, with heavier clay soils best plowed in fall so inverted soils are exposed to freeze and thaw cycles. Depth of plowing will depend on the soil type, but deeper plowing may result in excess fuel costs. Traditional cultivation implements include moldboard plow, disk plow and chisel plow.

Secondary tillage follows primary tillage to produce a finer tilth to the seedbed. The aim of secondary tillage is to maximize seed-soil contact at planting, and thus enhance moisture imbibition and accelerate germination and seedling establishment. Implements used include discs and harrows. If possible, multiple secondary tillage operations are completed at right angles. Secondary tillage is often associated with application of granular fertilizers and pre-plant incorporated herbicides.

Although primary and secondary tillage causes soil compaction, it is the most convenient methods used to manage soil compaction when it occurs. Other advantages of conventional tillage include:

- Makes it easy to apply fertilizer and perform other agronomic operations (i.e. seeding);
- Provides effective control of weeds that have germinated or established;
- Creates good soil tilth seedbeds which results in good seed-soil contact;
- Results in quicker soil warning in spring for more rapid seedling development;
- Reduces overwintering of pests (green bridge) due to the lack of residue on the soil surface.

However, conventional tillage is also associated with adverse effects, including:

- Increased chance of air and water erosion, due to lack of surface residue.
- Increased soil compaction, caused by making several trips of heavy machinery across land in a single season. Spring tillage is often conducted when soils are too wet, adding to soil compaction.
- Costs more than other systems due the increased number of operations and use of fuel.
- Decreased soil organic matter over time.
- Increased moisture loss due to tillage can cause drought stress later in the season.

Moisture availability is one major factor in the preparation of a conventional seedbed for spring canola. Canola seeds require shallow seeding depth. Unlike small grain cereals which can be planted 5 to 8 cm (2 to 3 inches) deep into available soil moisture, spring canola should not be planted to deep soil moisture when deep spring cultivations have resulted in excessive soil moisture loss. Spring tillage should therefore be limited to 2-5 centimeters (1-2 inches) to avoid soil moisture loss.

Conservation tillage systems

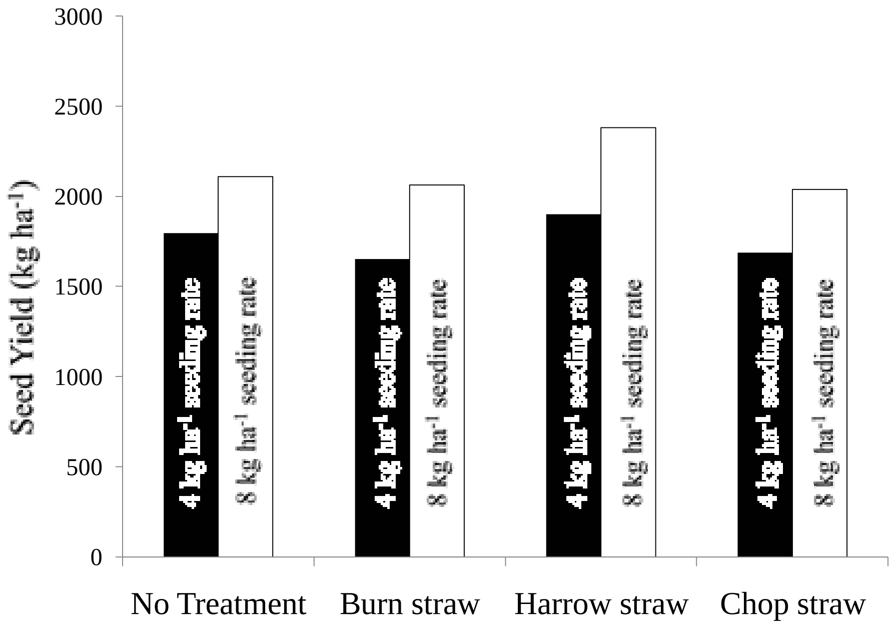
Conservation tillage systems are systems whereby the grower aims to conserve general soil health and moisture and reduce soil erosion. Direct seed systems, no-tillage systems, minimum tillage and reduced-tillage systems are all included within conservation tillage systems.

Conservation tillage systems maintain greater straw residue from previous crops to reduce soil erosion. These systems can reduce grower inputs by keeping tillage operations and associated fuel costs to a minimum, improving soil structure, reducing soil compaction and improving organic matter content, which increases soil water holding capacity (do all of these things increase soil water holding capacity, or just improving organic matter content?). In addition, researchers have shown that, particularly in spring canola crops, conservation tillage systems will increase earthworm populations.

In contrast to winter canola, spring canola crops have shown good performance under conservation tillage systems. Planting winter canola is not a good idea in situations where excessive amounts of fresh straw reduce seed-to-soil contact and soil temperatures are lower in fall months, when warm soils are needed for crop establishment. In many cases, spring canola is better suited to conservation tillage due to better soil moisture conservation and availability. In addition, cooler soil temperatures can be advantageous to spring canola crops. These crops have fewer problems in dealing with heavy cereal straw residue as the straw has partially degraded when seeding is done.

Cereal straw management can impact spring canola performance. In a 3-year study (15-year sites of data) conducted in the Pacific Northwest, spring canola was direct-seeded into standing winter wheat straw, harrowed straw, chopped straw and burned straw. In these studies, spring canola was planted at 4 and 8 kilograms per hectare (approximately 4 and 8 pounds per acre) seeding rates. Increased seeding rates always resulted in significantly higher seed yield (Figure 2.6). Seed yield from high seeding rates all exceeded 2,000 kilograms per hectare (approximately 2000 pounds per acre). Among straw treatments, the harrow treatment produced highest seed yield with the chopped straw treatment being lowest.

Figure 2.6. *Seed yield (kg/ha) of spring canola planted at 4 kg/ha and 8 kg/ha direct-seeded into standing winter wheat straw, harrowed straw, chopped straw and burned straw.*



Note that soil temperatures under conservation tillage systems are typically cooler than those from conventional tillage systems. High straw residue in the early years of a conservation tillage system can result in soils taking longer to dry out, delaying spring canola seeding. However, in an established direct seed system, improved water infiltration often allows growers to enter fields sooner, resulting in earlier planting and crop establishment and higher yields.

Seeding date

Seeding date of spring canola will have an effect on time of germination, crop emergence and establishment, days from planting to flowering, plant height, maturity and final seed yield. In general terms, seeding of spring canola should occur as early in the spring as possible, albeit that frost damage can occur and cause the need to re-seed later.

The optimum (early) seeding date for spring canola will depend on when farm machinery can get onto the ground, which is related to snow cover, precipitation, soil type and gradient. As noted above, seeding can be delayed where heavy straw residue holds soil moisture and lowers soil temperatures. For optimum seed germination, seeding should be delayed until soil temperatures exceed 10 ^{o}C (49 ^{o}F). Cooler soil temperature will cause slow and uneven germination, thin stands and greater weed competition.

Seeding rates

Always plant certified seed that is free from seed-borne blackleg (*Phoma lingum*), Sclerotinia stem rot (*Sclerotinia sclerotinium*), and Alternaria black spot (*Alternaria* spp.). Blackleg is not a problem in most U.S. canola growing regions, the southeast being a notable exception, and introduction of blackleg into some regions could greatly limit the potential for growing canola.

In many regions, seed treatments containing insecticides and fungicides (e.g. Helix XTra® or Prosper 400®) to prevent damping off and flea beetle damage are economically beneficial. These seed treatments also include a fungicide which offers control of seed-borne blackleg and Sclerotinia stem rot.

Canola seeds are small and round with approximately 90,000 to 115,000 seeds per pound (or approx. 200 to 250 seeds per gram).   Planting 1 pound of seed per acre at 115,000 seeds per pound will result in planting approximately 2.6 seeds per foot with 7.5-inch row spacing (this doesn't seem to add up). With larger seeds, planting 1 pound of seed per acre at 90,000 seeds per pound will result in planting approximately 2.0 seeds per foot with 7.5-inch row spacing. Certified seed bags each will have seeds per pound and the seed germination percentage listed. Use this information to help choose an appropriate seeding rate.

Spring canola crops have been successfully planted using seeding rates that range from less than 4 pounds per acre to over 10 pounds per acre. Choosing a seeding rate that is too low will result in poor crop establishment and most likely increase weediness, while choosing a seeding rate that is too high will result in high plant populations with thin-stemmed plants, high intra-crop competition, crop lodging at maturity and decreased yields.

Most seed drills used to plant small grain cereals or alfalfa can be used to plant spring canola. Double disk opener drills provide the best results when planting winter canola into well-cultivated seedbeds. However, shank, single disk and air-drills have all been used successfully to plant spring canola. Use of press wheels or other packers behind the openers improves seed-to-soil contact, creating better seed germination, emergence and stand establishment. Always check the drill calibration prior to planting. Many older small grain cereal seed drills do not allow accurate planting of very small seeds at low seeding rates. In these cases, seeder modifications may be necessary or the seed can be mixed with filler. Spring canola also can be broadcast seeded, in which case the seeding rate should be increased 25 to 30 percent compared to drill planting.

The resulting plant stand of spring canola will be determined by the seeding rate and seedling emergence. Under more adverse germination rates, higher seeding rates will need to be considered to achieve the same plant stands that would be achieved under ideal germination conditions. Spring canola seedlings have a markedly lower establishment rate than small grain cereals like wheat and barley. Under average seeding conditions only 40 to 60 percent of the seeds planted will develop into mature plants.   Planting into soil and seedbeds that are less than optimal will require increased seeding rates to compensate for poor seedling emergence. For example, direct seeding into standing wheat straw requires a 10 to 15 percent increase in seeding rate to achieve the same plant stands as seeding into a well-cultivated and firm seedbed.

Spring canola plants in low planting densities have the ability to compensate; individual plants will have broader stems and greater raceme branching because of less intra-crop competition. However, in extreme cases pods on these larger plants can mature at different times, increasing the chance of pod shatter and seed loss.

The aim is to use a seeding rate that results in 10 to 16 seedlings per square foot (105 to 170 seedlings per square meter), which should produce a plant stand count at harvest of about five to 10 plants per square foot (52 to 105 plants per square meter). Studies have shown that canola seed yields are not significantly reduced unless plant stand counts at harvest are less than 3.5 plants per square foot (37 plants per square meter) or greater than 19 plants per square foot (200 plants per square meter). Achieving such plant stands will require a seeding rate of six to seven pounds per acre, which is the rate most recommended with seven to eight inches of row spacing.

Seeding depth

Seeding depth should be as shallow as allows the seed to be covered given that the seed *must* be planted into moisture. Seeding recommendations are to plant ¼ to 1 inch deep. However, as noted, seed must be placed into moisture. Seeding too shallow can result in irregular germination and emergence and patchy plant stands as soil around the seed zone dries. Planting too deep can delay seedling emergence, resulting in poor plant vigor and increased potential for non-emergence as a result of soil crusting.

Spring canola can be planted on row spacing from six to 15 inches, depending on the seeder available. Wider row spacing will require lower seeding rates. For example, plant five pounds per acre when using a 7-inch row spacing and plant three pounds per acre with 15-inch spacing. Wider row spacing will cause less intra-crop competition so plants can be closer together within a row. Planting on narrower row spacing will achieve quicker ground cover, likely resulting in fewer weeds compared to planting on wider rows. Many direct seed planters use a wider row spacing to allow for difficulties in handling high straw residues. Some use a paired-row system whereby two rows are planted close together and separated further from the adjacent pair. Some of these seed drills have mechanisms to remove some or all of the residual straw over the planted row. Wider row spacing may, in an organic system for example, allow for mechanical post-emergence weed control.

Nutrients

High yield with high end-use quality of spring canola can only be obtained through effective nutrient management. As with nutrient management of any agricultural crop, appropriate soil sample analyses are essential. Make sure to take these samples early enough to allow sufficient time for the analyses to be completed and the results returned. Nitrogen, phosphorus, sulfur, potassium and boron are, depending on the region, the most limiting nutrients for successful spring canola production.

Nitrogen

All plants, including spring canola, assimilate nitrogen to form major plant components, primarily amino acids which are the building blocks of plant proteins. Suitable levels of nitrogen must be available for uptake by the plant before and during the times when the plant is growing fastest.

In spring canola the rate of nitrogen uptake increases significantly in early spring, just prior to the rapid accumulation of plant dry matter as plants move from a vegetative state to a reproductive stage. Flower buds develop and plant stems begin to elongate (bolt) in early June in the northern states. Spring canola flowers open in early July (depending on planting date and region), opening from the base of each primary and secondary branch or raceme. One to three flowers open per raceme each day. The duration of the flowering period depends on temperature and ranges from one to four weeks, by which time developing pods are visible on the flower positions that opened first. After flowering, seeds develop and eventually become mature as the plants senesce prior to harvest.

Note that almost half of the nitrogen uptake is completed while the plant is in the pre-bolt rosette stage, while most of the remaining nitrogen uptake occurs between the rosette stage and early flowering. Total plant nitrogen declines after flowering due to loss of blooms and leaves. Prior to plant senescence, nitrogen uptake and plant dry matter accumulation decline as the crop approaches maturity.

Nitrogen uptake and dry matter accumulation of spring canola are related, resulting in the following key points:

- Nitrogen uptake precedes dry matter accumulation.
- Plant dry matter accumulation (related to seed yield) is highly dependent of nitrogen uptake.
- Only half of the total plant dry matter has accumulated at the time of maximum nitrogen uptake.

Nitrogen is the most limiting of all plant nutrients in spring canola, and making sure that sufficient nitrogen is available to the plant at each growth stage is critical.

To determine the appropriate rate of nitrogen necessary requires the following:

- Estimate the expected yield of the crop. This will be determined by previous crops, rainfall potential, soil type and depth and planting date. In the Pacific Northwest region, spring canola yield potential can be estimated by considering the history of winter wheat yields, as winter wheat yield (bu/acre) multiplied by 35 estimates spring canola yield (lb/acre) from the same land.

  For example, winter wheat yields of 60, 70, 80, 90, and 100 bu per acre, would relate to winter canola yields of 1,500, 1,750, 2,000, 2,250, and 2,500 pounds per acre, respectively.

- Determine the amount of nitrogen needed to attain this seed yield. In general terms, the amount of nitrogen required is around 9.3 units of nitrogen for each 100 pounds per acre of harvested seed for low canola yield, 8.7 for moderate canola yield, and 8.4 for high yield. For example, nitrogen required for spring canola seed yield on 1,500, 2,000 and 2,500 pounds per acre are shown in Table 2.11.

Table 2.11. *Nitrogen requirement for spring canola with different seed yield potential*

Expected Seed Yield		Multiplier per 100 lb of canola seed harvested	Nitrogen required -- lbs N/acre--
Low	1,500	x 9.33	140
Moderate	2,500	x 8.75	175
High	3,500	x 8.40	210

Extracted from Northern Idaho Fertility Guide, Spring Canola, by Robert L. Mahler and Stephen O. Guy

Different U.S. regions have found similar but slightly different relationships between canola seed yield and nitrogen availability. The above multipliers were derived from studies in northern Idaho, although recommendations from Oregon are pounds N per acre = 100 pounds seed yield x 6.5 pounds N per acre with low seed yield potential up to = 7.5 pounds N per acre with low seed yield potential (high seed potential). Recommended nitrogen application in North Dakota also are lower than those in Table 2.11. North Dakota recommendations are 6.7 pounds N per 100 pounds of canola seed harvested for low seed yield potential (1,500 pounds per acre), 6.5 pounds N per 100 pounds of canola seed harvested for medium seed yield potential (1,500 pounds per acre), and 6.6 pounds N per 100 pounds of canola seed harvested for high seed yield potential (2,500 pounds per acre).

Once the yield potential of the crop and the total nitrogen required (Table 2.11) has been determined, add to this the nitrogen needed for residue breakdown (Table 2.13). Then subtract the mineralizable nitrogen (Table 2.14) and the nitrogen available in the soil (Table 2.12). This process in described in stages below.

- Collect appropriate soil samples from the top 2 feet (irrigated soils) or 3 feet (dryland soils) in 1-foot increments, and submit the samples for a nitrate-nitrogen (NO_3-N) analyses. Also test for ammonium nitrogen (NH_4-N) in the top foot of soil.
- Add the available soil nitrogen from the different soil depths. Note that parts per million (ppm) of nitrogen can be converted to pounds N per acre by multiplying by 3.5 (Table 3.5). For example if 5, 6 and 8 ppm NO_3-N are found in the first, second and third foot of soil, 1 ppm NH_4-N in the first foot total would be 5+6+8+1=20 ppm x 3.5 = 70 pounds N per acre.
- In conventional tillage systems, determine soil organic matter, and from this determine mineralizable nitrogen release (Table 3.5). Soils with less than 2 percent, 2-3percent, 3-4 percent, and greater than 4 percent organic matter will have 25, 35, 45, and 55 pounds of mineralizable nitrogen released per acre, respectively.

- Determine immobilized, or tied up, nitrogen in previous crop residue. Immobilization can cause problems in situations where large amounts of wheat straw or corn stalk residue tie up available nitrogen (Table 3.4). Increase applied nitrogen by 60, 45, 60, and 40 pounds per acre, when planting spring canola after winter wheat, spring wheat, corn and barley, respectively.

- Finally, add soil-available nitrogen to minerizable nitrogen, then subtract from the total required nitrogen and immobilized nitrogen to determine applied nitrogen.

Table 2.12. *Calculation to convert nitrogen soil test results in parts per million to pounds N per acre.*

Soil	Soil Test Results			Multiplication	
Depth	NO_3-N	NH_4-N†	Total N	Factor	Total N‡
(inches)	(ppm)	(ppm)	(ppm)		(lb/acre)
0 to 12	5	1	6	x 3.5 =	21
12 to 24	3	-	3	x 3.5 =	7
24 to 36	4	-	4	x 3.5 =	14
Total	11	1	12	x 3.5 =	42

Extracted from Northern Idaho Fertility Guide, Spring Canola, by Robert L. Mahler and Stephen O. Guy, University of Idaho.
† Ammonium content is usually low and is often not included in the soil test.
‡ ppm x 3.5 = pounds N per acre.

Table 2.13. *Nitrogen needed for cereal straw (residue) breakdown.*

Residue (tons)	N to add (lbs/acre)
0.5	7.5
1	15
2	30
3	45
4	50
More than 4	50

Extracted from Northern Idaho Fertility Guide, Spring Canola, by Robert L. Mahler and Stephen O. Guy, University of Idaho.

Table 2.14. *Mineralizable N release rates.*

Organic matter (%)	N released in growing season (lb/acre)
Less than 2	25
2 to 3	45
3 to 4	60
More than 4	75

Extracted from Northern Idaho Fertility Guide, Spring Canola, by Robert L. Mahler and Stephen O. Guy, University of Idaho.

Sulfur

Sulfur is often the second most limiting nutrient for successful spring canola production. Sulfur is required to attain high yield and good seed quality. Spring canola sulfur deficiencies result in pale yellow plants with poor plant growth and reduced seed yield. Spring canola crops require 1 pound of sulfur for each expected 100 pounds per acre of seed yield. Heavy precipitation over the previous winter can move sulfate (SO_4^-) deep into the soil profile away from spring canola roots. Apply sulfur according to appropriate soil tests. For 0-5 ppm SO_4-S, apply 20-40 pounds S per acre; 6-10 ppm SO_4, apply 10-20 pounds S per acre; more than 10 ppm SO_4-S, apply 0-10 pounds S per acre.

Note that some recommendations for sulfur application are limited to no more than 25 pounds S per acre, since sulfate is highly prone to leaching in the soil. However, others recommend application of higher rates, particularly with a field history of higher yield potential. In such case, apply enough sulfur to achieve 1 pound S per acre for every 100 pounds per acre of seed expected to be harvested, irrespective of the application rate.

Phosphorus

Spring canola has a moderate requirement for phosphorus, although phosphorus deficiency symptoms (plants remain green but are stunted) can be difficult to detect visually. However, phosphorus application will increase seed yields when soil test levels are less than 5 ppm, using the sodium bicarbonate determination (Table 2.15). Phosphorus is not mobile in the soil so it should be applied in the spring, either banded with the seed at planting, or incorporated into the soil before planting.

Table 2.15. *Recommended phosphorus fertilizer rates for spring canola based on soil test results.*

Soil test P (0 to 12 inches)[1]			Application rate[2,3]	
NaOAc (ppm)	Bray 1 (ppm)	$NaHCO_3$ (ppm)	P_2O_5 (lb/acre)	P (lb/acre)
0 to 2	0 to 20	0 to 8	60	26
2 to 3	20 to 30	8 to 10	40	18
3 to 4	30 to 40	10 to 12	20	9
Over 4	Over 40	Over 12	None	None

Reproduced From Northern Idaho Fertilizer Guide, Spring Canola. By Robert L. Mahler and Stephen O. Guy, University of Idaho

[1] Soil test P can be determined by three different procedures: sodium acetate (NaOAc), Bray 1 method, or sodium bicarbonate ($NaHCO^3$), the latter which should not be used on soils with pH values less than 6.2.

[2] $P_2O_5 \times 0.44 = P$, or $P = 2.29\ P_2O_5$

[3] Under reduced tillage, apply up to 20 lb P_2O_5 per acre on soils testing in excess of 4 ppm on the NaOAc test.

Potassium

Many U.S. soils are sufficient and application is only recommended after a soil test and according to the test results (Table 2.16). Potassium can be banded along with the seed, below the seed or alongside the seed at planting.

Table 2.16. *Recommended potassium fertilizer rates for winter canola based on soil test results.*

Soil test potassium (K) (0 to 12 inches)[1]	Application rate[2]	
	K_2O	K
(ppm)	(lb/acre)	(lb/acre)
0 to 50	80	66
51 to 75	60	50
Over 75	0	0

Reproduced From Northern Idaho Fertilizer Guide, Spring Canola. By Robert L. Mahler and Stephen O. Guy University of Idaho.

[1] Sodium acetate extractable K.

[2] K_2O x 0.83 = K, or K = 1.20 K_2O

Boron

Spring canola requires more boron than most other crops. Broadcast 1 to 2 pounds boron per acre if soil tests show less than 0.5 ppm boron. Boron should be applied before or at seeding in the fall. Never band boron, since high concentrations will cause toxicity.

Micronutrients

Although extensive studies have not been completed, spring canola has not been shown to respond to applications of chlorine, copper, iron, manganese, molybdenum or zinc. Do not apply any of these micronutrients unless suitable guidelines are established, as the chance of creating toxicity problems is greater than the chance of correcting any micronutrient deficiencies that might exist.

Lime application

The pH requirements of spring canola are similar to those of winter canola or spring wheat. Optimal plant growth occurs at pH between 6.0 and 7.0. Lime application is recommended with a soil pH less than 5.8. Lime recommendations using the Shoemaker, McLean and Pratt (SMP) Buffer are shown for winter canola in Table 2.17 and can be applied directly for spring canola.

Table 2.17. *Recommended lime application rates.*

Buffer pH	Target pH = 6.8 (lb ECC/acre) †	Target pH = 6.0 (lb ECC/acre) †
7.2	750	375
6.8	3,000	1,500

6.4	6,250	3,125
6.0	10,250 ‡	5,125
5.6	15,250 ‡	7,625

Reproduced from the Great Plains Canola Production Handout. By Mark Boyles, Thomas Peeper (Oklahoma State University) and Michael Stamm (Kansas State University).

† When using a continuous no-till production system, apply only ⅓ to ½ the recommended rate.

‡ When lime recommendations exceed 10,000 ECC per acre, apply at ½ rate, incorporate , and re-test after 12 to 18 months.

Cultivar choice

Over the past 15 to 20 years, many canola breeding organizations and seed companies have tested spring canola cultivars in different U.S. spring canola production regions. A number of cultivars have shown good adaptability in the U.S. and many more genetic improvements are expected in the future.

North Dakota Region

The largest acreage of spring canola is in North Dakota and Minnesota. North Dakota State University (NDSU) has been conducting spring canola yield trials for many years and further details of yield potential for a wide range of cultivars under North Dakota growing conditions can be found on the university web site (http://www.ndsu.edu). Cultivars tested by NDSU are grouped as non-Roundup Ready types (Table 3.18) and Roundup Ready types (Table 2.19). Cultivars shown in these tables only include the lines which have been in field testing trials in 2007 and 2008. Yield potential of Roundup Ready and non-Roundup Ready spring canola is very similar (2,342 and 2,303 pounds per acre, respectively).

Non-Roundup Ready in the NDSU trials comes from Bayer CropScience, Dow AgroSciences and DEKALB/Monsanto. Bayer CropScience cultivars are Liberty Link® or resistant to glufosinate herbicides, while those from Dow AgroSciences are Clearfield® or resistant to imidazolinone herbicides. Highest seed yield in the non-Roundup Ready trials over the past 3 years was InVigor 5550 with a yield of 2,782 pounds per acre. All cultivars in the non-Roundup Ready NDSU trials had good potential, and the lowest yielding cultivar in this trial (Nexera 830 CL) still produced an acceptable seed yield of 2,086 pounds per acre.

All the cultivars tested in the Roundup Ready NDSU spring canola trials are resistant to glyphosate herbicides. Cultivars entered into these yield trials were from Brett Young, Canterra, Cargill Specialty Oils, Croplan Genetics, DEKALB/Monsanto, Pioneer Hybrid, and Proseed. More Roundup Ready cultivars appeared in the NDSU trials in 2008 and 2009 than the non-Roundup Ready trials, and there was a greater range in seed yield from 45H26 with a yield of 2,750 pounds per acre, to 1818 RR with a yield of 1,850 pounds per acre.

Pacific Northwest Region

Since 1994 the Pacific Northwest Canola Research Program has funded a project at the University of Idaho to set up a spring canola cultivar testing scheme, the Pacific Northwest Canola Variety Trial (PNWCVT), to cover regions throughout the Pacific Northwest. These trials have been successful in attracting cultivar entries from seed and breeding companies. Both commercial cultivars and advanced breeding lines have been tested. During 14 years of spring canola testing in the Pacific Northwest, the project has evaluated 197 different spring cultivars representing 21 companies. In 1999, the spring-planted trial gave many Pacific Northwest farmers and researchers the first opportunity to see several Roundup Ready® cultivars in a variety of locations in the inland Pacific Northwest. These trials have allowed the farming community to observe these cultivars at a number of field demonstrations, and have provided yield data to help growers choose which cultivars to grow. A more complete summary of the PNWCVT can be found at http://www.ag.uidaho.edu/pses/brassica/.

All cultivars types (Roundup Ready®, Liberty Link®, Clearfield®, and traditional) are grown collectively in the same yield trial. Therefore, herbicide tolerant cultivars are not sprayed with the selective herbicide (i.e., Roundup Ready cultivars are not sprayed with Roundup), and weed control is universal over the trial area, usually involving Treflan as a pre-plant incorporated and Assure II as a gray herbicide applied post-emergence.

Seed yield of all entries that appeared in the 2007 and 2008 PNWCVT are shown in Table 2.20. The seed yield of these cultivars is also shown averaged over only the Idaho sites (Table 2.21), only over the Oregon sites (Table 2.22) and only averaged over the Washington sites in table 2.23). Cultivars entered into the PNWCVT over the past 3 years come from Bayer CropScience, Cargill Specialty Oils, Croplan Genetics, DEKALB/Monsanto, Wilbur Ellis, and the University of Idaho. Cultivars coded as LL are Liberty Link® or resistant to glufosinate herbicides, those coded as RR are Roundup Ready® or resistant to glyphosate herbicides, and those coded as CL are Clearfield® or resistant to imazamox herbicides.

Average seed yield of all cultivars in the PNWCVT in 2006, 2007 and 2008 was 1,852 pounds per acre. Average seed yield in 2006, 2007 and 2008 was 11,948, 1,973 and 1,734 pounds per acre, respectively. Highest seed yield was obtained from IS7145 RR (2,207 pounds per acre), followed by InVigor 5550 LL (2,200 pounds per acre), and V1035 RR (2,177 pounds per acre), although several other cultivars were not significantly different in seed yield from these top three. Hyola 401 has been an entry in the PNWCVT over the past 15 years and has consistently performed well in this region. Industrial oil quality (high erucic acid) spring cultivars Hero, Sterling and Gem have generally produced lower seed yield compared to canola cultivars.

Table 2.18. *Average seed yield (pounds per acre) over sites and years of non-Roundup Ready spring canola cultivars grown in North Dakota (extracted from the 2006, 2007 and 2008 North Dakota State University Spring Canola Trial results).*

	Average Yield	Yield Rank	Site Years	Year 2008	2007	2006
Cultivar	--------------------------		lb/acre	--------------------------------------		
InVigor 5440[1]	2,518	3	6	2,912	2,123	*
InVigor 5550[1]	2,782	1	9	2,902	2,171	2,492
InVigor 5630[1]	2,447	4	9	2,777	2,073	2,587
InVigor 8440[1]	2,423	5	6	2,724	2,123	*
Nexera 830 CL[2]	2,086	7	6	2,163	2,008	*
Nexera 845 CL[2]	2,287	6	5	2,472	2,010	*
IS7145[3]	2,663	2	2	2,729	2,596	*
Average	2,302			2,668	2,158	2,540
LSD 5%	456			543	432	n.s.

[1]Bayer CropScience (Liberty Link®); [2] Dow AgroSciences (Clearfield®); [3] DEKALB/Monsanto.

Table 2.19. *Average seed yield (lb/acre) over sites and years of Roundup Ready spring canola cultivars grown in North Dakota (extracted from the 2006, 2007 and 2008 NDSU Spring Canola Trial results).*

	Average Yield	Yield Rank	Site Years	Year 2008	2007	2006
Cultivar	---------------------------		lb/acre	------------------------------------		
4414 RR[1]	2,346	8	6	2,849	1,842	*
1818 RR[2]	1,850	15	9	2,837	1,622	1,225
V1035[3]	2,746	2	8	3,268	2,458	2,416
V2010[3]	2,380	5	8	2,734	2,518	1,933
V2018[3]	2,527	3	5	2,733	2,218	*
HyCLASS 410[4]	2,361	6	7	3,129	2,284	*
HyCLASS 712[4]	2,239	12	10	3,134	2,035	1,720
HyCLASS 924 RR[5]	2,288	10	12	2,967	2,081	1,772
DKL 52-41[5]	2,347	7	8	3,148	2,145	*
IS3057[5]	2,405	4	8	3,243	2,052	*
IS7145[5]	2,300	9	12	2,919	2,239	2,015
45H26[6]	2,750	1	8	3,129	2,615	2,461
2066[7]	2,094	14	10	2,717	2,074	1,964
30 Caliber[7]	2,286	11	7	2,961	2,238	*
50 Caliber[7]	2,217	13	7	2,760	2,113	*
Average	2,342			2,968	2,169	1,938
LSD 5%	453			522	439	401

[1] Brett Young; [2] Canterra; [3] Cargill Specialty oil; [4] Croplan genetics; [5] DEKALB/Monsanto; [6] Pioneer Hybrid; [7] Proseed.

Table 2.20. *Average seed yield(lb/acre) over sites and years of cultivars grown in the Pacific Northwest Region (Idaho, Oregon and Washington, extracted from the 2006, 2007 and 2008 Pacific Northwest Canola Variety Trial results).*

	Average	Yield	Site	Year		
	Yield	Rank	Years	2008	2007	2006
Cultivar	----------------------------------			lb/acre ------------------------------------		
Hyola 401	2,049	6	22	1,932	2,176	2,035
Westar	1,475	23	22	1,656	1,404	1,329
Profit	1,642	18	22	1,536	1,730	1,666
Hero†	1,587	22	22	1,431	1,689	1,661
Goldrush‡	1,602	21	22	1,389	1,796	1,627
InVigor 5550 LL[1]	2,200	2	16	2,203	2,198	*
InVigor 5630 LL[1]	2,006	7	16	1,876	2,135	*
V1035 RR[2]	2,177	3	22	2,052	2,143	2,390
V2010 RR[2]	1,972	9	22	1,770	2,021	2,175
HyCLASS 924 RR[3]	1,879	14	16	1,737	2,021	*
HyCLASS 940 RR[3]	1,999	8	16	1,737	2,261	*
Hyola357 Magnum RR	2,116	4	22	1,976	2,197	2,195
IS7145 RR[4]	2,207	1	22	2,050	2,201	2,424
Range RR[5]	1,946	11	16	1,796	2,096	*
INT 3789 RR[5]	2,114	5	16	1,937	2,290	*
Premier[6]	1,745	15	22	1,547	1,852	1,865
Clearwater CL[6]	1,742	17	22	1,516	1,872	1,870
03.IL.1 CL[6]	1,939	12	16	1,708	2,170	*
UISC00.3.1.17[6]	1,937	13	22	1,706	2,160	1,950
UISC00.3.8.DE[6]	1,964	10	22	1,679	2,141	2,108
Sterling†6	1,605	20	22	1,390	1,833	1,586
Gem CL†6	1,613	19	22	1,319	1,750	1,823
UISH00.3.19.23†6	1,743	16	22	1,525	1,917	1,802
Average	1,852			1,734	1,973	1,948
LSD 5%	435			376	422	452

† Industrial, high erucic acid cultivar; ‡ *Brassica rapa* cultivar.
[1] Bayer CropScience; [2] Cargill Specialty Oils; [3] Croplan Genetics; [4] DEKALB/Monsanto; [5] Wilbur Ellis; [6] University of Idaho.
LL = Liberty Link®; RR = Roundup Ready®; CL = resistant to imazamox herbicides.

Table 2.21. *Average seed yield (lb/acre) over sites and years of cultivars frown in Idaho (extracted from the 2006, 2007 and 2008 Pacific Northwest Canola Variety Trial results).*

Cultivar	Average Yield	Yield Rank	Site Years	Year 2008	Year 2007	Year 2006
	----------	----------	----------	lb/acre	----------	----------
Hyola 401	2,351	6	10	2,151	2,387	2,502
Westar	1,530	23	10	1,406	1,588	1,576
Profit	1,806	19	10	1,311	1,991	2,054
Hero†	1,717	22	10	1,193	1,830	2,089
Goldrush‡	1,740	21	10	1,400	1,866	1,911
InVigor 5550 LL[1]	2,457	2	7	2,405	2,496	*
InVigor 5630 LL[1]	2,139	12	7	1,701	2,469	*
V1035 RR[2]	2,399	3	10	2,021	2,282	2,934
V2010 RR[2]	2,257	7	10	1,729	2,259	2,782
HyCLASS 924 RR[3]	2,072	14	7	1,766	2,301	*
HyCLASS 940 RR[3]	2,217	8	7	1,879	2,470	*
Hyola357 Magnum RR	2,384	4	10	1,956	2,476	2,690
IS7145 RR[4]	2,524	1	10	2,137	2,437	3,027
Range RR[5]	2,112	13	7	1,811	2,337	*
INT 3789 RR[5]	2,371	5	7	1,955	2,684	*
Premier[6]	1,980	15	10	1,427	2,073	2,411
Clearwater CL[6]	1,917	17	10	1,321	2,183	2,157
03.IL.1 CL[6]	2,208	9	7	1,891	2,446	*
UISC00.3.1.17[6]	2,161	11	10	1,803	2,388	2,217
UISC00.3.8.DE[6]	2,200	10	10	1,718	2,293	2,558
Sterling†6	1,848	18	10	1,278	2,116	2,061
Gem CL†6	1,793	20	10	1,186	1,862	2,307
UISH00.3.19.23†6	1,923	16	10	1,447	2,118	2,139
Average	2,045			1,657	2,201	2,329
LSD 5%	412			394	476	508

† Industrial, high erucic acid cultivar; ‡ *Brassica rapa* cultivar.
[1] Bayer CropScience; [2] Cargill Specialty Oils; [3] Croplan Genetics; [4] DEKALB/Monsanto; [5] Wilbur Ellis; [6] University of Idaho.
LL = Liberty Link®; RR = Roundup Ready®; CL = resistant to imazamox herbicides.

Table 2.22. *Average seed yield (lb/acre) over sites and years of cultivars grown in Oregon (extracted from the 2006, 2007 and 2008 Pacific Northwest Canola Variety Trial results).*

Oregon

	Average	Yield	Site	Year		
	Yield	Rank	Years	2008	2007	2006
Cultivar	------------------------------		lb/acre	---------------------------------		
Hyola 401	1,430	26	6	1,214	1,519	1,556
Westar	1,483	20	6	1,519	1,293	1,636
Profit	1,528	13	6	1,476	1,337	1,770
Hero†	1,493	18	6	1,280	1,404	1,795
Goldrush‡	1,476	21	6	1,333	1,432	1,664
InVigor 5550 LL[1]	1,705	4	4	1,622	1,788	*
InVigor 5630 LL[1]	1,681	7	4	1,530	1,833	*
V1035 RR[2]	1,702	5	6	1,589	1,589	1,928
V2010 RR[2]	1,809	1	6	1,469	1,810	2,149
HyCLASS 924 RR[3]	1,513	14	4	1,428	1,599	*
HyCLASS 940 RR[3]	1,692	6	2	1,692	,	*
Hyola357 Magnum RR	1,742	3	6	1,650	1,659	1,918
IS7145 RR[4]	1,804	2	2	1,804	*	*
Range RR[5]	1,508	15	2	1,508	*	*
INT 3789 RR[5]	1,657	8	2	1,657	*	*
Premier[6]	1,597	10	6	1,339	1,671	1,780
Clearwater CL[6]	1,564	11	6	1,316	1,620	1,758
03.IL.1 CL[6]	1,650	9	6	1,407	1,893	*
UISC00.3.1.17[6]	1,459	22	6	1,315	1,259	1,803
UISC00.3.8.DE[6]	1,397	27	6	1,260	1,363	1,567
Sterling†[6]	1,449	23	6	1,231	1,382	1,735
Gem CL†[6]	1,438	25	6	1,080	1,451	1,784
UISH00.3.19.23†[6]	1,558	12	6	1,305	1,569	1,800
Average	1,555			1,422	1,538	1,771
LSD 5%	254			245	298	269

† Industrial, high erucic acid cultivar; ‡ *Brassica rapa* cultivar.
[1] Bayer CropScience; [2] Cargill Specialty Oils; [3] Croplan Genetics; [4] DEKALB/Monsanto; [5] Wilbur Ellis; [6] University of Idaho.
LL = Liberty Link®; RR = Roundup Ready®; CL = resistant to imazamox herbicides.

Table 2.23. *Average seed yield (lb/acre) over sites and years of cultivars grown in Washington (extracted from the 2006, 2007 and 2008 Pacific Northwest Canola Variety Trial results).*

	Average Yield	Yield Rank	Site Years	Year 2008	2007	2006
	----------------------------	lb/acre		----------------------------------		
Hyola 401	1,883	3	11	2,192	1,965	1,569
Westar	1,367	16	11	1,997	1,220	1,043
Profit	1,466	14	11	1,799	1,470	1,212
Hero†	1,,487	13	11	1,768	1,549	1,216
Goldrush‡	1,498	12	11	1,415	1,726	1,331
InVigor 5550 LL[1]	2,109	.	7	2,388	1,901	*
InVigor 5630 LL[1]	2,008	.	7	2,283	1,802	*
V1035 RR[2]	2,016	1	11	2,392	2,005	1,745
V2010 RR[2]	1,729	7	11	2,011	1,782	1,464
HyCLASS 924 RR[3]	1,815	6	7	1,914	1,742	*
HyCLASS 940 RR[3]	2,148	.	7	2,277	2,051	*
Hyola357 Magnum RR	1,924	2	11	2,214	1,918	1,713
IS7145 RR[4]	2,034	.	7	2,126	1,966	*
Range RR[5]	1,906	.	7	1,974	1,854	*
INT 3789 RR[5]	1,986	.	7	2,107	1,896	*
Premier[6]	1,535	10	11	1,805	1,632	1,236
Clearwater CL[6]	1,622	8	11	1,845	1,562	1,514
03.IL.1 CL[6]	1,822	.	7	1,727	1,894	*
UISC00.3.1.17[6]	1,774	5	11	1,869	1,857	1,621
UISC00.3.8.DE[6]	1,839	4	11	1,920	1,988	1,628
Sterling[†6]	1,406	15	11	1,608	1,551	1,112
Gem CL[†6]	1,506	11	11	1,610	1,637	1,297
UISH00.3.19.23[†6]	1,593	9	11	1,751	1,716	1,351
	1,748			1,915	1,758	1,405
Average	398			453	401	355

† Industrial, high erucic acid cultivar; ‡ *Brassica rapa* cultivar.
[1] Bayer CropScience; [2] Cargill Specialty Oils; [3] Croplan Genetics; [4] DEKALB/Monsanto; [5] Wilbur Ellis; [6] University of Idaho.
LL = Liberty Link®; RR = Roundup Ready®; CL = resistant to imazamox herbicides.

HARVEST AND STORAGE

Pre-harvest treatment

Large plant biomass associated with winter canola can result in direct harvesting being slow and seed being of non-uniform moisture. It is common that farmers will swath and windrow winter canola, which results in uniform drying and faster harvest. It should be noted that swathing winter canola at the wrong maturity stage will result in shriveled seed and reduced seed yield and oil content (see below).

More recently it has been suggested that an alternative over swathing winter canola is "pushing," where the canola plants are pushed over rather than being cut and windrowed. The pushing operation causes the stem to '*crink*', reducing nutrient flow upwards to the plant and hence accelerating maturity. One advantage of pushing canola is that it results in less seed shatter compared to direct cutting or swathing. Pushing can be effective in situations where the crop is uniformly standing (i.e. not lodged) and here the field is relatively flat. It is not an option on the steep fields that exist in the Palouse region of the Pacific Northwest.

Spring canola crops are new to many U.S. growers, and many have adopted cultural practices developed in the western Canadian prairies where spring canola is grown extensively. The short growing season in Canada requires that spring canola be swathed prior to threshing to hasten maturity and avoid frost damage.

As spring canola gained popularity in the Pacific Northwest region, researchers and growers questioned whether swathing spring canola was necessary given the longer growing season compared to Canada or North Dakota. A three-year study was conducted in which canola was swathed at different stages of maturity and direct harvested at full maturity to examine the effects of swathing on yield and seed quality.

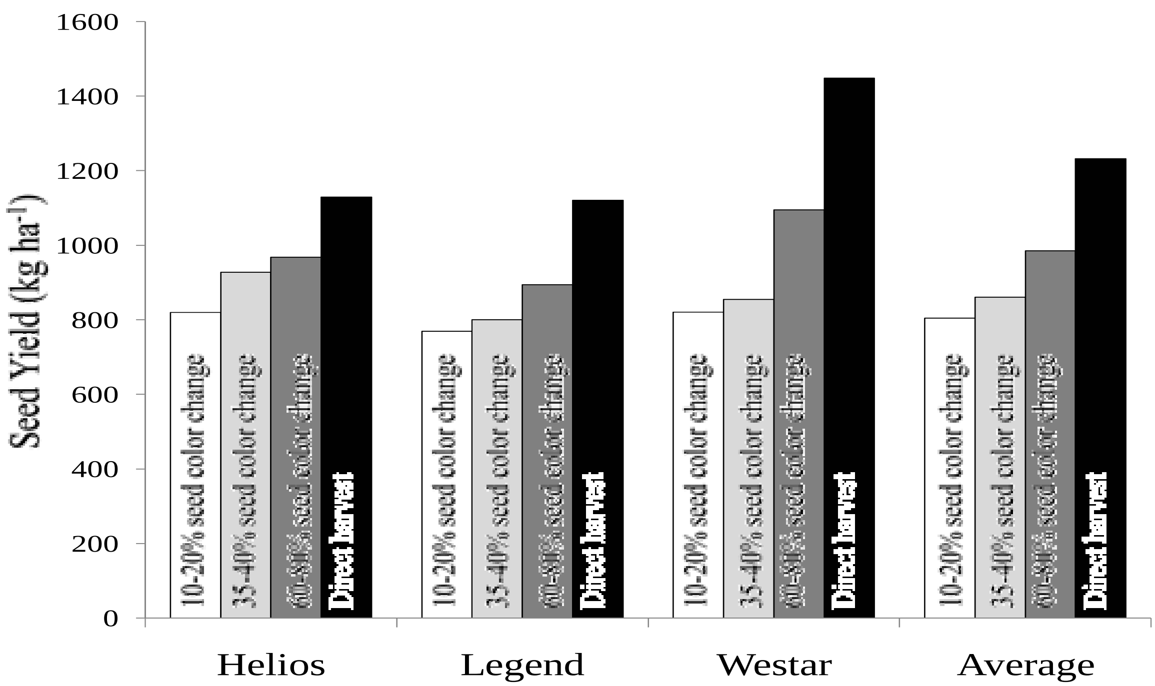
Averaged across years, swathed canola yields were lower than directly harvested canola (Figure 4.1). Yield loss due to swathing was significant only in the hot, dry years, so swathing canola would not be recommended under these conditions.

Some growers have suggested that swathing can help protect canola crops from seed shatter in the event of a delayed harvest. However, in all these studies when harvest was delayed considerably later than might be practical, greater yield loss always occurred in swathed windrows compared to a standing crop. In spite of these results, severe storms can cause significant pod shatter and seed loss in standing canola and in windrows, so mature canola should always be harvested in a timely fashion and without delay.

Chlorophyll in the seed is extracted with the oil during crushing and can increase the cost of refining the oil. Swathing can hasten the loss of green seed by about 2 days compared to seeds in standing crops. In some studies, however, swathing canola did not produce reduced chlorophyll content in the seed; in fact, chlorophyll content was actually higher in the swathed canola seed with highest chlorophyll levels in the earliest swathed plots. The highest levels of chlorophyll found in the Pacific Northwest trials were still low enough to allow the crop to be graded as No. 1 canola. However, growers should be aware that swathing too early results in increased chlorophyll content, which will increase the potential of reduced seed quality. Conditioning of canola seed at 75 ^{o}F and 90 percent relative humidity for 24 hours can decrease seed chlorophyll content but increases the cost of production.

After swathing, canola plants and seed have lower and more uniform moisture content at time of harvest compared to directly harvested canola. This can make harvest operations easier. Less chaff is found in swathed canola seed samples and excessive chaff is expensive to remove. In contrast, canola producers should note that swathing adds to the cost of crop production and requires an additional trip through the field. For example, if swathing costs $8 per acre and canola is $0.10 per pound, a grower could afford to lose about 80 pounds per acre with direct harvesting and still receive the same cash return as crops that were swathed.

Figure 4.1. *Seed yield (kg/ha) of three spring canola cultivars grown over three years and harvested at three maturity stages of crop swathing and at crop maturity without swathing.*



When to Swath

Time of swathing is critical. The crop must be swathed at the correct seed maturity stage and under the most favorable weather conditions if possible. Canola seed color is a good indication of the maturity of the crop. Spring canola seeds turn from green to reddish-brown, then to brown, depending on the weather and cultivar. In Canada, recommendations are to swath spring canola for optimum seed yield and quality is when average seed moisture content is 60 percent seed color change. Note that this recommendation has recently increased from a much lower preparation of brown seed color.

Canola crops only mature uniformly over a large area when the field is uniform. However, a wide range of maturity will often be found within a single field, particularly with large changes in topography. Canola will likely mature faster in shallow soils and on clay knolls than in deeper soils or draws. Since land with deeper soils generally produces higher seed yields than shallow soils, base swathing decisions on the maturity in the more productive areas. In extreme cases swathing different parts of a field at different time may be necessary.

Growers should try to avoid swathing canola when the air temperatures are higher than 30 °C (82 ^{o}F), particularly when humidity is low, since shatter losses can be higher under those conditions. Swathing under these conditions may also result in some immature green seed. Swathing in the evening or at night when air temperatures are cooler allows the seed to dry at a slower rate, which helps prevent green seed and low oil content.

Storage and Handling

Canola is very sensitive to heating in storage and therefore requires better quality storage bins than are required for cereals grains. The small size of canola seeds requires high quality silage construction to prevent seed loss through leakage. Heating and moisture migration problems tend to be more severe in large seed silos; therefore, canola seed should be stored in the smallest bins available. Maximum acceptable moisture content for storage of spring canola is 9 percent.

The susceptibility of canola to heating justifies extra care when placing the grain into storage. Because canola undergoes a sweating process before becoming dormant, the top hatch of the bin should be left open for several days during dry weather to allow heat and moisture to escape. Cleaning the seed prior to storage will enhance the efficiency of conditioning operations.

Canola seeds are considerably smaller than other cereal grains, so when transporting canola in trucks make sure that cracks are sealed with either duct tape or caulking to prevent seed loss. Growers should consider tarping canola seed trucks to prevent canola seeds from blowing out of the truck and causing weed problems along roads.

WEEDS AND WEED CONTROL

Compared to the major seed crops in the U.S. (e.g., corn, soybean, wheat and barley), relatively few herbicide options are available to canola growers. The list of registered herbicides in the U.S. remains a small subset of the chemistries available to Canadian and European growers. Herbicides registered for use on all canola cultivars, how to apply them, and weeds controlled are shown in Table 3.1. Note that herbicide users must read and follow all label instructions.

Table 3.1 *Registered herbicides on all canola cultivars, how to apply them, and weeds controlled.*

Herbicide	How to apply†	Weeds controlled	Comments
Assure II (quizalofop)	Foliar spray	Annual grasses and quackgrass	Different rates are required for effective control of different grasses ranging from 7-8 fl oz for green foxtail, yellow foxtail, wild oat and volunteer cereals, to 10-12 fl oz for quackgrass.
Poast (sethoxydim)	Foliar spray	Annual grasses	Rain fast one hour after spraying. Rates 4 fl oz for barnyard grass, green foxtail, yellow foxtail, but 5 fl oz for wild oat and volunteer cereals.
Select (clethodim)	Foliar, prior to plant bolting	Annual grasses	Crop injury can occur if applied after bolting. Do not apply more than 6 fl oz on each application.
Sonalan (ethalfluralin)	Preplant incorporated	Several annual broadleafs, foxtail, barnyard grass.	May be applied in the fall or spring. More effective than Treflan to control kochia. Crop injury may occur at high rates, particularly with cold and wet conditions.
Stinger (clopyralid)	Foliar spray when canola is 2- to 6- leaf stage	Canada thistle, perennial sowthistle, dandelion, curly dock, wild buck wheat, cocklebur, prickly lettuce, ragweed, chamomile, nightshade and biennial wormwood.	Can be expensive for full field control, most often spot-sprayed. Do not apply within 50 days of canola harvest.
Treflan (trifluralin)	Preplant incorporated.	Several annual broadleafs, foxtail, barnyard grass.	Treflan may be applied in the fall or spring. Most effective when these is good/sufficient soil moisture.

† Users must read and follow all label instructions.

In addition to the herbicides listed in Table 3.1, a number of canola cultivars have genetic resistance/tolerance to specific broad-spectrum herbicides. Information regarding use of these herbicides is shown in Table 3.2.

Table 3.2 *Herbicide-resistant canola cultivars.*

Herbicide†	Weeds controlled	Notes
Liberty (glufosinate) for LibertyLink® Cultivars	Annual broadleafs, annual grasses when applied when they are small.	Apply foliar from cotyledon stage up until early plant bolting.
Roundup (glyphopsate) for RoundupReady® cultivars	Most annual broadleafs and grasses.	Apply foliar from seedling emergence to plant bolting.
Beyond (imazamox) for imazamox tolerant cultivars	Many annual broadleafs and grasses.	Apply foliar from seedling emergence to full bloom.

† Read and follow all label instructions.

Weeds and Weed control in Winter Canola

When winter canola is planted on an appropriate date, and with proper pre-planting seedbed preparation or pre-plant herbicides (i.e., in direct seeding systems), then the crop will emerge and establish faster than most weed species and will be highly competitive with many annual weeds. However, poorly established winter canola crops are susceptible to weedy species. Given that very few herbicides are available on winter canola, preventative weed control is always a priority.

When winter canola is planted into fallow ground, perennial weeds such as Canada thistle, field bindweed and quackgrass should be managed in the fallow season by a combination of tillage and herbicides or by herbicides alone in chemical fallow. Roundup (glyphosate), 2,4-D and Fusilade (fluazifop-butyl) are labeled and effective herbicides for use on fallow ground. Do not use any herbicide in the fallow season that has plant back restrictions (e.g., dicamba (Banvel) or chlorsulfuron (Glean)).

Planting winter canola into a weed-free seedbed is essential for good weed management. As with fallow plantings, continuous cropping systems of winter canola will be highly competitive with weeds given good crop establishment. Winter canola is often planted after winter wheat so volunteer wheat can be problematic in the fall and may need to be controlled using a suitable grassy herbicide in the fall (i.e. Assure II, Poast or Select).

Pre-plant treatment with Treflan (trifluralin) applied at ½ to 1 pounds per acre or Sonalan (ethalfluralin) at 0.56 to 0.95 pounds per acre can be highly effective in controlling many annual broadleaf weed species and in suppressing many grassy weeds, including volunteer wheat and barley. Treflan and Sonalan are not effective in controlling wild oat (*Avena* spp.) or many canola-related mustard weeds. Both of these herbicides are applied before planting and must be incorporated into the soil, usually as a last-harrow operation. Both herbicides require sufficient soil moisture to be effective; they can be non-effective if the soil is too dry at the time of incorporation. Users must read and follow all label instructions.

One major rotational advantage of including winter canola in a predominant small grain cereal cropping system is to control grassy weeds like downey brome (*Bromus catharticus*), jointed goat grass (*Aegilops cylindrical*), wild oat (*Avena* spp.), Italian ryegrass (*Lolium multiflorum*) and feral rye (*Secale cereal*), which are all difficult to control in winter wheat. All of these things can be effectively controlled in winter canola by application of Assure II (quizalofop), Poast (sethoxydon) or Select (clethodim). Any of these herbicides can be applied in the fall after winter canola is partially established or in the early spring before plants begin to bolt.

Stinger (clopyralid) also is registered for use on winter canola and is effective in controlling many thistle-family weeds. However, stinger is very expensive and often can only be applied economically as a spot spray on problematic weedy patches, and hence, can help reduce thistle family weed problems in following crops..

A few winter canola cultivars now come with the Roundup Ready® trait and are therefore tolerant to application of Roundup (glyphosate) herbicide. If winter canola cultivar development follows the trend of spring canola, one can expect many more Roundup Ready® cultivars in the future. The Roundup Ready® system can be very effective in controlling a wide range of grasses and broadleaf weeds. Roundup Ready® technology also allows control of close relatives to canola like wild mustard (*Sinapis alba*), field or birdsrape mustard (*Brassica rapa*), black mustard (*Brassica nigra*) which can contaminate winter canola fields and reduce yields and end-use quality as it is difficult to separate the seeds of weed species from those of canola. The Roundup Ready® system can be used to control other less closely related, yet problematic broadleaf weeds like tumble mustard (*Sisymbrium altissimum*), tansy mustard (*Decurainia pinnata*), shepherds purse (*Capsella bursa-pastoris*) and field pennycress (*Thlapi arvense*). Of course, Roundup Ready® also can control volunteers of other susceptible varieties.

Winter canola cultivars will soon be available that are tolerant to imazethapyr herbicides (often referred to as Clearfield® technology). These cultivars, unlike the Roundup Ready® cultivars, are not genetically modified organisms (non-GMOs), which may offer a benefit when exporting to countries that have a ban on GMO crops. These cultivars would be handled in a similar manner to Roundup Ready® technology, but would be sprayed with Beyond (imaxamox) herbicide to control a broad spectrum of weeds. A further advantage of the imazethapyr-resistant cultivars is that they will not be affected by the plantback restriction that exists for Pursuit (imazethapyr), Assert (imazamethabenz) or Beyond/Raptor (imazamox). This will be a tremendous benefit in the Pacific Northwest, where winter canola is often grown in rotation with legumes (pea, lentil and garbanzo beans).

Although many spring canola cultivars are available that are resistant to Liberty (glufosinate), which is a non-residual, contact, broad-spectrum herbicide, there are currently no winter LibertyLink® cultivars commercially available in the U.S.

INSECT PESTS AND INSECT CONTROL

Insect infestation is a major limiting factor in successful and economic canola production. Insecticides are greatly limited in the U.S. compared to Canada and the European Union, and new products are unlikely to be available in the near future.

Foliar-applied insecticides currently registered in the U.S. include bifenthrin (Capture), deltamethrin (Decis), gammacyhalothrin (Proaxis and Prolex), lambda cyhalothrin (Warrier) and methyl parathion (cheminova Methyl). In addition, insecticide seed treatments (with or without fungicides) are also registered for canola and rapeseed (Table 3.3).

Spring and winter canola are impacted by the same insect pests albeit some pests negatively impact one type more than the other. Many of the newer canola growing regions in the U.S. or areas where large acreage of canola is yet to be realized may be relatively free from insect pests for now. However, the general adage that "*if you grow it, they will come*" certainly applies to canola. The larger the acreage and the longer the crop is grown in a region, the more prolific the insect pests become.

Table 3.3. ***Insecticide seed treatments registered for use on canola.***

Seed Treatment†	Comments
Gaucho 480 (imidacloprid)	Registered only for rapeseed grown and harvested for industrial uses and cannot be used for edible (canola) crops or any other human/feed consumption. States registered: AL, AR, AZ, CO, DE, FL, GA, IA, ID, IL, IN, KS, KY,LA, MD, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, OH, OK, OR, PA, SC, SD, TN, TX, VA, WA, WI and WY.
Gaucho 600 (imidacloprid)	Labelled for canola, but "rapeseed grown and harvested from GAUCHO 600 treated seed is only for industrial uses and cannot be used for edible oil or any other human/feed consumption." States registered: AL, AR, AZ, CO, DE, IA, ID, IL, IN, KS, KY, LA, MI, MN, MO, MS, MT, NC, ND, NE, NJ, NM, NY, OH, OK, OR, PA, SD, TN, TX, VA,WA, WI and WY.
Prosper 400 (clothianidin)	Features the next-generation systemic chloronicotinyl insecticide (clothianidin) to deliver flea beetle control that meets or exceeds any other seed-applied insecticide. In addition, Prosper 400 contains three proven and highly effective fungicides (thiram, carboxin, and metalaxyl) to help protect canola seedlings from seed rot damping off, seedling blight, and early season root rot caused by *Pythium*, *Rhizoctonia*, *Fusarium* and seedborne *Alternaria* spp and seed borne Blackleg.insect pressures. States registered: ID, KS, KY, MI, MN, MT, ND, OK, TX, VT, WA and WI.
Cruiser® (thiamethoxam)	Is a novel, systemic insecticide which belongs to a new subclass of neonicotinoids. With an excellent seed safety margin, Cruiser protects plants from a broad spectrum of seed, soil and foliar chewing and sucking insects to help get crops off to a healthy, vigorous start.
Helix XTra	Containing three low-rate fungicides (difenoconazole, mefenoxam and fludioxinil) and a low-rate insecticide (thiamethoxam), Helix™ XTra protects canola seed against seed- and soil-borne diseases as well as flea beetles. A ready-to-apply seed treatment, Helix XTra provides broad-spectrum protection against diseases such as seed rot, damping off, seedling blight, root rot and seed-borne blackleg.
Helix Lite	Contains three low-rate fungicides (difenoconazole, mefenoxam and fludioxinil) to protect canola seed against seed- and soil-borne diseases such as seed rot, damping off, seedling blight, root rot and seed-borne blackleg. With half the amount of insecticide component (thiamethoxam) as Helix XTra, Helix Lite is a strong option for growers who experience lower pressures of flea beetle or would like to protect against wireworms.

† Read and follow all label instructions.

Most insect pests of canola cause yield reduction and often an associated reduction in oil content, by damaging flowers, leaves, developing buds, seed pods, or by eating developing seeds. However, some aphids act as vectors for plant viruses like turnip mosaic, cauliflower mosaic virus, aster yellows, and beet western yellows.

Many insecticides are non-selective and will do damage to non-pest insects. Insecticide damage to non-target species can be particularly important with regard to natural parasites and parasitoids of canola pests which are often killed as a result of insecticide application. Also, winter canola is an early and very rich source of pollen and bee keepers frequently ask to site their hives close to flowering fields, so care should be taken to protect honey bees from insecticide sprays. Honey yields from canola pollen have been recorded between 90 to 450 pounds per acre, so honey may be an economical byproduct that growers and their families can utilize for additional outputs from the crop.

Cabbage Seedpod Weevil (*Ceutorhynchus assimilis* Paykull)

Importance in the U.S.: Cabbage seedpod weevil is the major insect pest of winter canola crops in the U.S. It causes maximum yield loss in the Pacific Northwest and is the most damaging insect pest of winter canola in Georgia.

Appearance: Adult: Ash-gray weevil less than ¼-inch long with curved snout (Figure 3.1). Larva: White, legless grub with light-brown head (Figure 3.2).

Figure 3.1 *Adult cabage seedpod weevil feeding on a developing canola pod.*

Figure 3.2. *Cabbage seedpod weevil feeding on developing canola seeds.*

Phenology: The cabbage seedpod weevil over-winters as an adult and flies to cruciferous crops when plants bolt and begin to flower (Figure 3.3). The peak emergence of the adult over-wintering generation of cabbage seedpod weevil usually coincides with half- to full-bloom in winter canola.

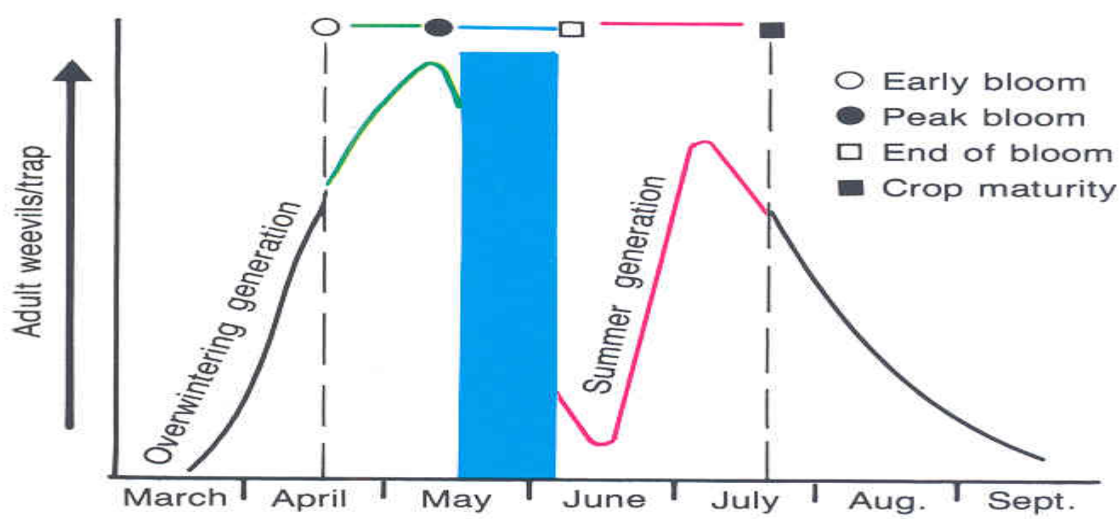


Figure 3.3. *Seasonal development of cabbage seedpod weevil populations in the Pacific Northwest region.*

Females feed on pods and lay a single egg in some of these feeding punctures. Eggs hatch in five to 30 days, depending on temperature. Each larva destroys five to six seeds as it develops. The second generation (summer) cabbage seedpod weevil adults do not lay eggs, so this population, which can feed on stems and green pods of spring canola crops but causes injury which is considered only superficial.

Crop damage: Larvae feed on seeds within pods (Figure 3.4). Each larva can destroy five to six seeds before exiting the pod through exit holes (Figure 3.5). In heavily infested crops without control, the cabbage seedpod weevil can reduce canola yields by up to 50 percent. However, winter canola can tolerate pod infestations of 25 percent or less without measurable yield loss, and insecticidal control is not justified until pod infestations exceed 25-40 percent.

Figure 3.4. *Seed damage caused by cabbage seedpod weevil larvae.*

Figure 3.5. *Cabbage seedpod weevil exit holes in canola pods.*

Control: Capture **(**bifenthrin), Warrior (lambda-cyhalothrin) and methyl parathion are currently the only registered insecticides for effectively controlling cabbage seedpod weevil in the U.S. Methyl parathion was used routinely in winter canola in the Pacific Northwest during past years, but its use has almost completely diminished due to strict handling regulations. Crops should be treated for cabbage seedpod weevil when an average of two or more adult weevils are observed on each plant. Capture should be applied when the adult females are about to lay eggs or at about 50 percent flower bloom.

Cabbage seedpod weevils have few natural predators, none of which offer much effective economic control that would avoid the use of insecticides. Two of the more prominent predators are the *Trichomalus perfectus* or Walker (Hymenoptera: Pteromalidae) and *Microctonus melanopus* (Hymenoptera: Braconidae).

Comments: Economic thresholds for cabbage seedpod weevil still need to be established. Bee protection has to be considered. Better plant resistance needs to be incorporated into new cultivars. Parasite and parasitoid impact needs study. Read and follow all insecticide label instructions.

Adult cabbage seedpod weevil are attracted to canola because of its yellow color. Yellow weevil traps have been designed to monitor weevil populations based on this premise. Isothiocyanates also play a role in the attraction of weevils, especially females, during oviposition. Some research has been done on an oviposition-deterring pheromone secreted by egg-laying female weevils.

<u>Aphids</u> (i.e., turnip aphid, *Lipaphis erysimi* (Kaltenbach), cabbage aphid, *Brevicoryne brassicae* L. and green peach aphid, *Myzus persicae* L.).

Importance in the U.S.: Aphids are important insect pests of winter and spring canola in all U.S. regions where the crops are grown. In the Great Plains and southeast, aphids are the most economically important pest.

Appearance: Winged and non-winged aphids measure ⅛ inch or less; green-gray body coloring. (Figure 3.6).

Figure 3.6. *Aphids colonizing on canola racemes.*

Phenology: Aphids are found on canola throughout the year. In winter canola crops, particularly in the southeast, winged and wingless aphid populations infest seedlings and plants as they develop into the rosette stage. In all winter canola growing regions, aphid populations infest plants from bolting, through flowering and on towards maturity.

Crop damage: Sap sucking by the aphids can affect rosette size and vigor. This can affect overwintering survival and yields the next season. Feeding by aphids can stop terminal growth, leading to reduction in plant size and seed yields, but damage may not be significant if infestations occur after pod fill is completed. Aphids have a greater impact on spring canola compared to winter canola as migrating aphid populations do not infest many regions until later in the season when winter canola is mature.

Aphids usually become abundant at the top of plants, and in most cases, individual or small groups of plants are infested. Species which form clusters on flowering stalks cause the most damage. Yield losses from cabbage aphids can exceed 50 percent in Poland, India, China, Australia and New Zealand, although aphids are minor pests at higher latitudes such as Canada and northern Europe. In the southeastern U.S., aphid infestations can cause yield losses in excess of 30 percent and significantly reduce seed oil content. Similar yield losses resulting from cabbage aphid infestations are reported in the northern U.S.

Control: Capture (bifenthrin) and Warrior (lambda-cyhalothrin) are currently the only registered foliar-applied insecticides that effectively control aphids in the U.S. Predators and parasites are very important and can successfully control aphids under the right conditions. In regions where there are significant fall infestations of aphid seed treatments Helix Extra, Poncho or Prosper would be effective. Indeed, these seed treatments have shown some activity against aphid infestations through the winter and early spring in the southeast regions.

During years of severe aphid infestations in the southeast, canola should be treated with an insecticide every two weeks. Thresholds for aphid treatment in Georgia are to spray insecticides when two or more aphids are observed on seedlings, five or more are observed on canola leaves at the rosette stage, or when 20 percent of racemes are infested while the crop is in full bloom.

Comments: The impact of fall and summer aphid populations on winter and spring canola needs to be evaluated in greater detail. The majority of research in the U.S. has been in Georgia, but this needs to be translated for other regions. Parasites and predators need further study. Aphid flight pattern and canola planting date relationships need study. Read and follow all insecticide label instructions.

Flea Beetle (*Phylotreta cruciferae* (Goeze))

Importance in the U.S.: The flea beetle is a major insect pest in spring canola wherever it is grown in the U.S. Flea beetles tend to be less important in winter canola, unless the winter crop is planted very early or in regions where winter and spring canola crops are both grown.

Appearance: Adults: About ⅛-inch long and shiny green-black (Figure 3.7). Some species have light-colored markings on wing covers. Larvae: Whitish, cylindrical and worm-like with small legs and brownish heads (Figure 3.8).

Figure 3.7. Adult flea beetle.

Figure 3.8. Flea beetle larvae.

Phenology: Flea beetles overwinter as adults and become active in the spring when temperatures reach 68 ^{o}F. The beetles fly to canola fields just as seedlings are emerging in the spring.

Crop damage: Adult beetles feed on cotyledons shortly after seedling emergence. The first symptoms of feeding injury are holes or small pits in the leaves and cotyledons (Figure 3.9). Feeding injury can result in plant death and significant stand loss, especially in hot, dry weather. The beetles are most active when the weather is sunny, warm and dry. They will also feed on canola leaves (Figure 3.10). Cool, damp conditions can reduce the feeding intensity of beetles and aid plant growth so that they can withstand the feeding damage. After the crop is beyond the seedling stage and the first leaves are fully extended, serious damage usually does not occur. By mid-June, adult flea beetles decrease in number.

Figure 3.9. *Flea beetles feeding on canola cotyledons.*

Figure 3.10. *Flea beetles feeding on seedling leaves.*

Control: Flea beetle damage tends to be the most severe around the outside of canola fields and impacts of flea beetle feeding can sometimes be reduced by simply double-planting around the field. Spring canola should be planted early to avoid flea beetle injury.

Registered insecticide seed treatments to control flea beetle include the neonicotinoid class. Helix Lite® and Helix XTra® are produced by Syngenta, and contain the active insecticidal ingredient, thiamethoxam. Helix XTra® contains a higher dosage of thiamethoxam than Helix Lite®. Prosper 400® features the next-generation systemic chloronicotinyl insecticide (clothianidin) to deliver flea beetle control that meets or exceeds any other seed-applied insecticide. Helix and Prosper seed treatments provide excellent flea beetle control through the seedling stage.

Helix Lite® and Helix XTra® contain three fungicides (difenoconazole, mefenoxam and fludioxinil) and Prosper 400® contains three fungicides (thiram, carboxin, and metalaxyl) that help protect canola seedlings from seed rot, damping off, seedling blight and early season root rot caused by *Pythium, Rhizoctonia, Fusarium* and seedborne *Alternaria* spp and seedborne blackleg.

Gaucho® 480 and 600 (imidacloprid) is registered for use only on industrial rapeseed crops and not registered for use on edible crops (Table 3.3). Neither of the Gaucho formulations are as effective in flea beetle control compared to Prosper of Helix products.

Flea beetles can be controlled in non-treated seed by foliar-spraying Capture (bifenthrin) as soon as flea beetles are observed or at the first signs of damage.

Comments: Flea beetle control has been helped greatly by registration of seed treatments. Read and follow all insecticide label instructions.

Diamondback Moth (*Plutella xylostella* L.)

Importance in the U.S.: Very minor economic importance in winter canola crops. Minor to severe in spring canola, particularly in regions like the Pacific Northwest where adult diamondback moths overwinter.

Appearance: Adult: Small brown and light gray moths about ⅓-inch long (Figure 3.11). Moths have a row of three diamond-shaped yellow spots down the middle of their back. Larvae: Small ⅓ inch-long greenish worms with fine, scattered erect hairs on their bodies (Figure 3.12).

***Figure 3.11.** Adult diamondback moth.*

***Figure 3.12.** Diamondback moth larvae.*

Phenology: Adult diamondback moths overwinter and migrate north over summer. Over-wintering populations of these moths may therefore pose a greater risk of injury to canola in the U.S. than in Canada. The first eggs are laid on the lower leaves. Later generations lay eggs higher on the plants. Hatching larvae feed first on leaves, then move to the buds, flowers and developing seedpods.

Crop damage: Damage by young larvae is characterized by irregular small holes and surface stripping on the underside of leaves. More severe damage is caused by older larvae, which feed on buds, flowers and young pods, resulting in seeds that do not develop properly. Some cultivars are affected more than others, but plant resistance is more related to avoidance. Early infestations of larvae feed on newly formed buds of spring canola, while later infestations feed only on plant leaves.

Control: Capture (bifenthrin) is currently the only registered insecticide for effectively controlling diamondback moth in the U.S. Canadian entomologists have reported an economic threshold of 300 worms per square meter on spring canola. However, if larvae infestation occur with early bud development, then Capture should be immediately applied. Parasites and predators are often important in controlling these adult moths.

Comments: Crop damage could be significant if the plants come under severe drought or heat stress at the time of diamondback moth larvae feeding. Read and follow all insecticide label instructions.

Lygus Bugs

Importance in the U.S.: Very minor pest of winter or spring canola in the Pacific Northwest.

Appearance: Adults: Pale green-brown (Figure 3.13). Nymphs: Similar in general appearance to adults but smaller and without developed wings (Figure 3.14).

Figure 3.13. *Adult lygus bug.*

Figure 3.14. *Lygus bug nymph.*

Phenology: Adult lygus bugs feed and lay eggs on canola plants during the budding stage.

Crop damage: Cause most feeding damage during dry years. Their feeding causes shedding or blasting of buds and flowers. Damage can include flower or seed abortion and shriveled seed. When they feed on pods, seed growth is inhibited. Seeds fed on by lygus bugs often collapse or have lesions.

Control: Lygus bug numbers seldom exceed the treatment threshold to merit chemical control.

Comments: Winter canola can be an early season host for lygus bugs. The crop may increase populations sufficiently so that they become a more serious problem in adjacent crops that are later maturing. Read and follow all insecticide label instructions.

Cutworms

Importance in the U.S.: There are several species of cutworms that can cause damage to canola; however, none of them cause significant damage to the crop in the U.S.

Appearance: Many cutworms are stout, smooth, soft-bodied, plump caterpillars. They vary from brown or tan to pink, green or gray and black. Some are all one color, others are spotted or striped. Some larvae are dull, others appear glassy. The adults are generally very robust brown or black moths showing various splotches, blotches or stripes in shades of gray, brown, black or white.

Phenology: These insects overwinter as eggs or larvae in the soil and attack emerging plants in the spring. The worms feed during the night and eat until they're fully grown and pupate. Adults emerge in August or September and lay their eggs in loose soil.

Crop damage: Damage caused by cutworms usually occurs in patches and if control is required, it is usually only in small areas.

Control: The treatment threshold is three larvae per square yard and pesticide should be applied at night while the larvae are feeding. Read and follow all insecticide label instructions.

Loopers and Armyworms

Importance in the U.S.: Minor, especially in well established crops.

Appearance: Adults: Brown moths of various sizes. Larvae: Looper larvae can be green, tan or brownish. Armyworms are dark blackish-brown with a yellowish stripe. All larvae are from ½ to 1¼ inches long.

Phenology: The adults begin laying eggs on weeds in canola fields in early spring. The next generation of armyworms will lay eggs under the newest canola leaves just before plants start to flower. They overwinter as pupae and emerge as adults in the spring.

Crop damage: Once the larvae hatch, they begin feeding on the foliage and cut of buds and flowers. Usually damage is not severe enough to warrant control, but if necessary it's normally only needed in patches.

Control: There are no established treatment guidelines to date.

DISEASE AND DISEASE CONTROL

Sclerotinia Stem Rot

Sclerotinia stem rot (often called white mold or Sclerotinia for short) in canola and rapeseed is caused by the fungus *Sclerotinia sclerotinium*. Sclerotinia is a soil-borne fungus and can survive in the soil for several years as sclerotia. Sclerotinia is a serious problem throughout the world and has a wide range of broadleaf hosts, including soybean, field bean, pea, lentil, garbanzo, alfalfa, potato and wild mustard. Sclerotinia stem rot, however, does not infect any grass crops. The first step in minimizing this disease in canola is to avoid growing the crop within three years of another host crop species.

Initial infection comes from sclerotia-infested soils or seeds (Figure 3.15). Avoiding the spread of sclerotia via seed is critical, and therefore, it is very important to plant only certified seed. Spread of Sclerotinia can be further reduced by using an appropriate seed insecticide treatment combined with a seed fungicide (e.g., Helix Lite®, Helix XTra® or Prosper 400®) or by using a fungicide seed treatment alone.

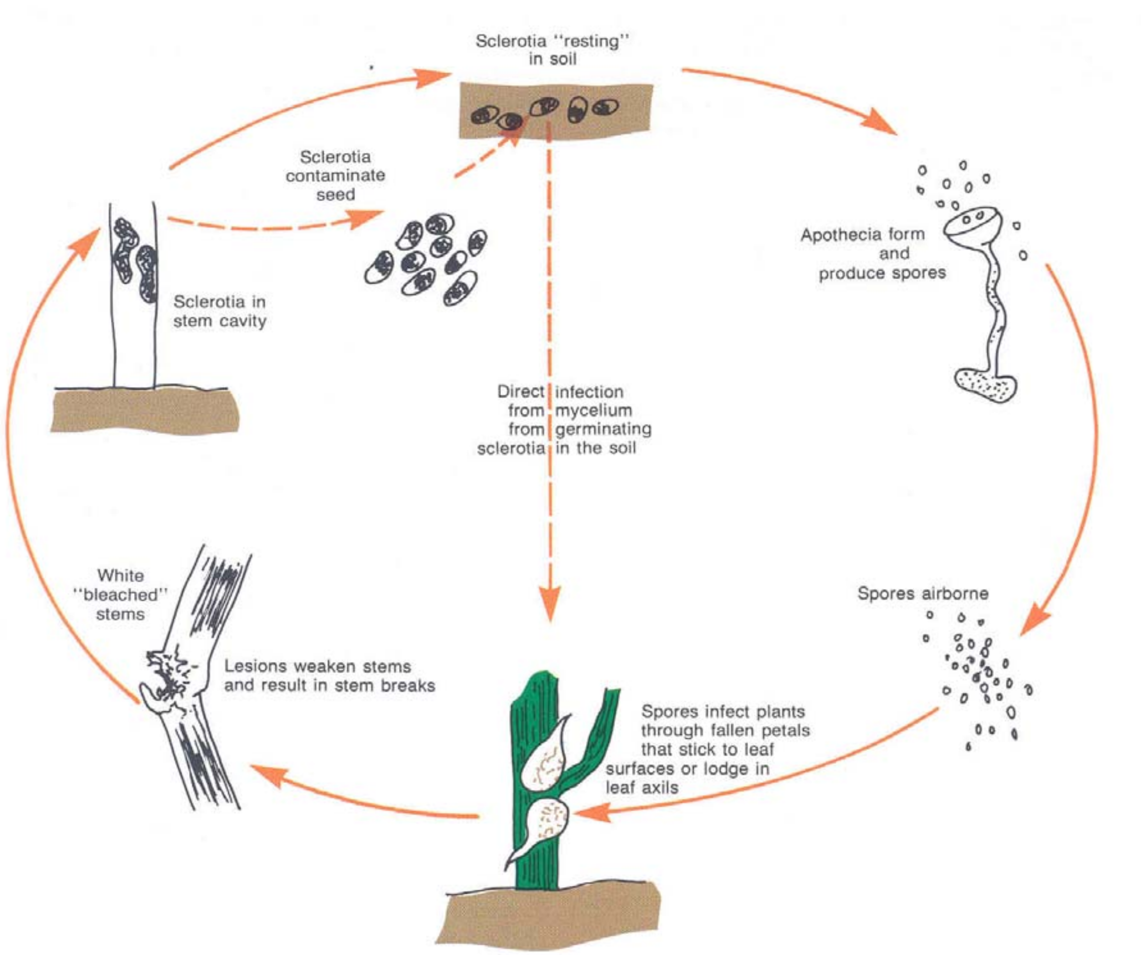


Figure 3.15. *Life cycle of Sclerotinia fungus.*

Soil-borne sclerocia apothecia (cup-shaped fruit bodies of Sclerotinia fungi) form and produce fungal spores. Sclerotia require prolonged (five- to six-day) periods of moist soil conditions to germinate, usually after canopy closure. Once produced, spores become airborne and can travel vast distances via winds. Spores infect canola plants through fallen petals that stick to leaf surfaces or lodge in leaf axils. Sclerotinia infection is temperature and humidity related, with the highest infection rates occurring in warm and wet conditions.

After infection, Sclerotinia lesions weaken plant stems and cause stems to have a white, bleached appearance. Stem rot symptoms usually become noticeable 10 to 14 days after infection. In most instances, the first visible symptoms are patches of what appears to be accelerated maturity, and crop lodging (Figure 3.16). Sclerotia and white moldy growth can often be seen at the base of an infected canola stem (Figure 3.17). This interferes with water movement up through the stem cavity and hence, results in premature ripening. Sclerotia in the stem cavity, combined with sclerotia on seeds, become the sources of inoculum for the following year's infection.

Figure 3.16. *Sclerotinia patched with earlier maturity.*

Figure 3.17. *Sclerotia growth at base of an infected canola plant.*

In winter canola, *Sclerotinia* is most damaging during wet springs or in irrigated canola. *Sclerotinia* is the most serious disease of spring canola in the Northern Plains states (North Dakota, Minnesota, Missouri, etc.), where summer rains and warm temperature increase problems. In the southeast, Sclerotinia is only a serious problem over the wetter winter months, although severe damage can be caused by the disease, particularly combined with winter tissue damage. In the Pacific Northwest, Sclerotinia is not a problem in spring canola due to the very low humidity and low rainfall throughout the summer months, and is only a minor problem in non-irrigated crops. The instance of Sclerotinia stem rot in the Midwest and Great Plains has been low in the past few years when winter canola has been grown commercially. However, as acreage of winter canola in these regions increases, the observation of more Sclerotinia stem rot would not be surprising.

Few winter or spring canola cultivars have good plant resistance to Sclerotinia stem rot and by far the best means to control the disease is to avoid it. As mentioned above, plant only certified seed, preferably with a seed fungicide. If *Sclerotinia* is noted in a field, use a suitable rotation of three to four years of non-host crops, preferably grass.

Fungicide applications to control Sclerotinia stem rot are not economical under most situations, unless the disease has been a major problem in the past and if a prolonged period of wet weather is expected. If a situation arises where fungicides are considered economical, then apply either:

- Endura® at 5 to 6 oz/acre when plants are between 20 and 50 percent bloom. Do not apply more than two applications or more than 12 oz/acre per season.
- Ronilan EG® at 10 to 16 oz/acre when plants are between 20 and 50 percent bloom.

Blackleg

Blackleg fungus (*Leptosphaeria maculans* and *Leptosphaeria biglobosa*) is potentially the most serious disease of either spring or winter canola. Blackleg is a serious problem in spring canola in the northern Midwest and southeast regions and in winter canola in the southeast. Blackleg is a seed-borne fungus and is most commonly introduced to an area by planting infected seeds (Figure 3.18). Once introduced, it will be in that region as long as canola crops are grown there. For example, blackleg was first found in Georgia in 1993 and caused significant crop loss in susceptible cultivars the following year. It is now recommended that only blackleg- resistant cultivars are planted in the southeast.

Figure 3.18. *Blackleg fungus infection on canola stems (top and bottom left) and infected seeds (bottom right).*

The blackleg pathogen can survive for several years on infected stubble and other crop residue (Figure 3.19). Spores can be produced until the infected crop residue completely degrades. In the spring, the blackleg pathogen forms fruiting structures on infected crop residue, which produce airborne spores capable of traveling long distances (up to 3 miles) on the wind and cause infection of canola seedlings. Leaf infections (spots) appear as round to irregular shaped lesions, which are white to light tan in the center, become papery and can break up towards maturity.

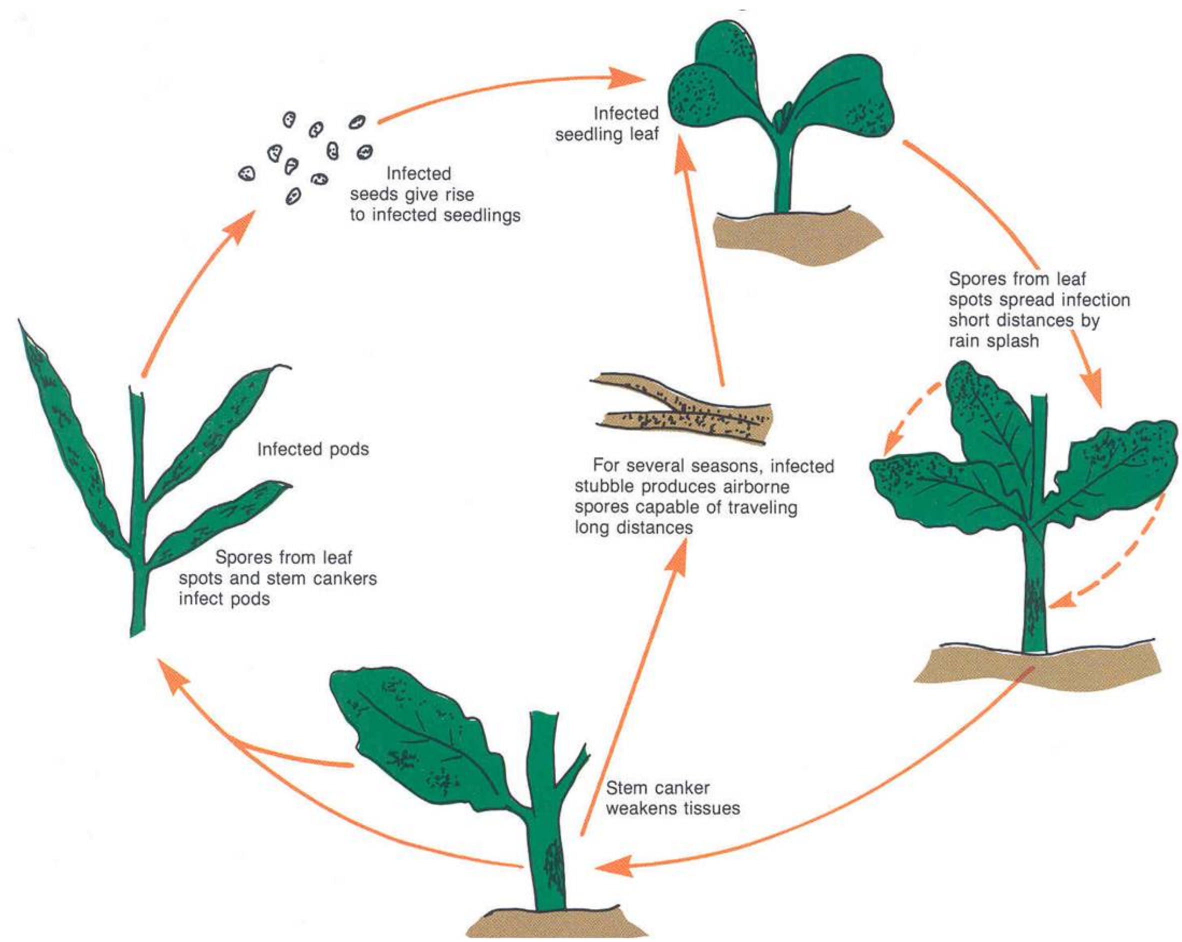


Figure 3.19. *Life cycle of blackleg fungus.*

Spores from leaf spots spread by first producing pycnidia (minute fungus fruit bodies) and during wet weather, these release conidia (fungus spores) that are dispersed by rain, and cause spread of the blackleg fungus into leaf spots. Blackleg infection is favored when the crop canopy is wet and air temperatures are between 70 ^{o}F and 75 ^{o}F (21 ^{o}C and 24 ^{o}C). Conversely, blackleg disease spread is when temperatures exceed 85 ^{o}F (30 ^{o}C) or fall below 50 ^{o}F (10 ^{o}C). Stem infections of blackleg fungus cause stem cankers, black spots and girdling (Figure 3.20). Stem infections cause cankers that weaken stems and cause crop lodging (Figure 3.21).

Spores from leaf spots and stem cankers infect pods, which in turn infect developing seed where the blackleg pathogen can survive for several years. Infected seeds give rise to infected seedlings. Infections from seed can result in early and widespread epidemics of the disease. Planting infected seed from one (infected) region to other (non-infected) regions has been the major cause of blackleg spread throughout the world.

Figure 3.21. *Blackleg fungus cause stem cancers with characteristics black spots and girdling.*

Figure 3.21. *Blackleg infections cause crop lodging.*

In regions where blackleg has not been introduced, plant only certified and inspected seed, preferably from regions where blackleg does not exist. Blackleg has yet to be introduced in the Pacific Northwest, perhaps due to the dry and hot summer conditions. This is an area where it is better to buy locally produced seeds rather than imported seed from a highly infected area. Where blackleg is prevalent, it is essential to plant only resistant cultivars.

Chemical control of blackleg by application of Quadris® is possible; however, see label for application directions and resistance management.

Alternaria Black Spot

Alternaria black spot is caused by the fungi *Alternaria brassicae* and *A. raphani*, and is a canola disease which infects leaves, stems and seed pods. Alternaria black spot has been found in all canola growing regions of Canada and the U.S. Spots vary in size and color from all grey to grey centers with black or purplish borders to all black. Infected seed pods can contain shrunken seeds infected by the fungus (Figure 3.22).

Initial inoculum comes from planting infected seeds or from infected canola stubble, volunteers or infection from related Brassicaceae weed species (Figure 3.23). Once infected, symptoms appear as spots on seedling leaves, which lead to dark brown to black leaf spots. The leaf spotting phase is usually relatively harmless, but serves as a buildup stage to increase the fungus for later stem and seed pod infection. As the crop matures, infected seed pods have a grey sooty appearance rather than the tan brown color of healthy seed pods. Yield loss can exceed 20 percent and can be worsened by an increase in pod shatter and subsequent seed loss.

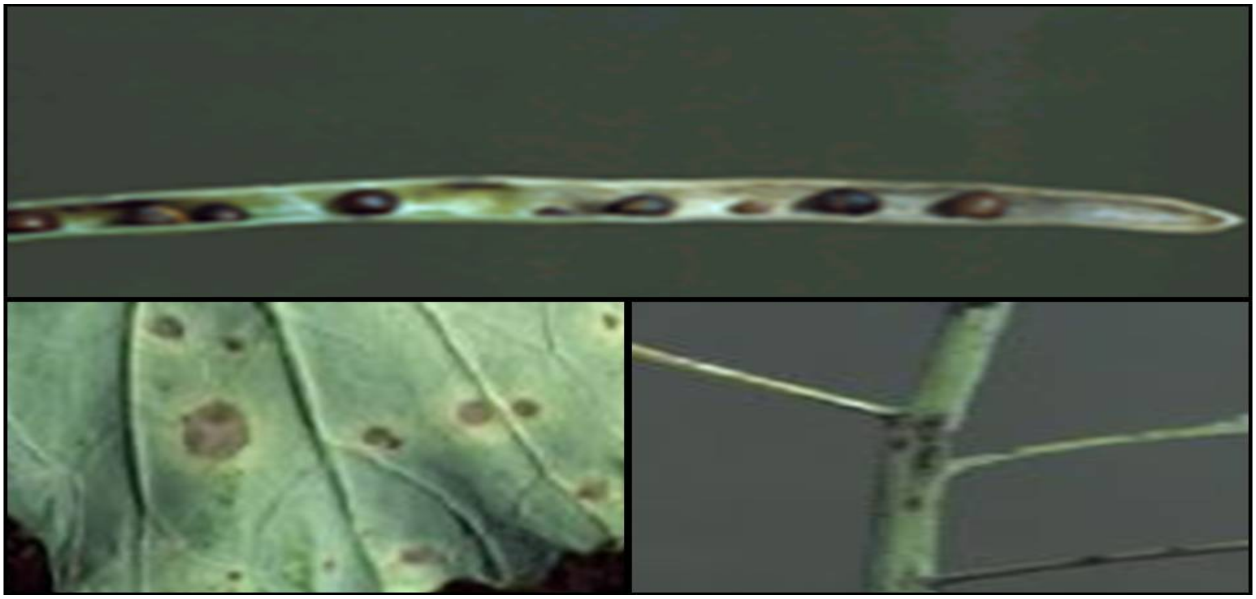


Figure 3.22. *Alternaria black spot on canola leaves (bottom left) and stem (bottom right) and can cause shrunken and aborted seeds (top).*

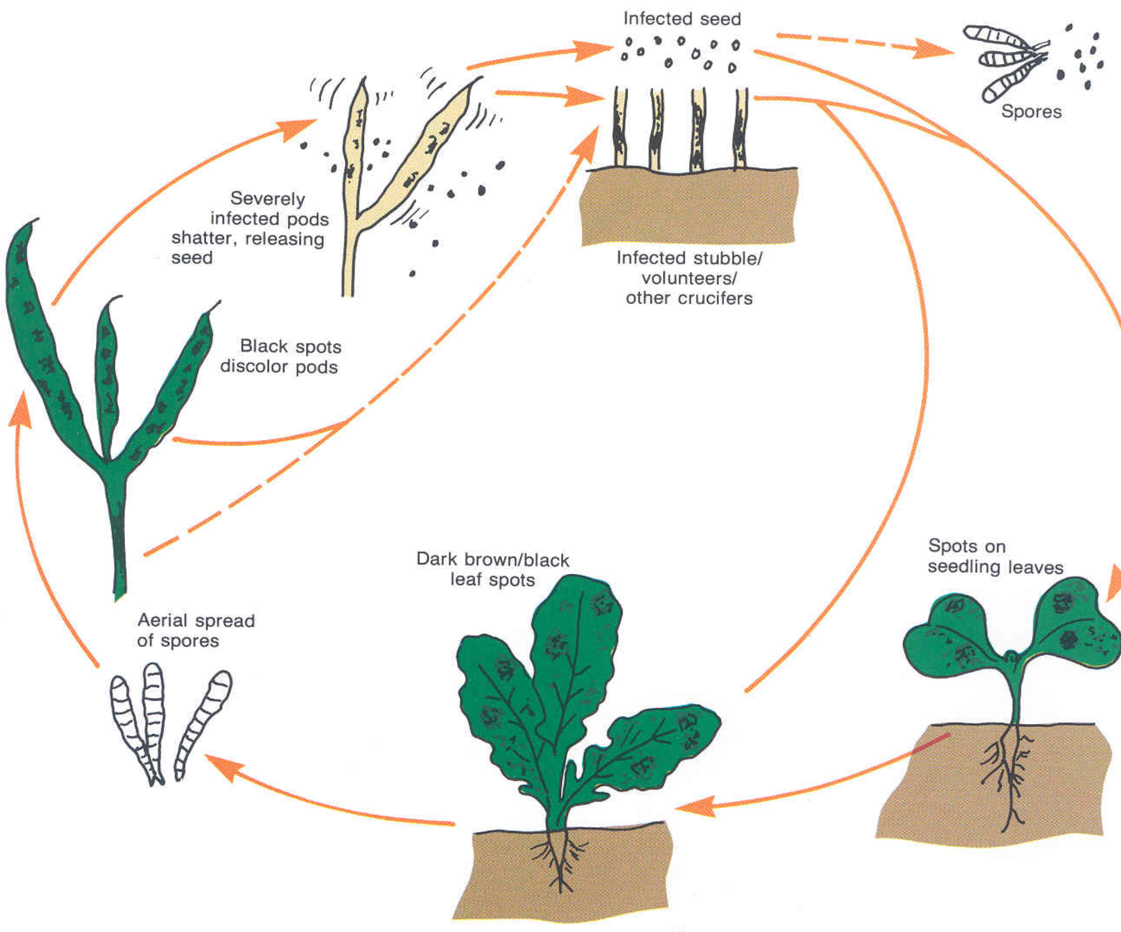


Figure 3.22. *Life cycle of Alternaria fungus*