Growing FLAX

Production, Management & Diagnostic Guide

Flax Council of Canada


JOHN DEERE
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Acknowledgements

This edition of the Growing Flax Guide has been thoroughly reviewed and updated. Chapter Leads with subject matter expertise were selected to co-ordinate these revisions by networking with their interprovincial colleagues. Chapter drafts were sent to all Chapter Leads for peer review to ensure excellence.

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Fifth Edition

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The fifth edition of the Growing Flax Guide builds on every edition preceding it. The Flax Council of Canada would like to acknowledge all contributors of past editions.

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Flax Council of Canada
MANFLAX
SaskFlax
Growing Forward 2
A federal-provincial-territorial initiative

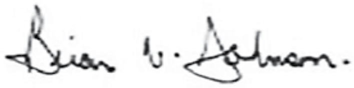
Forward

The Flax Council of Canada along with the Manitoba Flax Growers Association and the Saskatchewan Flax Development Commission proudly present the fifth edition of Growing Flax. Good agronomic practices play an important part in maintaining Canada's position as world leader in flax production and exports.

In this edition, production and management practices have been completely reviewed and updated.

Expanding uses for flax, both as an ingredient in foods and as a renewable resource, indicate a crop with a strong future. Today, premium quality flax is sold as a food and food ingredient. Increasingly, too, there is a greater recognition of the value of flax as an animal feed for improved animal health and production. Flax is also the source of linseed oil, which is a main ingredient in environmentally-friendly linoleum flooring and in quality oil-based paints and stains. Further value from flax is obtained from the straw, which is processed for industrial purposes. Thus, for thousands of producers in Western Canada, flax is a viable, expanding crop.

While the Canadian climate favours a high quality flax crop, the efficiency of Canadian flax producers, and the excellence of Canadian agronomic research is also widely acknowledged. In the development of this edition, we have had the expert help of many knowledgeable people, whose support is greatly appreciated. It is hoped that this edition will be useful to producers in the growing and management of the flax crop.



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Introduction

Flax is a self-pollinated crop widely adapted to temperate climates of the world. The scientific name for flax is *Linum usitatissimum L. Usitatissimum* literally means ‘most useful’. Flax indeed has many uses with seed used for industrial, food and feed purposes. **In 2014, flax was approved by Health Canada for a health claim linking eating ground whole flaxseed to lowered blood cholesterol levels, a major risk factor for heart disease.** Flax straw contains fibres that may be used from making textiles to automobile components.

It is believed that flax originated in the Middle East or Indian regions. Flax is an ancient crop dating back to 7,000 BC. Utilization of stem fibre and seed oil can be traced back to early civilizations in Egypt and the Middle East. Flax was one of the first crops brought to Canada, with production believed to have occurred in 1617, at the site of the old courthouse in Quebec City. Early breeding efforts date back to the establishment of the Experimental Farms Branch of the Canada Department of Agriculture in 1888. Cereal grains and flax were among the first crops produced in Western Canada.

The acreage of flax on the Prairies varies from 400,000 to 800,000 hectares (one to two million acres). Two main reasons why Canadian farmers choose to include flax in their crop choices:

- Its value in rotations; and
- A crop providing good returns on investment (low input crop).

Flax is an important crop to break up disease and insect populations common with our cereal and other oilseed crops. Flax often seems to pencil out as one of the best crops for net returns.

Canadian flax is sought-after in world markets for its high seed quality. Production in a northern country like Canada increases the alpha linolenic fatty acid (ALA) content and iodine value of the seed. ALA is an essential fatty acid for human nutrition. High iodine value is an important measure of drying capacity which is valued in the manufacture of linoleum, printing inks, paints and stains.

The stem fibre of flax is of considerable interest for the emerging bio-fibre industry. Flax fibre has good strength, is lightweight and is gaining momentum as key ingredient in the manufacturing industry.

Chapter 1: Crop Rotation

Flax is adapted and fits well in crop rotations in all soil zones of the Canadian Prairies. Flax provides producers with an alternative to cereals (spring and winter wheat, barley and oats), other oilseeds (canola and mustard) and pulses (peas, lentils and soybean).

With adequate weed control, the major factors influencing the yield of flax are drought, excess soil moisture, plant density and heat stress. Due to its shallow rooting character, the top 70 cm of the flax root system is responsible for at least 95% of its water and nutrient requirements. Although lack of moisture usually limits flax yield, there is usually a carryover of nutrients and moisture for the next crop below the 70 cm soil depth. To get optimum returns from the addition of fertilizer, it is important to soil test and fertilize to reasonable yield targets. Medium to heavy textured fertile soils are ideal to achieve high flax yield. After growing flax, limited residue (straw) is left and this may increase the risk of soil loss from wind and water erosion. As such, flax should be followed by a cereal crop in the rotation.

Flax seed yield is susceptible to high temperatures during the critical flowering period.

Effect of Preceding Crops on Flax

Most research carried out on the Canadian prairies indicates that previous crop and cropping sequences have a significant impact on flax production and flax yield.

EFFECT OF CANOLA STUBBLE ON FLAX

Flax performs poorly on canola and mustard *(Brassica)* stubble compared to cereal or other broadleaf crop stubble, particularly in the presence of volunteer canola seedlings. The lower flax yield observed after canola may be attributed to the negative impact canola has on soil arbuscular mycorrhizae. Arbuscular mycorrhizae are important fungi for a restricted root system crop like flax, as they result in greater surface area for nutrient uptake. This is especially important for nutrients that are relatively immobile in the soil, such as phosphorus, copper and zinc.

Flax is sensitive to phytotoxic compounds released from canola residue (straw) degradation and this may result in reduced flax germination and seedling growth. Nitrogen and soil moisture depletion from canola is high compared to that of most other annual crops. This is especially critical during years of below average precipitation. Reduced soil moisture would be of particular concern in the more drought prone, semi-arid areas of the Prairies, where water availability tends to be lower and less reliable than in sub-humid areas.

Production Tip

Rotate flax crops to prevent admixtures and minimize disease build-up; only one year in four in oilseed flax is advisable.

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Canadian producers grow an excellent flax crop—efficiently and expertly.

A Manitoba farmer harvesting flax in Holland, Manitoba – a bountiful crop!

1

EFFECT OF FLAX STUBBLE ON FLAX

Generally, lowest yields and quality of most crops occur when seeding on its own stubble. This may be attributed to major plant pathogens affecting crop productivity. The rotation responsible for lowest yield in flax is flax sown on flax stubble. The second lowest yield of flax usually results from growing flax on canola/mustard stubble. Reduced productivity of flax on flax stubble may be due to;

- A build-up of soil pathogens (fusarium wilt and pasmo).
- A dry seed bed due to a reduced capacity of straw to trap snow and conserve moisture and/or depleted soil moisture reserves in the top 70 cm of the soil profile.
- Soil crusting after seeding in the spring, especially when heavy rains precede crop emergence. This is particularly an issue in heavy (clay) soils that have little trash coverage from the previous flax crop.

EFFECT OF CEREAL STUBBLE ON FLAX

Research shows that flax sown on cereal stubble favours high yield in flax. Yields are higher when flax is sown on barley and wheat stubble versus oat stubble.

EFFECT OF LEGUME STUBBLE ON FLAX

Research indicates that flax sown on pea stubble has yield similar to flax sown on wheat and barley stubble. This may be partially related to soil moisture availability or the nitrogen benefit from the legume, or both. Recent research from North Dakota indicates that the greatest mean yield of flax occurred when flax was sown after legumes such as soybean, field peas or field beans. Flax grown on other legume stubble such as sweet clover and alfalfa had higher yield than after hay crops. Legumes, such as field peas, tend to use lower amounts of water compared to other annual crops. Field pea stubble results in greater nitrogen mineralization as pea roots with nitrogen fixing nodules degrade.

Effect of Flax on Subsequent Crops

EFFECT OF FLAX STUBBLE ON CEREALS

Research conducted on the Canadian Prairies demonstrated that higher cereal yields (spring wheat, winter wheat and barley) are observed on flax stubble rather than wheat stubble. An important consideration for this yield advantage was excellent weed control when growing flax. Weedy flax fields use water less efficiently than weed-free flax crops and result in less soil moisture available for the following crop. In addition, since flax gets almost all of its moisture needs from the top 70 cm of the soil profile, deeper and more fibrous cereal crop roots can often use the moisture and fertility available beyond the 70 cm depth.

Crop sequence improves water efficiency in flax and cereals. In years of drought, cereals grown on cereal stubble had greater yields than on flax stubble. The major reason for this appears to be that wheat stubble provides increased capacity to trap snow and conserve critical soil moisture. Increased water efficiency in flax under reduced tillage has also been attributed to arbuscular mycorrhizae since reduced tillage encourages the persistence of arbuscular mycorrhizae. Therefore, during periods of drought, flax stubble appears to be a poor choice for cropping of cereals. Nevertheless, soil moisture conservation may be enhanced by a cereal-flax rotation instead of a cereal-canola, since the soil profile tends to be drier after canola.

Flax stubble breaks up cereal pathogen and insect population cycles. This usually reduces the prevalence of disease and insect pests during the cereal portion of the rotation.

Market News

Canada is the world's leading exporter of flax seed

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EFFECT OF FLAX STUBBLE ON OILSEED AND LEGUME CROPS

Canola grown on flax stubble produces higher yields than canola grown on canola stubble, except in a drought where yield is reduced. Higher yields were partially associated with reductions in blackleg incidence and severity, when canola was grown in rotations with flax and wheat, or with the inclusion of flax in diverse rotations (canola-wheat-flax-canola) with conventional and minimum tillage.

As flax is not favoured by many canola insect pests, it is a break in the cycle of these organisms. This may result in reduced populations of pests and an overall reduction of infestation.

Similarly, yield of peas was higher on flax stubble than on pea stubble except under drought conditions. Sowing peas on flax stubble did not reduce the severity of mycosphaerella in peas, as was the case for sowing peas on cereal stubble.

Flax may be beneficial to succeeding crops in semi-arid climates found on the Canadian prairies because it tends to deplete soil moisture less than other oilseeds such as sunflower, safflower and soybean. With regards to depleting soil moisture, flax is similar to wheat, canola, millet and chickpea.

The unique drying properties of linseed oil permit it to be used as a base for the manufacture of protective coatings such as paints, stains, lacquers and varnishes.

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Chapter 2: Seed and Seeding Practices

Step 1–Choice of Seed

The use of certified seed of a suitable variety (see Photo 2-1) is recommended. Certified seed is tested to ensure genetic purity, good germination, minimal weed seed content and consistently yields better than farm-saved seed, producing a higher net return from the crop.

Choosing good seed is critical for stand establishment. Reductions in plant stand and seedling vigour will occur if damaged seed such as cracked (see Photo 2-2), split (see Photo 2-3), blighted or mouldy (see Photo 2-4), shrivelled, weathered (see Photo 2-5), or frozen seed (see Photo 2-6) is used. Seedlings with inadequate vigour tend to be negatively affected by the previous season's growing and harvesting conditions, as well as by soil pathogens. Seedlings produced from damaged seed may germinate very slowly and may also have injured root tips, broken or cracked cotyledons, split hypocotyls, twin radicles, radicles trapped inside the seedcoat and roots that are blunt, broken, long and spindly, or gnarled and distorted. All of these conditions may affect stand establishment and can reduce overall yield.

The flax seedcoat is fragile and can be damaged mechanically when flax is threshed at excessively high cylinder speed, low concave clearance, combined when seed is too dry, or from a combination of any of these. Large seeded varieties may be more prone to cracking than small seeded varieties. Split seed occurs when the two halves of the seedcoat become separated at the small end, exposing the embryo to soil microorganism invasion. This condition starts in the immature boll as the seed develops and is more likely to be seen with yellow seedcoat varieties. Blighted seed is often the result of weathering and may appear discolored (dull grey to black) or shrivelled. If harvest is delayed and the field is subjected to repeated high moisture conditions over the harvest season, the seedcoat often has a rough texture due to adherence of boll tissue. Other conditions that may contribute to blighted seed include drought during grain filling and disease. The pathogen *Alternaria* can colonize seeds under high moisture conditions during harvest and this may result in black discoloration of the seed. When Alternaria infested seed is sown the following year, the pathogen colonizes the seedling and may eventually kill it. If seed has shiny black discoloration, then it likely has been frozen and will not germinate.

Step 2–Seedbed Preparation

Flax requires a well prepared, firm, relatively even and moist seedbed for maximum emergence. Preparation for planting begins by reviewing the previous crop grown and herbicides used. Deciding when and where to grow flax in your rotation should be made on the basis of weed management and maintenance of soil organic matter. Flax has been found to have equal or better yields under reduced tillage (minimum or zero till) versus conventional tillage systems. This has been attributed to improved soil organic matter, increased soil moisture availability and increased arbuscular mycorrhiza colonization and rooting capacity despite reduced emergence commonly experienced under reduced tillage systems. Another advantage to minimum and zero tillage is a reduction of early weed emergence compared with conventional tillage systems.

Photo 2-1–Sound seed

Photo 2-2–Cracked seed

Photo 2-3–Split seed

Photo 2-4–Blighted and mouldy seed

Photo 2-5–Weathered seed

Photo 2-6–Frozen seed

Photo 2-7–Lodging

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If tillage is being used, then the land should be worked to minimize soil drifting and to ensure effective snow trapping. If spring tillage is required, it should be shallow in nature in order to maintain a firm seedbed. The effect of pre-seeding tillage in terms of the type of implement, the depth of tillage and the effect of packing either before or after seeding is not clearly defined. Research from the University of Alberta has shown that deeper tillage reduces stand establishment and that packing before or after seeding may be required.

Regardless of whether conventional, minimum or zero tillage is being used; sow the seed soon after the land is worked, before the soil dries out and before weeds seeds have a chance to germinate. Winter annual weeds, such as stinkweed, flixweed and shepherd's purse should be controlled using recommended herbicides in the previous fall or early spring (pre-plant or pre-emergent).

Step 3–Plant Stand Establishment

Good plant establishment is critical to attain high yield and high quality seed. A minimum plant population for optimum yield is 300 plants per square meter, unless grown under irrigation. Yield potential is reduced when plant stands are less than 300 plants/meter^2 (~300 plants/yard^2). Plant stands above 400 plants/meter^2 (~400 plants/yard^2) do not necessarily increase yield and may actually predispose the crop to lodging (see Photo 2-7). For maximum yield, farmers should generally seed between 40 and 45 kg/ha (35 and 40 pounds/acre). If seedbed conditions are poor, slightly higher seeding rates may help ensure adequate stands. Seeding rate should be adjusted on the basis of seed size, percent germination and soil fertility. When optimal, higher plant populations can take advantage of exceptional growing conditions. Yellow seeded varieties should be seeded at a slightly higher seeding rate, particularly if seed treatment is not used.

Higher yield potentials are common under irrigation and under these conditions, higher seeding rates such as 50 kg/ha (45 pounds/acre) may prove beneficial. Under high soil fertility or where crops are grown under irrigation, it is extremely important to choose a flax variety that has good lodging resistance, as both high soil fertility and increased moisture conditions increase the potential for lodging. Severe lodging in flax may reduce yield by 30%, whereas severe lodging in cereals may reduce yield by half that much. While flax is not prone to Sclerotinia stem rot, sclerotinia can occur under lodged conditions where flax stems are in contact with the soil. Under this situation, flax straw is usually inferior for fibre utilization.

Flax has relatively small seeds which do not have sufficient food reserves to overcome deep seeding or soil crusting. However, these small seeds are prone to drought if planted too shallow. Soil crusting may occur particularly with rainfall soon after seeding or on soils with high clay content and this may result in poor stands and reduced yield potential. Flax should be sown into moist soil, 2.5 cm to 4.0 cm (1.0 to 1.5 inches) deep with row spacing 15 to 20 cm (6 to 8 inches). Compared to that of other crops, flax seedlings are weaker and shallow seeding depth is more critical. Deeper seeding or seeding in soils that are prone to crusting should be avoided whenever possible as emergence will be decreased and delayed, resulting in weaker seedlings and reduced stands that would be prone to excessive weed competition, injury by herbicides and disease.

If stands are thin, a decision must be made whether or not to reseed. Flax seedling emergence is sometime poor due to the use of damaged seed, soil crusting, seedling diseases, adverse weather conditions, deep seeding, herbicide injury or other reasons. Generally, reseeding reduces yield potential as the early seeding advantage is lost and soil moisture is reduced from additional tillage. The added costs of reseeding must also be taken into account.

SEEDING DATE

Early seeding produces greater and more reliable yields, better control of later emerging weeds and reduces the risks of disease and insects. Additionally, it reduces the risk of damage caused by early fall frosts. Generally, flax that is sown in early to mid-May results in maximum yield and minimal harvest challenges. Flax may be sown up to June 1 with reasonable yield expectations. Seeding flax after June 1 lowers yield potential and increases harvest challenges as the crop would be maturing under cooler, wetter and shorter days. In part, this can be attributed to the fact that when seeds are planted earlier, moderate temperatures and ample soil moisture during flowering and seed development will favour high yield, oil content and oil quality. As well, seeding in mid-May generally results in high quality straw. In contrast, seeding after June 1 usually results in decreased yield, increased lodging, lower oil content and lower oil quality. Green stems and secondary growth are also more prevalent under late seeding conditions and may lead to difficulties in harvesting. Some flax varieties perform better than others under late seeding conditions and use of these varieties under these conditions is advised.

Flax plants just emerging (cotyledon stage) are the most susceptible to early spring frost, but can withstand temperatures down to approximately -3° Celsius. After the seedlings have passed the two leaf stage and are hardened by exposure, they can withstand temperatures as low as -8°C for a short time, without significant damage.

Water Use and Irrigation

Flax is a good fit in many irrigated crop rotations. It can quite reliably produce high yields and it is less susceptible or resistant to many of the specific diseases and pests that attack other important irrigated crops. Examples of pests in other crops include Sclerotinia stem rot, blackleg, clubroot, flea beetles, and the specific species and strains of Fusarium that cause Head Blight in cereals and wilts in other crops. Flax has generally been grown on one to several percent of the irrigated cropland in Alberta and Saskatchewan. The number of flax acres under irrigation varies with price and its perceived profitability in relation to other crop choices. Irrigation results in heavier crop stands that are more prone to lodging. To mitigate this, cultivars with good lodging resistance should be selected and excess nitrogen fertilization should be avoided.

The root mass of flax is among the lowest of all Prairie field crops. Also, the proportion of flax roots below 60 cm (and especially 80 cm) depth is lower than other field crops, except pea and lentil. Therefore, the depth of soil moisture management for flax irrigation should be somewhat shallower than cereals and canola, but deeper than beans or potatoes; 60-80 cm is suggested, depending on soil type.

Production Tip

Use good, preferably certified, seed of a recommended variety.

Market News

Over the past two years and ending with the 2014/15 crop year, Canadian flax production has averaged 810,000 tonnes (31.9 million bushels) per year, confirming Canada as a major contributor to world flax production.

Production Tip

Sow clean, sound seed; treat the seed with a recommended fungicide.

Over the growing season, crop water use by irrigated flax on the Prairies is similar to cereals. This is typically 350-450 mm, depending upon growing conditions. Daily crop water requirements normally increase rapidly through June as the crop canopy develops and the weather warms. It can reach 7-8 mm on a hot day in July, but would typically average 6 mm per day or less for any extended periods of time, even in the peak water use period. To optimize yield, drought stress must be avoided during flowering and early pod fill. Irrigation is usually terminated in the second or third week of August (depending on crop stage and soil moisture status) to avoid lodging, delayed maturity and frost damage.

Many factors affect irrigation requirements, including all aspects of weather, day length, crop stage, stored soil moisture, soil texture, runoff, and drainage. Therefore, appropriate tools should be used to provide information for irrigation scheduling. This can mean as little as checking soil moisture levels by the hand feel method every several days, using a hand soil probe to obtain soil from throughout the depth of moisture management. Other more advanced methods may be employed, such as use of weather data with crop water use models, or soil moisture monitoring devices.

Irrigating prior to crop emergence can cause soil to wash in over the seed row and may promote soil crusting and result in poor and/or uneven stands. When it is necessary to raise soil moisture for germination, irrigating prior to seeding is preferred for small-seeded crops like flax.

Production Tip

Prepare a firm, weed-free, and moist seedbed.

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Chapter 3: Fertilizer Practices

Soil tests, science-based research, and experience should guide fertilizer practices. Nutrient levels in the soil vary greatly among regions, with soil types, cropping history and fertilizer use. Soil tests and provincial fertilizer nutrient fact sheets should be referred to for recommendations regarding fertilizer requirements, rates and placement.

Placement Methods

SEED-PLACED FERTILIZER

Flax is very sensitive to seed-placed fertilizer and even low rates may cause seedling injury. Some provinces recommend that a low rate of phosphate may be placed with the seed; not more than 17 kg/ha (15 lb./acre) of P_2O_5. Other provinces recommend that no fertilizer be placed with the seed of flax. Considerable research has now shown that placement of phosphate banded to the side of the seed row or in a mid-row placement, is an effective method to improve phosphorus nutrition for flax. Nitrogen (N) should not be placed directly with the seed. Recent work has shown that adding nitrogen to the phosphorus when placed to the side or mid-row does not change the benefits of the phosphorus placement.

Also, recent work has shown that adding the nutrients P-K-S together in a single band did not negatively influence the response to nitrogen, indicating the feasibility of applying all nutrients together in a single band to the side or mid-row for flax. For nutrient uptake by flax throughout a typical growing season see Figure 3-1.

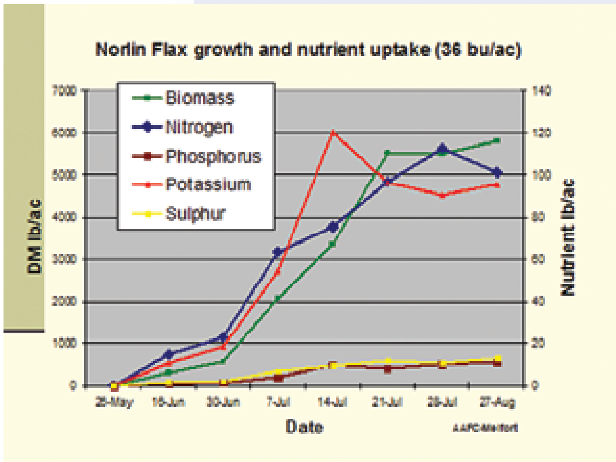

Figure 3-1. Nutrient uptake by flax during a typical growing season. Agriculture and Agri-Food Canada-Melfort.

ESTIMATED NUTRIENT UPTAKE BY FLAX IN POUNDS PER BUSHEL.

Total uptake lbs Nitrogen/bu 2.6–3.2	Total uptake lbs Phosphorus/bu 0.75–0.92	Total uptake lbs Potassium/bu 1.6–2.0	Total uptake lbs Sulphur/bu 0.5–0.6
Removal of N in the harvested flax seed lbs N/bu* 1.9–2.3	**Removal of P_2O_5 in the harvested flax seed in lbs P_2O_5/bu 0.6–0.7**	**Removal of K_2O in the harvested flax seed in lbs K_2O/bu 0.5–0.7**	**Removal of S in the harvested flax seed in lbs S/bu 0.2–0.3**

* Removal refers to the nutrients in the harvested seed portion of the crop that is removed from the field and exported off the farm.
- Estimates are calculated from the Nutrient Uptake and Removal by Field Crops. Western Canada 2001. Canadian Fertilizer Institute.

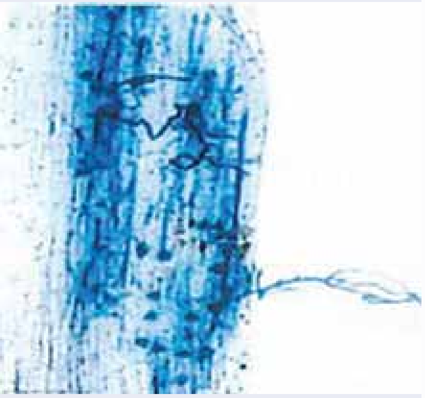

Figure 3-2. Mycorrhizae on flax root. Photo from Agriculture and Agri-Food Canada.

APP for the Nutrient Removal Calculator for Flax

The International Plant Nutrition Institute (IPNI) has prepared an APP Nutrient Removal Calculator (removal refers to the nutrients in the grain portion of the crop and a separate calculation is made for nutrients in flax straw) to provide producers with quick access to estimates of nutrient removal by crops.

The IPNI Nutrient Removal Calculator can be found at: **http://www.ipni.net/article/IPNI-3346** or can be downloaded as an APP from the APP Store at iTunes for free.

For more accurate nutrient recommendations for crop production, conduct a soil test. Nutrient uptake charts and Nutrient Removal Calculator APPs only provide quick guidance for making last minute adjustments to nutrient plans. The nutrient charts and APPs are not intended to replace soil testing. Values presented in nutrient uptake and removal tables and calculator APPs will vary because these are only estimates.

NITROGEN

Flax responds well to nitrogen (N) fertilizer application when available soil N is low. Follow soil test recommendations for optimum yield and quality. However in the absence of a soil test, apply 45 to 110 kg/ha (40 to 98 lb./acre) of actual N; with the rate selected based on anticipated N-supplying capacity of the soil and flax yield potential. N should not be placed directly with the seed. At higher rates of N, lodging may occur, so select varieties with the best lodging resistance. Also, seeding flax earlier tends to produce shorter straw which may help reduce lodging under higher yield targets.

PHOSPHORUS

The flax plant appears to prefer high soil phosphorus (P) levels originating from P fertilization of preceding crops (soil residual P), compared to the application of a high rate of P fertilizer at seeding. Flax requires arbuscular mycorrhizal fungi (AMF) to use soil residual P efficiently (see Figure 3-2). AMF is a microorganism that creates a symbiotic relationship with plant roots, whereby plants benefit with enhanced nutrient uptake from the thread-like fungal mycelia.

Studies have shown that flax following wheat, a mycorrhizal crop, performed better than flax following canola, a non-mycorrhizal crop. However, there appeared to be no difference in mycorrhizal activity in flax in long-term zero-till fields. Studies with AMF inoculants in flax suggest the AMF are ubiquitous organisms and occur widely in prairie agricultural soils. There is good evidence to indicate that flax is dependent on AMF colonization, in part to optimize uptake of relatively immobile nutrients such as P, as well as some micronutrients. Results suggest that yield response to commercial AMF inoculants may be limited, at best. Results also suggest that the indigenous populations of AMF, made up of hundreds of AMF species, may be more than adequate to support effective and beneficial associations for flax. Follow soil test recommendations and do not exceed the safe rate of phosphate applied with the seed.

POTASSIUM AND SULPHUR

Deficiencies of potassium (K) and sulphur (S) can limit production of all crops; but they are soil-specific. Soil testing is required to determine the K and S status of your soils. Deficiencies of K are often associated with coarser textured (sandy) soils and deficiencies of S may occur in low organic matter soils. On irrigated land, there is normally enough sulphur in most irrigation waters to meet crop requirements. Approximately 34 kg/ha (30 lb./acre) of sulphur is added to the soil with each 30 cm (12 inches) of irrigation water.

IRON AND ZINC

Flax may be sensitive to soil deficiencies of iron (Fe) and zinc (Zn). Under wet soil conditions, temporary iron deficiency can cause chlorosis (yellowing of the leaves) in irregular patterns in the field. However, field tests have seldom shown any flax yield increase attributable to application of micronutrients. If a micronutrient deficiency is suspected, confirm with a soil test. Strip tests of micronutrients can be carried out to confirm if flax is responsive.

Chapter 4: Growth and Development

Flax is an annual plant that grows to a height of 40 to 91 cm (16 to 36 in.), depending on variety, plant density, soil fertility, temperature and available moisture. Flax is highly self-pollinating, with outcrossing rates from 0.3 to 2.0% under normal circumstances. Insects are the primary agents of outcrossing.

The life cycle of the flax plant consists of a 45- to 60-day vegetative period; a 15- to 25-day flowering period; and a maturation period of 30 to 40 days. Although there is a period of intense flowering, a small number of flowers may continue to appear right up to maturity. Maturity is delayed under cool, wet conditions. The crop lifecycle from seeding to maturity is typically 90 to 125 days, depending on overall environmental conditions. Drought, high temperature and disease can shorten the growth period and crop lifecycle. If ripening occurs under high soil moisture and fertility conditions, stems may remain green and new growth may result in a second period of intense flowering. Some Canadian flax varieties are more determinate and resist reflowering. Maturity will be delayed under cooler than normal growing conditions, at higher altitudes characterized by lower heat units (i.e. western Alberta and Peace River region), or in the northern prairies. Under these conditions, the lifecycle may be extended to over 125 days.

Photo 4-1. Growth stage 5–stem extension

Growth Stages

There are 12 distinct growth stages (GS) in the development of a flax plant (see Fig. 4-1). In the illustration below, these GS's are shown as numbered line drawings. Each illustration has a title description and, in some cases, additional identifying information. **These growth stages also correspond to the growth stages referred to in the Diagnostic Guide.**

Photo 4-2. Growth stage 6–buds visible, and 7–first flowering

After germination, the cotyledons (two small seed leaves) emerge in stage 1 and the young seedling proceeds to first true leaf formation in stage 2. After this, a second pair of leaves (stage 3) are unfolded, then the third pair of true leaves (stage 4), and so on to more leaves and stem extension (stage 5 and Photo 4-1). The flax plant has one main stem, but two or more branches (tillers) may develop from the base of the plant when plant density is low and/or high soil nitrogen levels. Basal branching is also prominent if the main stem of a young seedling is damaged (loss of apical dominance). Canadian flax varieties vary with regards to basal branching, from limited to extensive. The main stem continues to extend and buds form at the top of the plant (stage 6 and photo 4-2). In stage 7, early branching of the main stem becomes obvious towards the top of the plant, at about 30 cm up (12 in.). Around this time, the first flower will begin to open. The main stem and branches give rise to a multi-branched, irregular arrangement of flowers. The plant has a short, branched taproot which may extend to a depth of more than 1 m (39 in.) with side branches stretching approximately 30 cm (12 in.). Compared with other major crops of the prairies, flax has a relatively limited root system (shallow with limited root volume).

Production Tip

Flax is more sensitive to low levels of iron (Fe) and zinc (Zn) in the soil than are most other Western Canadian field crops.

GROWTH STAGES

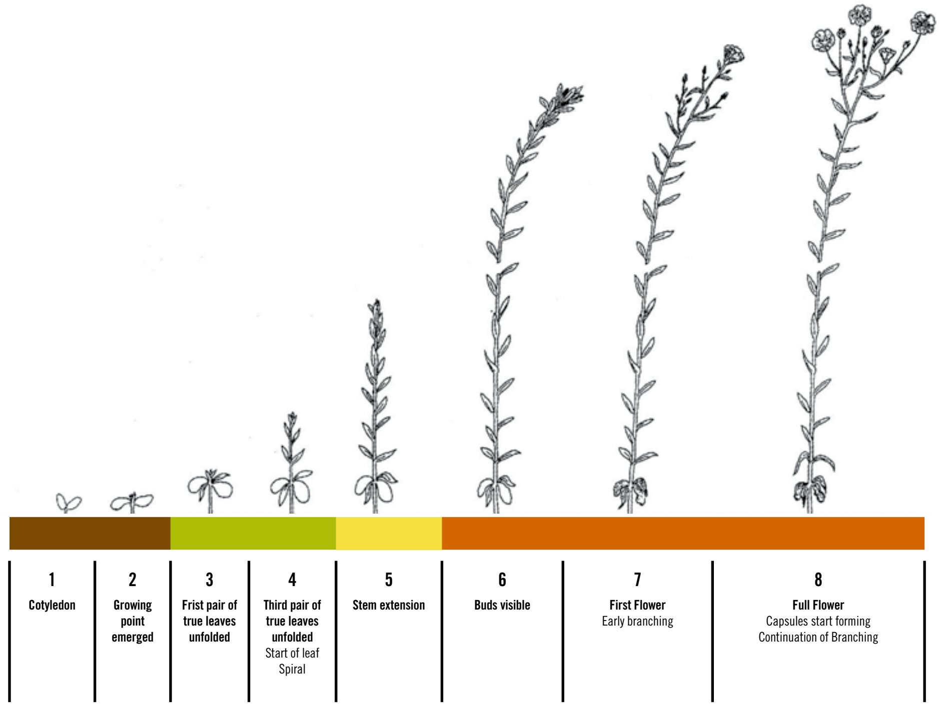

Fig 4-1. Growth Stage Description

Market News

Canada's flax seed is higher in oil content and quality than seed from other countries.

FLOWERING

New flax flowers open early each morning and petals are usually shed by mid-day. The flower parts (petals, sepals and anthers) all occur in units of five (Fig. 4-2).

Flax varieties may be distinguished by the colour of their flower parts; which can range from a dark to a very light blue, white or pale pink. The flower bud just prior to opening is about 14 mm (0.5 in.) long and flowers on opening contain nectar that attracts insects. Insect pollination is not necessary for seed production as flax is highly self-pollinated. The anthers are a shade of blue or are yellow. The style and filaments (bear the anthers) are blue or colourless.

Flowering typically lasts from 15 to 25 days, although under wet and fertile conditions, a small amount of flowering may continue on late formed branches throughout the season. After pollination, the petals fall and the base of the flower, the ovary, starts to swell. The ovary is the seed house, known as a boll or capsule, which contains the developing seeds (stages 8 and 9). In cases where crop growth is delayed, or low plant densities, or when there is damage to the apical dominance of the main stem; the plant will also produce more secondary branching. This results in a lengthening of the flowering period, a greater range in boll development and a delay in maturity.

9	10	11	12
Late Flower Most Branches and Capsules formed	**Green capsule** Seed white Lower leaves yellow	**Brown capsule** **Seeds light brown (or otherwise pigmented) plump and pliable–maximum dry matter** **Branches, stem and upper leaves green/yellow** **Middle leaves partly senescent and lower leaves shrivelled or dropped**	**Seed ripe** **Seeds brown (or otherwise pigmented) and rattle in capsules** **Branches and upper leaves senescent but stem still green/yellow**

RIPENING

The mature fruit of the flax plant is the dry boll or capsule. Ripening of the boll begins 20 to 25 days after flowering. The boll has five segments which are divided by a wall (septum) (Fig. 4-3). Each segment produces two seeds separated by a low partition called a "false septum", whose margin may be hairy or smooth, depending on the variety. With complete seed set, the boll contains ten seeds, though an average of six to eight seeds per boll is usual. Seed development is staged as green bolls containing white immature seeds (stage 10) proceed to a brown boll containing seeds having a light brown coloured seed coat with plump pliable seed contents (stage 11).

When ripe, the bolls of Canadian varieties are slightly gaping (Fig. 4-4), that is, the boll opens at the apex (tip of the boll) and the five segments separate slightly along the margin. The bolls rarely open so far as to allow the seeds to fall out, as dehiscence is a wild trait that was selected against. Usually the boll will open slightly under conditions of low relative humidity and close up when relative humidity is high. This characteristic allows the flax plant to resist seed weathering as excess moisture is liberated from within the boll. At physiological maturity, ripe seeds will rattle within the boll or capsule. Stage 12 is when a majority (90 to 95%) of bolls contain seeds that rattle. Dry down after the crop has reached physiological maturity (75% brown boll stage) can be hastened with crop desiccants, drought or disease. However, premature ripening often results in the production of small, thin, immature seed.

Market News

Flax seed contains very high amounts of alpha-linolenic fatty acid, an Omega-3 fatty acid shown to be beneficial to health.

4

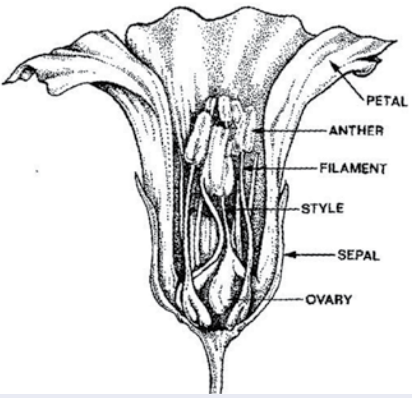

Fig 4-2.

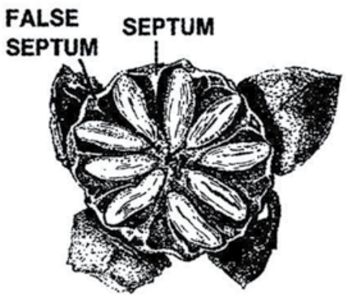

Fig 4-3.

Fig 4-4.

SEEDS

Flax seeds are flat, oval and are pointed at one end. A thousand seeds weigh from about 5 to 7 g (less than 1 oz.), depending on variety and growing conditions. Canadian flax varieties range in colour from light brown to dark reddish brown or yellow. Mottled seed, a combination of yellow and brown on the same seed, may be the result of environmental conditions.

The seed is covered with a coating (mucilage) that gives it a high shine and causes the seed to become sticky when wet. At times, this mucilage absorbs moisture from the air, causing the mature seeds to stick to the boll surface. This removes the shine on the seeds, giving them a scabby appearance which may result in a reduced grade.

Chapter 5: Diagnostic Guide

1. Pre-emergence to emergence: Growth stages 1 & 2

WHAT TO LOOK FOR	WHAT TO DO: RIGHT NOW	WHAT TO DO: NEXT TIME AROUND
1. Pre-emergence to emergence: Growth stages 1 & 2 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17		
POOR STAND REGULAR PATTERN Seeder problems	–	• Maintain seeder and check often for plugged runs • Make sure shovels, knives and discs are levelled before seeding
IRREGULAR PATTERN OR PATCHES Do not find seed *Low seeding rate*	–	• Use suggested seeding rate for local growing conditions
Deep seeding	–	• Use suggested seeding rate and depth for local growing conditions
Wireworms	–	• See Field Insect Pests
Cutworms	• Apply recommended insecticide if >4-$5/m^2$ • Determine if infestation limited to patches or over entire field	• See Field Insect Pests
Find adequate seed *Evidence of insect activity* *Wireworms*	–	–
Cutworms	• Apply recommended insecticide if >4-$5/m^2$	–
No evidence of insect activity ADEQUATE GERMINATION Normal seedlings –cold soil	–	• Plant a little later, especially in a cold spring • Use treated seed
–deep seeding	–	• Plant at 2.5-4 cm (1-1.5 in.) deep into firm moist soil
–soil crusting	• Use a harrow or packer bar to break up crust	• Leave more crop residue on soil surface • Adopt 0-till to build soil organic matter long-term • Avoid soils that crust easily • If irrigation is possible, sprinkle to soften crust
–untreated seed	–	• Buy certified seed • If you use farm-produced seed, slow down combine cylinder and/or open concave to reduce cracking
–seeding implement did not clear field trash properly	–	• Do a better job of spreading and chopping trash from previous crop
Abnormal seedlings –cracked or poor quality seed	–	• Buy certified seed • If you use farm-produced seed, slow down combine cylinder to reduce cracking
POOR GERMINATION Pre-emergent herbicide –trifluralin damage	–	• Apply trifluralin in fall only • Plant certified seed, shallow into firm, moist seedbed
No Pre-emergent herbicide –herbicide residues	–	• Check previous year's herbicide for residual characteristics
–adequate moisture • poor seed quality	–	• Buy certified seed
• fertilizer burn	–	• Band some or all fertilizer away from seed
• treated seed stored too long	–	• Treat seed as needed
• saline soils	• Provide proper fertility levels	• Use soil tests to choose land that is suitable for flax
–low moisture • too much spring tillage	• Use a packer to improve the seedbed	• Apply trifluralin and/or fertilizer in the fall • Avoid sandy land
• loose, unpacked soil	• Pack the soil	• Pack the soil • Adopt 0-till seeding
• treated seed stored too long	–	• Treat seed as needed

WHAT TO LOOK FOR	WHAT TO DO	
2. Seedling: Growth stages 3 & 4 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17	**RIGHT NOW**	**NEXT TIME AROUND**
YELLOWING LEAVES GENERAL OR UNIFORM GRADIENT OR PATTERN Chlorosis	–	• Plant more tolerant varieties
Herbicide drift injury from cyanazine	–	• Watch wind speed and direction when applying herbicides
Herbicide injury *Typical result of herbicide application*	–	• Separate grass and broadleaf weed control under hot, humid conditions
Stressful environmental conditions	• Spray in the evening or very early in the morning, or wait until the stressful conditions pass	• Spray in the evening or very early in the morning, or wait until the stressful conditions pass
IRRIGULAR PATTERNS OR PATCHES Wet or saturated soil	• Improve drainage on the field	• Improve drainage on the field • Plant crops that improve the water infiltration capacity of the soil • Adopt 0-till
Nutrient deficiency	• See Environmental Disorders • Improve drainage on the field • Do a plant tissue analysis test • Use a comparative soil plus tissue test from a good area in the field compared to a soil plus tissue test from a poor area within the same field	• See Environmental Disorders • Improve drainage on the field
Seedling blight and root rot	–	• Use treated, uncracked seed • Use seeder with on-row packing • Follow at least a three-year flax rotation • Avoid legumes or sugar beets as previous crops • For breakdown of quackgrass patches, spray in fall
WILTED PLANTS CUTWORMS	• Apply recommended insecticide if >4-5/m^2	–
HEAT CANKER	–	• Plant early at a high seeding rate
FROST DAMAGE	–	• Plant late to avoid spring frost
FUSARIUM WILT	–	• Plant resistant varieties and practise recommended crop rotations
STUNTED OR SHORT PLANTS COLD, WET WEATHER	–	–
HERBICIDE INJURY Bromoxynil/MCPA	–	• See Environmental Disorders • Separate grass and broadleaf weed control under hot humid conditions
Inappropriate rates of pre-emergent herbicides for soil type	–	• Read and follow label precautions, check levels of organic matter in the soil
Flax plants presensitized from pre-emergent herbicide	–	• Use post-emergent herbicides cautiously especially under stressful environmental conditions (e.g. cold and wet soils)
FERTILIZER BURN ESPECIALLY IN DRY SOIL CONDITIONS	–	• Follow the guidelines for safe rates of fertilizer applied with the seed • Apply low level of starter fertilizer with the seed and band the rest of the fertilizer in side or mid-row bands
ASTER YELLOW DISEASE AND CRINKLE DISEASE	–	• See Diseases • Seed early to avoid migrating leafhoppers
STUNTED OR SHORT PLANTS Quackgrass	• Apply a post-emergent graminicide (e.g. clethodim, Poast ® Ultra, quizalofop) • Apply a pre-harvest treatment (e.g. glyphosate)	• Apply pre-harvest or post-harvest treatment (e.g. glyphosate) to the previous crop (if registered on that crop)
Wild oats and volunteer cereals	• Apply a post-emergent graminicide (e.g. clethodim, Poast® Ultra, quizalofop)	• In areas where it is recommended, use fall tillage to encourage germination of volunteers • Apply a pre-emergent herbicide (e.g. Avadex®, Eptam 8-E®, trifluralin or Fortress®) • Use spring tillage to destroy the first flush of weeds and volunteers
Annual broadleaf weeds (no or few thistles or dandelions)	• Apply a post-emergent herbicide (e.g. Basagran® Basagran Forte®, bromoxynil and/or MCPA) • Check the crop 5-10 days after spraying for regrowth of weeds; re-spray if necessary	• Apply a pre-emergent herbicide (e.g. Authority®, trifluralin,Eptam 8-E®, Fortress®)
Canada thistle and sow thistle	• Apply post-emergent herbicide (e.g. Basagran®, bromoxynil/MCPA, Curtail M®, Lontrel®, MCPA) • Apply a pre-harvest, post-harvest treatment (e.g. glyphosate) • Check the crop 5-10 days after spraying for regrowth of weeds; re-spray if necessary	• Apply a pre-harvest, post-harvest treatment (e.g. glyphosate) in the previous crop (if registered on that crop)
Other perennials (e.g. Toadflax, dandelion)	• Apply a pre-harvest, post-harvest treatment (e.g. glyphosate)	• Apply a pre-harvest, post-harvest treatment (e.g. glyphosate) in the previous crop (if registered on that crop
All weeds		• Use a higher seeding rate and/or a seeding implement with a narrower row spacing and/ or wider seed spread pattern to increase in-crop crop competition for late emerging weeds

Weed Control Options In Flax

WEED CONTROL OPTIONS IN FLAX	RIGHT NOW			NEXT TIME AROUND		
	Action	Crop stage	Weed stage	Action	Crop stage	Weed stage
Quackgrass	Quizalofop Poast Ultra® Clethodim	82 days* 60 days* 60 days*	2-6 leaf 1-3 leaf 2-6 leaf	Glyphosate Glyphosate	pre-harvest post-harvest pre-plant	4-5 green leaf 3-4 actively growing leaf 3-4 actively growing leaf
Wild oats, green and yellow foxtail, and volunteer cereals	Quizalofop Poast Ultra® Clethodim	82 days* 60 days* 60 days*	2-early tillering 1-6 leaf (GF, YF),1-4 leaf (WO, vol. cereals) 2-6 leaf	Fall tillage Spring tillage Glyphosate Eptam 8-E® (not in SK)	post-harvest pre-plant pre-plant spring or fall pre-plant	post-emergent post-emergent post-emergent pre-emergent
Wild oats, green and yellow foxtail				Trifluralin or Fortress®	pre-plant pre-plant	pre-emergent pre-emergent
Wild oats only				Avadex®	fall or spring pre-plant	pre-emergent
Annual broadleaf weeds – Lamb's Quarters, Redroot Pigweed, Smartweed, Wild Mustard, Russian Thistle	Basagran®/ Basagran Forte® Bromoxynil Bromoxynil/ MCPA Curtail M® MCPA	>5 cm (>2 in.) 5-10 cm (2-4 in.) 5cm (2 in.) to early bud, 5-10 cm (2-4 in.) best 5-15 cm (2-6 in.) 5cm (2 in.) to prebud, 5-10 cm (2-4 in.) best	See Herbicide label 1-4 leaf,1-8 leaf (LQ) <4 leaf, <8 leaf (LQ, W. Mustard) 1-4 leaf (not R. Thistle) 2-4 leaf (LQ, W. Mustard only)	Authority® Glyphosate Trifluralin Eptam 8-E® (not in SK) Fortress®	Pre-plant (spring only) Pre-plant pre-plant (fall only) pre-plant fall or spring pre-plant	pre-emergent (LQ, Pigweed only) post-emergent pre-emergent (LQ, Pigweed, R.Thistle only) pre-emergent (LQ, Pigweed only) pre-emergent (suppress LQ, Pigweed, R.Thistle only)
Annual broadleaf weeds – Kochia, Wild Buckwheat	Bromoxynil Bromoxynil/ MCPA Curtail M® Lontrel 360®	5-10 cm (2-4 in.) 5cm (2 in.) to early bud, 5-10cm (2-4 in.) best 5-15cm (2-6 in.) 5-10cm (2-4 in.)	1-4 leaf (Kochia), 1-8 leaf (W.Buckwheat) <4 leaf (Kochia), <8 leaf (W.Buckwheat) 1-4 leaf (W.Buckwheat only) Young and actively growing (W.Buckwheat only)	Authority® Fortress® Glyphosate Trifluralin	pre-plant (spring only) fall or spring pre-plant pre-plant pre-plant (fall only)	pre-emergent pre-emergent post-emergent (W.Buckwheat only) pre-emergent (W.Buckwheat only)
Canada thistle	Basagran®/ Basagran Forte® Bromoxynil/ MCPA Curtail M® Lontrel 360® MCPA/MCPA K	>5 cm (>2 in.) 5 cm (2 in.) to early bud, 5-10cm (2-4 in.) best 5-15cm (2-6 in.) 5-10 cm (2-4 in.) 5cm (2 in.) to pre-bud, 5-10cm (2-4 in.) best	15-20 cm (6-8 in.) top growth 1-4 leaf rosette to pre-bud stage 2-4 leaf	Glyphosate Glyphosate	Pre-harvest Post-harvest	Bud and beyond 20-25cm (8-10 in.) or actively growing

***pre-harvest interval, **plus above herbicides, CAUTION! Always read and follow label directions.**

2. Seedling: Growth stages 3 & 4 (cont'd)

WHAT TO LOOK FOR	WHAT TO DO	
2. Seedling: Growth stages 3 & 4 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17	**RIGHT NOW**	**NEXT TIME AROUND**
WEEDS ARE NOT CONTROLLED STRESSFUL ENVIRONMENTAL CONDITIONS Temperature extremes (hot and cold)	–	• Read and follow label cautions relating to environmental conditions
Drought	–	• Read and follow label cautions relating especially to environmental conditions
RAIN TOO SOON AFTER APPLICATION OF HERBICIDE	• Wait to see if control symptoms appear before respraying	• Spray only when rain not imminent
INCORRECT APPLICATION RATE	–	• Read and follow label directions, especially under stressful environmental conditions
INCORRECT WATER VOLUMES	–	• Use recommended water volume and pressure, especially with contact herbicides
SURFACTANT NOT ADDED AS NEEDED	–	• Add all recommended components of a herbicide for maximum efficiency
INADEQUATE SOIL INCORPORATION OF PRE-EMERGENT HERBICIDES Incorporation delayed too long after application	–	• Incorporate according to the manufacturers' directions
Incorrect incorporation depth	–	• Incorporate according to the manufacturers' directions
Incorrect number or direction of incorporation passes	–	• Incorporate according to the manufacturers' directions
ANTAGONISTIC HERBICIDE TANK MIX	–	• Use only registered tank-mixes
INCORRECT WEED STAGE	–	• Identify weeds, then read and follow label directions for leaf stages for each weed
NOT ENOUGH DAYS BETWEEN TWO HERBICIDE APPLICATIONS	–	• Allow recommended number of days between non-tankmixable herbicides
RESISTANCE OF WEEDS TO A HERBICIDE OR HERBICIDE GROUP	–	• Rotate between herbicide groups (see provincial guides) • Use integrated weed-control strategies (cultural, biological, physical, and chemical control)
UNSUITABLE WATER USED TO MIX WITH HERBICIDES	–	• Use water known to produce good results when mixed with herbicides
NOT ENOUGH IN-CROP COMPETITION FROM FLAX	–	• Use a higher seeding rate and/or a seeding implement with a narrower row spacing and/or wider seed spread pattern to increase in-crop competition for late emerging weeds.

3. Stem extension and tillering: Growth stages 5

WHAT TO LOOK FOR	WHAT TO DO: RIGHT NOW	WHAT TO DO: NEXT TIME AROUND
3. Stem extension and tillering: Growth stages 5 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17		
LEAF FEEDING BERTHA ARMYWORM	• Monitor the problem and spray with a recommended insecticide if feeding is extensive or before boll feeding begins	–
ARMY CUTWORM	• Monitor and spray with a recommended insecticide when larvae populations reach 4-5/m^2	–
ZEBRA CATERPILLAR	• Not normally a significant problem in flax	–
LEAF SPOTS RUST	–	• Practise recommended crop rotations • Use rust-resistant varieties
LEAF LOSS PASMO DISEASE	–	• Use treated seed early at recommended rates, use lodge resistant varieties, control weeds and practise recommended crop rotation • Foliar application of fungicide at early flowering
DEFORMED OR PUCKERED LEAVES CRINKLE	–	• See Diseases
ASTER YELLOWS	–	• See Diseases • Plant as early as possible to reduce incidence and severity of the disease
REDUCED TILLERING CRINKLE	–	• See Diseases
TOO HEAVY SEEDING RATE AND PLANT STAND	–	• See Seed and Seeding Practices • Plant at recommended seeding rate for local soil type and moisture conditions
Bending stem (S shaped) HERBICIDE INJURY FROM MCPA, ESPECIALLY IN HOT HUMID WEATHER	–	• Delay application of MCPA to evening or early morning if hot conditions persist

4. Top branching, bud formation and early flowering: Growth stages 6-8

WHAT TO LOOK FOR	WHAT TO DO: RIGHT NOW	WHAT TO DO: NEXT TIME AROUND
4. Top branching, bud formation and early flowering: Growth stages 6-8 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17		
LODGING TOO HEAVY SEEDING RATE AND PLANT STAND	–	• Plant varieties more tolerant to lodging • Plant at recommended seeding rate for local soil type and moisture conditions
TOO MUCH NITROGEN	–	• Soil test and apply fertilizer according to a realistic target yield
ROOT ROT	–	• See Diseases • Practise recommended crop rotations • Use a recommended seed treatment • Avoid legumes or sugar beets as previous crops
STEM BREAK AND BROWING DISEASE	–	• Use disease-free, certified seed • Use a recommended seed treatment • Practise recommended crop rotations
REDUCED FLOWING OR NO FLOWERS Lygus bug damage to growing tips of plants	• Monitor with a sweep net • Economic thresholds not developed	–
DIEBACK OF TERMINAL BUDS Soil too high in lime	–	• Soil test and add nutrients to correct the imbalance in the soil
Wet or saturated soils	• Improve surface drainage on the field	• Practise recommended crop rotation for local soils
Chlorosis	–	• Practise recommended crop rotation for local soils • Use chlorosis resistant varieties
EXCESSIVE BRANCHING FROM LOWER STEMS WET OR SATURATED SOILS	• Improve surface drainage on the field	• Practise recommended crop rotation for local soils
LOW PLANT DENSITY	–	• Use suggested seeding rate for local growing conditions

5

5. Flowering and boll formation: Growth stages 9, 10 & 11

WHAT TO LOOK FOR	WHAT TO DO	
5. Flowering and boll formation: Growth stages 9, 10 & 11 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17	**RIGHT NOW**	**NEXT TIME AROUND**
EGGS IN FLOWERS FLAX BOLLWORM	• Economic infestations not common	–
SMALL GREEN INSECTS ON STEMS AND LEAVES APHIDS Note: Juvenile Lygus bugs are also small green insects but are very active compared to aphids	• Apply a recommended insecticide if 3 or more aphids are found on a stem at full flower, or 8 or more at green boll stage	–
DEFORMED FLOWERS ASTER YELLOWS	–	• Seed as early as possible to avoid migrating leafhoppers in mid to late season
HOLES IN BOLL FLAX BOLLWORM	• Economic infestations not common	–
BOLLS MISSING GRASSHOPPERS Note: Bertha armyworm can also clip bolls in flax	• If damage is from grasshoppers, apply a recommended insecticide when populations exceed 2/m^2	• Plant trap crop around field
PASMO DISEASE ALONG WITH STRONG WINDS AND RAIN	–	• Practise recommended crop rotations
PREMATURE RIPENING PASMO DISEASE	–	• See Diseases • Practise recommended crop rotations
DEAD PLANTS IN PATCHES ESPECIALLY IN LODGES AREAS PASMO DISEASE	–	• See Diseases • Practise recommended crop rotations
WILTED PLANTS ESPECIALLY ON WARM DAYS ROOT ROT	–	• See Diseases • Practise recommended crop rotations

6. Mature: Growth stage 12

WHAT TO LOOK FOR	WHAT TO DO	
6. Mature: Growth stage 12 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17	**RIGHT NOW**	**NEXT TIME AROUND**
LOW YIELD LOW SOIL PHOSPHORUS LEVELS	–	• Soil test to determine P level. Apply safe rate of phosphate with the seed and side or mid-row band any additional amounts needed • Apply additional phosphorus to the crop previous to flax
LOW NITROGEN LEVELS	–	• Soil test and apply fertilizer according to a realistic target yield
DESICCATED CROP TOO EARLY	–	• Apply desiccant when 75% of bolls have turned brown
ROOT ROT	–	• See Diseases • Use treated, uncracked seed • Use seeder with on-row packing • Follow at least a three-year flax rotation • Avoid legumes or sugar beets as previous crops
LATE PLANTED CROP	–	• Do some or all seedbed preparation the previous fall • Seed earlier, if possible
TOXIC EFFECTS FROM CANOLA/MUSTARD STUBBLE ESPECIALLY IN UNSPREAD SWATH	–	• Use a chaff spreader and a fine-cut straw chopper on the combine • Practise recommended crop rotation • Do not seed flax on canola/mustard stubble
BOLLS MISSING OR SCATTERED ON THE GROUND HIGH WINDS	–	• Plant varieties more tolerant to boll drop • Harvest the crop at the appropriate stage of maturity, especially if a desiccant has been used
LOW BUSHEL WEIGHT DESICCATED CROP TOO EARLY	–	• Apply desiccant when 75% of bolls have turned brown
SWATCH BLOWS EASILY CROP CUT TOO LOW	–	• Leave 10-15 cm (4-6 in.) of stubble • Straight harvest flax • Consider use of a swath roller
SWATH TAKES A LONG TIME TO DRY CROP CUT TOO LOW	–	• Leave 10-15 cm (4-6 in.) of stubble to keep swath off ground and facilitate drying

WHAT TO LOOK FOR	WHAT TO DO	
6. Mature: Growth stage 12 The colour box corresponds to the growth stages in Figure 4-1, pages 16-17	**RIGHT NOW**	**NEXT TIME AROUND**
SWATHER GUMS UP CUTTING KNIVES TOO OLD AND DULL	• Replace cutting knives	• Replace worn cutting knives • If knives are OK, lubricate the cutting bar with light oil
DELAYED MATURITY HERBICIDE INJURY FROM MCPA, BROMOXYNIL	–	• Read and follow label cautions relating especially to environmental conditions • Plant earlier maturing varieties
EXCESS NITROGEN	–	• Soil test and apply fertilizer according to realistic target yield
CRACKED OR DAMAGED SEED COMBINE CYLINDER SPEED TOO HIGH	• Reduce cylinder speed	• Reduce cylinder speed
COMBINE CONCAVE SET TOO TIGHT	• Increase concave clearance • REFER TO OWNERS' MANUAL TO DETERMINE THE CORRECT COURSE OF ACTION FOR CHANGING COMBINE SETTINGS	• Increase concave clearance • REFER TO OWNERS' MANUAL TO DETERMINE THE CORRECT COURSE OF ACTION FOR CHANGING COMBINE SETTINGS
SEED TOO DRY	• Adjust combine during day to adjust for changes in temperature and humidity	• Adjust combine during day to adjust for changes in temperature and humidity
HIGH DOCKAGE UNCONTROLLED WEEDS IN FIELD	–	• Recheck fields for weeds after control measures have been taken • Increase crop competition by increasing the seeding rate and/or decreasing the row spacing and/or increasing the seed spread in the row
VOLUNTEER CROPS IN FIELD	–	• In areas where suitable, use previous fall tillage to encourage volunteers to grow • Control crops with suitable herbicides • Increase in-crop competition by increasing the seeding rate and/or decreasing the row spacing and/or increasing the seed spread in the row
BROKEN SEEDS IN SAMPLE	• Slow down combine cylinder speed, open cylinder, open bottom sieve	• Slow down combine cylinder speed, open cylinder, open bottom sieve
EARTH PELLETS	• Raise the combine pickup	• Leave a 10-15 cm (4-6.) stubble to keep the swath off the ground • Raise the combine pickup
EXCESS DOCKAGE IN HOPPER	• Close bottom sieve	• Close bottom sieve
EXCESS DOCKAGE IN HOPPER AND LOW SHOE LOSS OUT OF REAR OF COMBINE	• Increase fan speed	• Increase fan speed
LOW GRADE LOW TEST WEIGHT	• Increase combine fan speed	• Leave at least a 10-15 cm (4-6 in.) stubble so swath does not touch ground • Raise combine pickup • Pack or roll the field after planting
STONES	• Raise combine pickup	• Leave at least a 10-15 cm (4-6 in.) stubble so swatch does not touch ground • Raise combine pickup • Pack or roll the field after planting
INSEPARABLE SEEDS (e.g. LADIES THUMB OR GREEN SMARTWEED)	–	• Check fields after weed control and re-spray if necessary • Plant varieties with larger seed size
Occasionally small wild oats, mustard, canola	–	• Check fields for weeds often and after using a control method
BROKEN SEEDS	• Slow down the combine cylinder speed, open cylinder, open bottom sieve	• Slow down the combine cylinder speed, open cylinder, open bottom sieve

NOTE:

RIGHT NOW—means this year
NEXT TIME AROUND—means the next time you plant flax

CAUTIONARY NOTE:

This Diagnostic Guide describes many commonly observed flax production problems. Because the guide is written for general information only, it is recommended that the reader obtain the opinion of professionals such as provincial Agrologists, crop consultants, or manufacturers' representatives to confirm specific field problems.

Weed control recommendations for flax are published annually by provincial departments of agriculture. For these publications and for the latest information and specific recommendations for your area, consult your provincial Agrologists, crop consultants, pesticide company rep or weed supervisor.

Chapter 6: Weed Control

Important weeds and their impact

Weeds can be a serious problem in flax if left uncontrolled. Because flax does not compete well with weeds, compared with other crops such as cereal grains, weeds have an excellent chance to develop in flax thereby reducing flax yield and seed quality. Excessive weed populations reduce availability of water and nutrients to the crop. As flax is slow to grow, weeds allowed to establish can easily overtop young flax seedlings and lead to substantial yield reductions. This may also result in increased harvest difficulties and higher dockage in harvested grain. Competition with weeds can also reduce flax oil quality by lowering the iodine number. Clean fields at harvest are critical for flax fiber production where the presence of weeds complicates processing the flax fibers and increases production costs. Sound agronomy and crop management throughout the growing season, in addition to the use of effective herbicides at the correct time, are critical to achieve optimum flax yields, minimal dockage and high oil quality.

Refer to the Guide to Crop Protection publication available on provincial department of agriculture websites. The Guide to Crop Protection is updated annually and contains pertinent additional information on weed control management including a listing of currently registered herbicides.

Troublesome weed species

Weed surveys across the Prairie Provinces have been conducted by Agriculture and Agri-Food Canada Saskatoon for the past five decades. Weeds are surveyed in mid-summer, after in-crop herbicides have been applied. The top ten weeds found in flax crops ranked by relative abundance (Leeson et al. 2005) were:

1. Green foxtail
2. Wild oats
3. Wild buckwheat
4. Redroot pigweed
5. Volunteer wheat
6. Lamb's-quarters
7. Canada thistle
8. Pale smartweed
9. Russian thistle
10. Wild mustard

It is important to note that these are mid-season residual weed species that remained after in-crop weed management had been completed and their relative abundance is based on the number of each species present. Weeds with the highest abundance may not necessarily result in the greatest yield loss in flax. For example, even though green foxtail is the most abundant weed in flax, yield loss caused by green foxtail plants is about 10 times less than for the same number of wild oat plants.

Relative abundance of a weed species often varies somewhat among regions and this is also observed in the top ten weeds in flax among the four ecoregions of the Canadian Prairies. The top ten weeds in the Aspen Parkland ecoregion included chickweed, hemp-nettle, cleavers, field horsetail, stinkweed, kochia, barnyard grass, dandelion, and yellow foxtail. More than half of all flax fields surveyed was located in the Aspen Parkland ecoregion.

Production Tip

Control weeds with proper use of recommended herbicides and other weed management strategies.

Market News

With the current trends towards healthy eating, flax consumption will continue to rise.

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There is no substitution for sound agronomy

Flax is not a very competitive crop and herbicide options for weed control remain limited. Therefore, an integrated weed management strategy is the best approach for flax production. The goals of integrated weed management are to establish and maintain the most competitive crop stand possible. Crop and weed management strategies work better in combination, resulting in better and more comprehensive weed management than any of the strategies used alone.

An integrated weed management approach for flax begins with effective weed management in the preceding crops in the rotation. Weed control in preceding crops impacts the amount of weed seeds added to the weed seedbank thereby affecting the number of weeds that emerge during flax production. Growing competitive crops with effective herbicide programs in rotation with flax to manage grassy and broadleaf weeds throughout the rotation is critical. A competitive flax crop will also provide protection against yield losses caused by herbicide-resistant weed biotypes that may not be managed by the herbicide choices available for use in flax.

Using sound agronomic management practices to establish a competitive flax crop in combination with pre-emergent or in-crop herbicides to manage weeds is of great benefit. Establishing a flax crop that results in early ground cover will enhance its ability to compete with weeds and also provides excellent insurance against other pests that could impact productivity. A uniformly dense canopy provides excellent insurance for maximum production under less than ideal conditions including that resulting in reduced herbicide performance. In addition, a uniform and dense flax stand can extend the window for herbicide application before weed competition reduces flax yield. Key factors that contribute to successful weed management in flax production include the following:

Flax is an excellent and profitable crop to raise in rotation with many other crops grown in Canada.

a. Planting a competitive variety

b. Narrow-row spacing

c. Higher seeding rates

d. Adequate fertilization and optimum fertilizer placement

e. Early seeding date

f. Early and effective weed management

a. Many crops have varieties with different abilities to compete with weeds. Often, taller varieties with more early-season vigour that tiller or branch more and have greater leaf production tend to be more competitive. Initial results from ongoing research on flax indicates that weed biomass in a taller flax cultivar was half that of a shorter cultivar, irrespective of planting densities, planting date, and whether or not a herbicide was used. The more competitive flax cultivar performed particularly well in the presence of herbicides where weed biomass was reduced by 70% to 87%.

b. Reducing row spacing can be an important mechanism to speed up canopy closure and thereby increasing the crop's competitive ability with weeds. Narrow-row spacing maximizes solar absorbance by the crop early in the season, which can increase total crop biomass production and crop yield. More research is required to quantify the impact of row spacing, seed row width and weed management on yield and dockage.

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c. Increased seeding rates can have many benefits. Higher seeding rates contribute to rapid and even stand establishment and in conjunction with narrow-row spacing, contribute to rapid ground cover which is key to establishing a competitive crop canopy. Later in the season, high density stands lead to more rapid and even crop maturation. Initial results from ongoing research show that increasing seeding rates from about 40 to 80 seeds per square foot (400 to 800 seeds per square meter) can reduce season-long weed biomass production by half, whether herbicides are used or not.

d. Studies at Agriculture and Agri-Food Canada Lethbridge have shown that banding fertilizer beside each row or beside alternate rows at the time of seeding is much more effective than broadcasting fertilizer. This practice resulted in dramatically reducing weed populations in cereal crops over a period of three years. Adequate fertilization, side-banded adjacent to seed rows, enhanced crop uptake of fertilizer and reduced fertilizer availability to weeds. Although no data for this exists for flax production, it is likely that this principle also applies.

e. Early seeding dates are associated with increased yield for most crops grown in Western Canada. Early planting results in a crop better positioned to compete with later emerging weeds, such as green foxtail or redroot pigweed.

f. Flax, however, is impacted by early and late emerging weeds. The important factor is to maximize the number of days between the emergence of the flax crop and the emergence of weeds. Weeds that emerge before the crop will be more advanced and cause greater reduction to crop yield than the same weeds emerging after crop emergence. Flax yield was reduced by 80% when the final pre-seed tillage pass to control weeds occurred five days before planting, compared to that completed on the same day as planting the crop. Thus, timely weed management just prior to planting by whatever means, is critical to ensure that crop emergence is ahead of weed emergence by as many days as possible.

Given that flax is typically not a good competitor with weeds, early in-crop management of weeds is important to prevent yield loss. New research is required to quantify the impact of early weed management, flax yield and dockage.

Integrated weed management

Used alone, weed management techniques are effective; however, the real benefits of weed management occur when multiple techniques are used in combination. First year results of a multi-year, multi-location study show that by combining a taller cultivar with higher seeding rates and herbicide application; late season weed biomass production was reduced 20-fold compared to the shorter cultivar with lower seeding rate and no in-crop herbicide application. Clearly, integrated weed management techniques are effective and essential for flax production.

Herbicides for weed management in flax

Early removal of weeds is necessary to minimize crop losses caused by weed competition. Weeds at the seedling stage are more easily controlled by herbicides than at any other growth stage. Early treatment usually decreases the risk of herbicide injury to the flax crop. Risk of injury is also reduced by using correct water volumes, usually 110 l/ha (10 gallons/acre). The performance of many herbicides can also be affected by soil moisture conditions, air and soil temperatures and humidity, as well as other environmental factors. **Always read and follow label instructions carefully when using herbicides.**

Herbicides continue to be a key component of weed management programs in conventional flax production. According to the 2014 Manitoba and Saskatchewan Guide's to Crop Protection, a total of 15 different pre- and post-emergence herbicides are registered for early season weed control in flax. These herbicides, however, only comprise six different modes of action (Groups 1, 3, 4, 6, 8, 14) and only three of these modes of action are registered for in-crop use (Group 1, 4, 6). Each of these three herbicide Groups has a limited spectrum of weeds they manage with limited species spectrum overlap between Groups (only Group 6 shares species with Group 1 and Group 4). This limited overlap in weed control with the registered modes of action for in-crop herbicides means that flax growers should be aware of their weed populations and whether they have herbicide-resistant weed biotypes. For example, grassy weeds resistant to Group 1 herbicides are common in many fields in Western Canada and therefore, good records of herbicide-use histories and herbicide performance is essential.

PRE-EMERGENT HERBICIDES

Pre-emergent herbicides include pre-plant soil-incorporated herbicides and herbicides applied to weeds that emerge before the crop. Sulfentrazone (see provincial Guide to Crop Protection for product names and instructions for use), a Group 14 (PPO inhibiting) herbicide, has recently been registered for use in flax and can provide excellent control of some difficult-to-control broadleaf weed species. This is a pre-emergent, soil-applied herbicide that does not require incorporation by tillage but relies on rainfall for incorporation/activation. This herbicide also has a restricted range of soil organic matter and soil pH values to work effectively and these ranges need to be adhered to. Other pre-emergent herbicides include soil applied or incorporated herbicides in Groups 3 and 8, as well as glyphosate or other pre-emergent burn-down products. Research conducted at Morden Agriculture and Agri-Food Canada indicates that glyphosate applied in a high residue system (cereal stubble) within seven days before flax emergence could impact flax stand establishment and yield.

POST-EMERGENT HERBICIDES

Spring applied post-emergent herbicides (see provincial Guide to Crop Protection for recommended product brands) are most effective when applied to weeds at the seedling stage. These herbicides are applied after the weeds have emerged and the flax seedlings are 2 to 12 cm (1 to 5 inch) tall. Check the growth stages of both crop and weeds, and then follow recommended instructions on the herbicide label.

All post-emergent applications of herbicides must be applied within the pre-harvest interval indicated on the herbicide labels. This ensures that herbicide residues are reduced to acceptable levels when the crop is harvested and marketed.

PRE-HARVEST HERBICIDES

Formulations of glyphosate registered (see provincial Guide to Crop Protection for recommended product brands) for pre-harvest weed control are applied when the flax is mature. These herbicides control perennial weeds before the weeds are cut. Perennial weeds controlled by pre-harvest applications of glyphosate include quackgrass, Canada thistle, common milkweed, toadflax, and dandelion. For the developmental stages of these weeds that are controlled by pre-harvest glyphosate please refer to the 'Herbicide Options to Enhance Harvesting FAQ' webpage maintained by Saskatchewan Agriculture. Sufficient time for the herbicide to translocate to the root systems of the weeds prior to harvesting the crop is required for high efficacy on the target weeds. In other crops, early applications of pre-harvest glyphosate can result in glyphosate residue in harvested seed above the minimum residue level which may affect marketability. It is advisable not to apply pre-harvest glyphosate or other translocated pre-harvest herbicides until the flax seeds have reached sufficient maturity to minimize this risk.

Herbicide injury to flax

Flax is sensitive to a number of herbicides and can easily be injured by them. There also is anecdotal evidence that sensitivity to herbicides varies among flax cultivars. Weed control recommendations for flax are published annually in the Guide to Crop Protection by provincial departments of agriculture. For these publications and for the latest information and specific recommendations for your area, consult the provincial departments of agriculture, weed supervisor or your appropriate technical representative.

Herbicide-resistant weed biotypes

Limited effective herbicide modes of action can make managing herbicide-resistant weed biotypes challenging as alternate modes of action may not be available, particularly in flax production. Integrated crop management methods when used in conjunction with herbicides will assist greatly in reducing the impact of herbicide-resistant weeds in flax.

When choosing a product for weed control, records from previous years must be checked to ensure that the same herbicide (or a member of the same herbicide Group) is not used continuously on that field. Frequent use of a herbicide Group may lead to the development of weed resistance to that group of herbicides. Herbicide rotations and rotation of herbicide mixtures within crops and between crops are recommended to reduce evolution of and selection for herbicide-resistant weed populations.

Control of volunteer flax in other field crops

Flax is not a strong competitor, so volunteer flax does not usually result in significant yield losses in competitive crops like cereals and canola. However, volunteer flax can cause considerable difficulty at harvest time because they can remain green long after the main cereal or canola crop is mature. This interferes with harvesting and can cause grain storage problems.

Despite the sensitivity of flax to many different herbicide modes of action, there are few herbicides that provide sufficient control, or even suppression, of volunteer flax in broadleaf crops. Glyphosate is one of these herbicides and flax is highly sensitive to it. In fact, glyphosate drift from in-crop use in glyphosate resistant crops can be harmful to neighbouring flax crops. Quinclorac herbicide provides excellent control of volunteer flax in wheat. Quinclorac also provides control of cleavers and green foxtail. Products or mixtures that contain dichlorprop (see provincial Guide to Crop Protection for recommended product brands) will provide some suppression of volunteer flax in cereal crops. Use the maximum recommended rates. Products that include 2,4-D LV ester will be slightly more effective to control flax than 2,4-D amine or MCPA.

Because of the poor level of control likely to be achieved with herbicides, crop management practices are important to control volunteer flax. A competitive cereal crop managed for maximum competitiveness (early seeding, shallow seeding depth, adequate banded fertilizer, competitive cultivar sown at maximum seeding rate for the area) and treated with one of the herbicides mentioned above, should maximize the level of volunteer flax suppression.

Flax performance under reduced in-crop herbicide use

A rotation including flax with reduced in-crop herbicide use was established at the University of Manitoba in 2000 and has been reviewed in detail in the Prairie Soils and Crops Journal that is available free online (http://www.prairiesoilsandcrops.ca/articles/volume-5-2-screen.pdf). For more than a decade, this rotation has shown that weed populations and seedbank densities are influenced by weed management programs used throughout the rotation. Nevertheless, continuously skipping in-crop herbicides in oats, a very competitive crop, had little impact on yield and did not affect adjusted gross returns in flax or other crops in rotation negatively, compared to using in-crop herbicides in all crops in the rotation. In fact, adjusted gross returns tended to be greater when in-crop herbicides were not used in oats over the duration of the study as the cost of herbicides outweighed the benefits of weed management. However, omitting in-crop herbicides in flax, in addition to omitting in-crop herbicides in oats, did reduce flax yield and adjusted gross returns noticeably. The effects of omitting in-crop herbicides on adjusted gross returns in flax and oats, however, were only observed in the flax crop with no obvious effect in the other crops in rotation (cereals and/or canola). Integrated weed management practices have not been optimized in this rotation.

Chapter 7: Field Insect Pests

Various insects will be present in fields of flax from emergence to maturity. Some insects will be beneficial, while others may feed on the crop and at high enough levels, management of such insects may be cost effective. To keep damage low, fields should be examined regularly and controls applied when insect populations reach economic threshold levels. The following species will all feed on flax. Some may reach economic thresholds warranting pesticide application, while others, although visible on the crop, usually remain at too low a level to cause economic loss.

Refer to the Guide to Crop Protection publication available on provincial department of agriculture websites. The Guide to Crop Protection is updated annually and contains pertinent additional information on insect control management including a listing of currently registered insecticides.

Photo 7-1–Redbacked Cutworms

Photo 7-2–Pale Western Cutworms

Photo 7-3–Wireworms

Belowground and seedling feeders

CUTWORMS

The redbacked, *Euxoa ochrogaster*, and the pale western, *Agrotis orthogonia*, are two of the more common species of cutworms that will feed on flax (Photos 7-1 and 7-2). Larvae will feed on many different types of crops and weeds. The adults are moths that lay eggs in late-summer. Eggs overwinter and larvae hatch and feed on crops and other plants in the spring. Larvae may feed on weeds before flax seedlings emerge. Larvae of the army cutworm, *Euxoa auxiliaris* (Grote), will also feed on flax and many other crops, in years when their populations are high. They overwinter as partially grown larvae, and can be an important pest in southern Alberta, to a lesser extent in southern Saskatchewan, and rarely in Manitoba.

Monitoring: Young larvae of some species climb plants and feed mainly on leaves, while older larvae eat into the stems and often sever them. Look for severed or partially severed plants on the soil surface. In fields with small hills or knolls, damage may first appear in the highest areas of the field. Larval densities can be estimated by sifting the top 5 cm of soil near the margin of the damaged area using a hand trowel and #5 to #8 mesh sieve. Another method is to inspect loose soil around plants showing cutworm damage. This method requires a measuring of row spacing by length of row inspected to determine larval density. When disturbed, larvae curl up.

Economic thresholds: Economic thresholds for cutworms in flax have not been developed. A nominal threshold of 4-5 larvae/m^2 in flax has been suggested. The loss of some flax plants may be partially compensated by a small increase in yield of remaining plants.

Management options: Insecticide applications, if needed, should be made late in the afternoon or evening. It may be most economical to just treat infested patches and not entire fields.

WIREWORMS

Wireworms, although potential pests of cereal grains in the seedling stage, seldom damage flax (Photo 7-3). No insecticides are registered to control wireworms in flax.

Photo 7-4–Potato Aphids

Photo 7-5–Lygus bug

Photo 7-6–Aster leafhopper

Sap feeders

POTATO APHID (*Macrosiphum euphorbiae*)

One species of aphid, the potato aphid, commonly occurs in flax (Photo 7-4) and can reduce the plant's ability to set healthy seed. They use their mouthparts to pierce and extract sap from stems, leaves and developing bolls. Potato aphids fly from winter host plants into flax in late June to early July, go through a number of generations and depending on natural controls, may reach peak densities in late July or early August. There is a rapid drop in aphid populations in flax fields in mid-August, when winged adult aphids migrate back to winter host plants. Farmers need not sample or control potato aphids in flax after mid-August.

Monitoring: The easiest way to check for the presence of aphids in flax is to sample the upper portions of the plants with a sweep net. If aphids are found, fields need to be inspected closer by randomly collecting plants when the crop reaches the full bloom or early green boll stage. To collect plants, stems should be severed at the base. Aphids can be counted by lightly tapping the severed plants on a hard surface, such as a tray, to dislodge the aphids. To determine if the economic thresholds are exceeded, at least 25 plants at full bloom or 20 plants at early green boll stage should be randomly collected.

Economic threshold: The economic threshold varies with the value of the crop and cost of control, but generally if aphid densities exceed three per plant when the crop is in full bloom, or eight per plant at the green boll stage, insecticidal control is cost effective. The yield loss of flax is 0.3346 bushel/acre per aphid per plant for flax sampled at full bloom, and 0.1275 bushel/acre per aphid per plant for crops sampled at the green boll stage.

Management options: Insecticides are registered for control of potato aphids in flax. Potato aphids are highly susceptible to attack by pathogenic fungi, especially in years with high rainfall and humidity in late June and July. A number of predators such as lady beetles, lacewings, hover fly larvae and parasitic wasps attack potato aphids.

LYGUS BUGS

In Manitoba, three species of Lygus bugs were found in flax (Photo 7-5), although the most common species was the tarnished plant bug *(Lygus lineolaris)*. Adults move into flax from nearby host plants in July when flax produces buds and flowers. Feeding by Lygus bugs can cause buds to become necrotic and abscise, and may result in flower abortion.

Monitoring: Lygus bug levels can be assessed using a sweep net. Research in England found that Lygus bugs were more numerous close to field edges.

Economics of feeding: Although Lygus bugs can reach high densities in flax; flax is tolerant of their feeding damage under good growing conditions. A study in Manitoba found that under good growing conditions, populations of up to 100 per 10 sweeps were not economical to control. Whether this tolerance extends to flax growing under less favourable conditions in uncertain.

Notes: Flax can compensate for insect injury by producing additional flowers.

ASTER LEAFHOPPER (*Macrosteles quadrilineatus*)

The aster leafhopper feeds by sucking juices from flax plants (Photo 7-6). Leafhoppers can carry aster yellows phytoplasma and crinkle virus and can infect the plants with these diseases while feeding.

Defoliators

GRASSHOPPERS

Grasshoppers may feed on flax (Photo 7-7), particularly after other food sources have become scarce. The twostriped grasshopper, *Melanoplus bivittatus*, is the most common species that periodically can damage flax by feeding on flowers and buds and by cutting off the capsules.

Monitoring: While walking through the crop, estimate the average number of grasshoppers per m^2, both along the edge and into the field, and the amount of boll clipping that has occurred.

Thresholds: A nominal threshold of about two grasshoppers per m^2 on average has been suggested if grasshoppers are clipping bolls.

Management options: In years of high grasshopper populations, damage to flax can be reduced by controlling young grasshoppers in surrounding crops and vegetation before they begin to migrate. If grasshoppers start to clip flax bolls late in the season, harvesting the crop as soon as possible may help minimize damage.

DEFOLIATING CATERPILLARS ON FLAX

Although several species of caterpillars will feed on flax, they rarely are at levels that result in economic damage. Specific economic thresholds for these caterpillars in flax are not available.

BERTHA ARMYWORM (*Mamestra configurata*)

Bertha armyworm was a regular pest of flax before canola and mustard were grown on the Prairies (Photo 7-8). However, since the widespread introduction of the *Brassica* crops, bertha armyworm rarely causes economic damage to weed-free flax fields. If bertha armyworm-infested canola fields are swathed and green flax fields are nearby, flax can suffer significant damage from invading larvae. When abundant, bertha armyworms cause serious damage by chewing through the stems below the bolls, causing bolls to drop to the ground. Young bertha larvae are green but larger larvae are usually velvet-black.

CLOVER CUTWORM (*Discestra trifolii*)

Although flax is one of the crops that clover cutworms will feed on, this insect occurs only sporadically at densities that can cause economic damage.

BEET WEBWORM (*Loxostege sticticalis*)

The beet webworm is a slim, active, dark-green caterpillar which eats leaves, flowers and patches of bark from flax stems and branches (Photo 7-9). Larvae will often consume weeds before feeding on flax. Higher levels of beet webworm in flax may occur in years when weed growth is reduced by hot, dry summer weather. Determine if a significant number of bolls are being damaged before applying insecticides. Beet webworm is attacked by a number of species of parasitic insects.

Photo 7-7–Twostriped grasshopper

Photo 7-8–Larvae of bertha armyworm

Photo 7-9–Beet webworm

Photo 7-10–Zebra caterpillar

Photo 7-11–Variegated fritillary

Photo 7-12–Flax bollworm

ZEBRA CATERPILLAR (*Melanchra picta*)

The zebra caterpillar is another species which feeds on flax as well as many other plants (Photo 7-10). This is not normally a significant pest.

VARIEGATED FRITILLARY (*Euptoieta claudia*)

Larvae of the variegated fritillary will feed on flax, including flowers and seeds. However, larvae of this migratory butterfly are usually not sufficiently abundant to cause economic damage (Photo 7-11).

FLAX BOLLWORM (*Heliothis ononis*)

Flax bollworm is a climbing cutworm. It has other host plants but prefers flax over other crops. The moths deposit their eggs in the open flowers and the young larvae eat the developing seed within the boll (Photo 7-12). The older green and white-striped worms leave the bolls and complete development by feeding on other bolls from the outside. Economic infestations of this insect have been limited. Populations are usually kept low by parasites and disease.

Chemical Control of Insects

Extra considerations are needed when applying insecticides to flax that is flowering or when getting close to swathing.

Pollinators: Flax is a self-pollinating species and inadequate pollination is not usually a factor limiting yield. However, honey bees will forage in flax fields, so efforts should be taken to minimize harm to bees during flowering.

Pre-harvest intervals: The number of days that must pass between application of a pesticide and when flax is swathed, can vary from 1 to 40 days for insecticides registered in flax. Ensure the pre-harvest interval required for the insecticide will not be greater than the anticipated number of days until swathing.

Current recommendations for chemical control of insects of field crops are published annually as ‘Guides to Crop Protection’, by most provinces. For more information on insects and their damage, and for up-to-date information on control, consult your local agronomist, provincial Agrologist or provincial entomologists.

NOTE: Information on storage insect pests will be dealt with in the section Storage of Seed

Photos are courtesy of Dr. John Gavloski, Extension Entomologist with MAFRD.

Chapter 8: Diseases

Historically, fusarium wilt and rust have been considered major limiting factors in flax production in Western Canada. However, these two diseases have been effectively managed by multigenic resistance incorporated in all commercially registered flax varieties in Canada. Recently, pasmo and powdery mildew have been widespread causing local disease epidemics. Maintaining resistance to rust and wilt and breeding for resistance to pasmo and powdery mildew are objectives in developing new varieties.

Refer to the Guide to Crop Protection publication available on provincial department of agriculture websites. The Guide to Crop Protection is updated annually and contains pertinent additional information on disease control management including a listing of currently registered fungicides.

Rust

Rust is potentially the most destructive disease affecting flax. The last major rust epidemic occurred in the 1970's. Although it is effectively controlled by genetic resistance, it remains a potential threat to flax production as it can survive locally and complete its life cycle on flax, thus having the ability to produce new races that attack hitherto resistant varieties.

The causal organism is *Melampsora lini*, a fungus that overwinters by means of teliospores on flax debris. Early infections produce the aecial stage with aeciospores on volunteer flax seedlings which subsequently produce the uredial stage. Urediospores can cycle through several generations during the growing season resulting in completely defoliated flax plants and reduction of seed yield and fiber quality. Flax rust completes its life cycle on the flax plant, unlike many other rusts that require an alternate host.

Symptoms: Rust is readily recognized by the presence of bright orange and powdery pustules, also called uredia (Photo 8-1). Rust pustules develop mostly on leaves (Photo 8-2), but also on stems (Photo 8-3) and bolls (Photo 8-4). The pustules produce numerous urediospores which are airborne and cause new cycles of infections during the season. Spread and infections are favored by high humidity during cool nights, warmer day temperatures and on plants growing vigorously. As the season progresses, the orange pustules turn black and produce overwintering telia and teliospores (Photos 8-3 and 8-4). The black pustules are most common on stems.

Control: Complete control is achieved by the use of rust-resistant varieties. All registered Canadian varieties listed in Table 11-1 are immune to local races of rust. Planting susceptible varieties may not only result in serious yield loss, but also affords the fungus a chance to produce new races that may attack resistant varieties. Additional safeguards include: destroying plant debris, using certified and disease-free seed of a recommended variety, crop rotation and planting the flax crop in a field distant from that of the previous year.

Photo 8-1–Flax rust

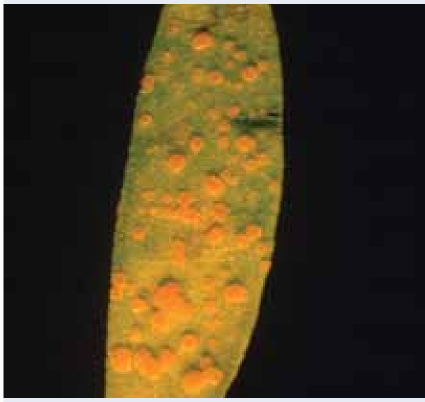

Photo 8-2–Flax rust on leaf

Photo 8-3–Rust uredia and telia on flax stems

Photo 8-4–Uredia and telia on flax boll

Photo 8-5–Flax fusarium wilt at seedling stage

Photo 8-6–Flax fusarium wilt at adult stage

Photo 8-7–Pasmo on flax leaves

Photo 8-8–Pasmo brown banding on stems

Fusarium Wilt

Flax wilt or fusarium wilt is caused by the seedborne and soilborne fungus *Fusarium oxysporum* f.sp. *lini*. The fungus invades plants through the roots at any growth stage during the growing season and continues infection inside the water-conducting tissue of the root. This interferes with water uptake and warm weather therefore aggravates plant symptoms from the disease. All Canadian flax varieties are resistant/moderately resistant to fusarium wilt (Table 11-1).

Symptoms: Early infections may kill flax seedlings shortly after emergence (Photo 8-5), while delayed infections cause yellowing and wilting of leaves, followed by browning and death of plants (Photo 8-6). Roots of dead plants turn ashy grey. The tops of wilted plants often turn downward and form a "shepherd's crook". Affected plants occur more commonly in patches but may also be scattered throughout the field. The fungus persists in the soil, as mycelia and spores survive for many years in debris of flax and other organic matter in the soil. Wind-blown and water run-off soil may spread the fungus from one field to another.

Control: The most important control measure is the use of available resistant/moderately resistant varieties (Table 11-1). Crop rotation of at least three years between flax crops helps to maintain low levels of inoculum in the soil. Seed treatment with recommended fungicides may protect the crop from early infection at the seedling stage and helps maintain good stands and seedling vigor.

Pasmo

The causal organism of this disease is *Septoria linicola*, a fungus that attacks above-ground parts of flax and overwinters in the soil on infected flax stubble. Flax is susceptible to pasmo from the seedling stage to maturity. Epidemics can occur early in the season when favorable conditions of high humidity with frequent rain showers prevail. Pasmo can cause defoliation; premature ripening and can weaken the infected pedicels resulting in heavy boll-drop under rain and wind conditions. Depending on the earliness and severity of the infection, pasmo reduces seed yield as well as seed and fiber quality. Commercial flax varieties lack resistance to this pathogen.

Symptoms: Pasmo is characterized by circular brown lesions on the leaves (Photo 8-7) and brown to black infected bands that alternate with green and healthy bands on the stem (Photo 8-8 and Photo 8-9). Infected flax tissue is characterized by tiny black pycnidia which are the fruiting bodies of the fungus. The debris carries numerous pycnidia which overwinter and produce masses of spores that cause the initial infections on leaves and stems. Spores are dispersed by rain and wind. High moisture and warm temperatures favor the disease. Lodging favors the development of pasmo, because of increased humidity within the crop canopy and this may result in patches of dead plants completely covered with the fungus.

Control: In the absence of genetic resistance to this pathogen, the best disease management is achieved by early seeding to avoid high moisture conditions in late summer and fall, using clean seed with recommended seed treatment to protect the crop at the seedling stage, using lodging-resistant varieties, applying the recommended seeding rate and control of weeds to avoid a thick crop canopy which create favourable microclimate conditions for disease development. Growers should follow a crop rotation of at least three years between flax crops to minimize the inoculum pressure of the pathogen. Foliar application(s) using recommended fungicides can be applied around early flowering to protect the crop from disease spread and the development of epidemics, thus reducing the loss in yield and quality of harvested seed.

Powdery Mildew

This disease was first reported in Western Canada in 1997. Powdery mildew has spread quickly and its incidence and severity have increased sharply in Manitoba and Saskatchewan.

The causal agent is the fungus *Oidium lini* and little is known about the overwintering and host range of this fungus in Western Canada. Early infections may cause severe defoliation of the flax plant and reduce seed yield and quality. Some flax varieties are resistant/moderately resistant to this disease (see Table 11-1).

Symptoms: The symptoms are characterized by a white powdery mass of mycelia that start as small spots and rapidly spread to cover the entire leaf surface (Photos 8-10 and 8-11). Heavily infected leaves dry up, wither and die. Early infections may cause complete defoliation of flax plants.

Control: The most economical control is through the use of resistant varieties (see Table 11-1). Early seeding will reduce the impact of this disease on yield loss by avoiding early infections and buildup of epidemics. Foliar application of recommended fungicides around flowering time may protect the crop from severe powdery mildew epidemics and reduce losses in yield and seed quality.

Stem Break and Browning

Stem break and browning are phases of a disease caused by the seedborne and soilborne fungus, *Aureobasidium pullulan* var. *lini*, also called *Polyspora lini*. This disease is of minor importance in Western Canada; however, it may cause some damage in the Parkland regions of Saskatchewan and Alberta in some years.

Symptoms: Stem break is the first conspicuous disease symptom. Development of a canker at the stem base weakens the plant. The stem may break at this point when the plants are still young, or at a later stage (Photo 8-12). Plants may remain alive after stem breakage, but any seed produced may still be lost in harvesting as seed produced will be smaller and thin. Initial infections in spring may start from spores produced on diseased stubble and are spread by wind and rain. Infections may start during seedling emergence when seed coats of diseased seed are lifted above the ground and the fungus produces the first cycle of spores of the season.

The browning phase is initiated by infections on the upper part of the stem that appear as oval or elongated brown spots, often surrounded by narrow, purplish margins. The spots may coalesce, and leaves and stem turn brown. Patches of heavily infected plants appear brown, giving the disease the name of 'browning'. The fungus may penetrate bolls as well as seeds, or may produce spores on the seed surface. Affected seeds may remain viable.

Control: Use of disease-free seed produced by healthy plants is the most important control measure. Fungicidal seed treatment controls surface-borne inoculum, but is unlikely to be effective against inoculum borne inside the seed. Rotating crops and planting flax in a field distant from that of the previous year reduces spread of infection from diseased stubble.

Photo 8-9–Severe pasmo on flax stems

Photo 8-10–Powdery mildew on flax

Photo 8-11–Severe powdery mildew in flax field

Photo 8-12–Flax browning and stem break

Photo 8-13–Flax seedling blight

Photo 8-14–Sclerotinia stem shredding

Photo 8-15–Sclerotia of sclerotinia inside flax stem

Seedling Blight and Root Rot

In spite of seed treatment, seedling blight and root rot can develop, leading to reductions in yield. Seedling blight and root rot may be due to soilborne fungi such as species of Fusarium, Pythium and Rhizoctonia. However, *Rhizoctonia solani* is the principal causal agent and can be particularly destructive in soils that are loose, warm and moist. *R. solani* survives as a composite of strains that differ in host range and pathogenicity. Strains attacking sugar beets and legumes such as alfalfa and field peas, also attack flax. Seed coats of yellow-seeded flax varieties are more prone to cracking and splits, which renders them more susceptible to infections causing seedling blight and root rot than brown-seeded varieties.

Symptoms: Blighted seedlings turn yellow, wilt and die. Infected seedlings may occur singly or in patches (Photo 8-13). Seedling blight may be inconspicuous and gaps in the row may be the principal sign of disease occurrence. Roots of recently affected plants show red to brown lesions, and may later turn dark and shrivel. Diseased plants are often difficult to distinguish from those killed by the wilt fungus.

Root rot symptoms usually appear in plants after the flowering stage. Plants may wilt on warm days and turn brown prematurely. Plants with root rot usually set little or no seed.

Control: Seedling blight and root rot can be controlled by a combination of farm practices. Use certified seed of a recommended variety. Reduce cracking of seed by adjusting combine settings during harvest. Treat the seed with a fungicide. Practice a crop rotation of at least three years between flax crops and plant in a field that is distant from fields sown to flax in the previous year. Avoid legumes and sugar beets in the rotation. Prepare a firm seedbed and use recommended fertilizer and seeding practices to promote vigorous stands. Sow flax on cereal stubble rather than on summerfallow.

Sclerotinia Stem Rot

This disease has been reported from Alberta, Manitoba and Saskatchewan in lodged flax crops with saturated soil moisture conditions. Severity of the disease depends on the level of Sclerotinia inoculum in the soil from previous crops, the soil water saturation and the severity of lodging.

The causal agent is *Sclerotinia sclerotiorum* which is a widespread pathogen causing diseases on canola, sunflower, soybean, leguminous crops, and 100s of plant species.

This fungus survives for 3-4 years in the soil as compact masses of mycelia called sclerotia. The infection in flax is caused by mycelial infection on plants touching the infested soil in heavily lodged flax. No evidence of airborne ascospores infection of this pathogen in flax.

Symptoms: The symptoms are water-soaked longitudinal lesions on the stems girdling the stems resulted in bleaching, shredding of the stems (Photo 8-14), breakage and lodging in Sclerotinia heavily infested fields. Mycelia grow on the stem surface and cylindrical shaped sclerotia are formed inside the stem (Photo 8-15).

Control: As Canadian flax varieties do not have genetic resistance to Sclerotinia, it is recommended to use lodging resistant varieties, proper seeding rate and recommended fertilizer rate to avoid dense crop canopy. Producers should avoid fields with previous history of heavy Sclerotinia inoculum and water saturated or heavily irrigated fields.

Aster Yellows

The six-spotted leafhopper is the main vector which transmits the phytoplasma organism that causes aster yellows in flax, canola, sunflower and some weeds. The disease occurs annually but commonly only traces and low level infections occur in Western Canada. However, early migrations of leafhoppers from the United States resulted in aster yellows epidemics in 1957 and 2012, causing widespread severe yield losses in flax and other crops.

Symptoms: Aster yellows symptoms include yellowing of the top part of the plant, conspicuous malformation of the flowers and stunted growth (Photo 8-16). All flower parts including the petals are converted into small, yellowish green leaves (Photo 8-17). Diseased flowers are sterile and produce no seed. The severity of the disease depends at the stage plants become infected and the number of insect vectors that carry the pathogen. The mycoplasma-like organism overwinters in perennial broadleaved weeds and crops, but most infections are carried by leafhoppers that migrate from the United States.

Control: Seed early to avoid the migrating leafhoppers in mid to late season. Early summer migration of leafhoppers occurs when abnormal warm weather prevails early in the growing season thus resulting in major epidemic and yield loss.

Photo 8-16–Flax Aster Yellows stunting and malformed flowers

Photo 8-17–Flax Aster Yellows, petals turn to yellowish-green small leaves

Crinkle

Crinkle is caused by a virus called oat blue dwarf that also causes disease in oats, wheat, and barley. Only traces of the disease occur in flax in Western Canada.

Symptoms: The symptoms are characterized by a conspicuous puckering of leaves, stunted growth and reduced branching. Flowering may appear normal but seed production is reduced. Like aster yellows, crinkle is a disease of flax that depends for infection via transmission by the six-spotted leafhopper.

Control: Seed early to avoid migrating leafhoppers in mid to late season.

Minor Diseases

In certain localities, occasional fungal diseases may be due to *Alternaria linicola* causing seedling and stem blight, *Colletotrichum lini* causing anthracnose of leaves and seedling blight, *Phoma exigua* causing root rot and *Selenophoma linicola* causing dieback. *Alternaria* and *Colletotrichum* are seedborne and may be controlled by fungicide seed treatment. Occasionally, *Sclerotinia sclerotiorum* causes stem mold, stem shredding and breakage in heavily lodged flax sown in Sclerotinia infested fields.

Photos are courtesy of AAFC, and remain property of AAFC.

Production Tip

Use a variety that is resistant to rust and wilt and adapted to the growing conditions in your area.

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9-1–Flax chlorosis general view

9-2–Flax chlorosis

9-3–Flax Heat and frost Canker

Chapter 9: Environmental Disorders

Chlorosis and Top Dieback

These disorders are associated with an imbalance of nutrient elements in the plant. Such disorders are often found in soils high in lime and are most severe under high soil-moisture conditions. Leaf chlorosis may also occur in flax on water-logged soils.

Symptoms: Under high soil-moisture conditions, plants become yellow, which may or may not be accompanied by dieback of the terminal bud and the development of basal branching (Photo 9-1 and Photo 9-2).

Control: Choose cultivars such as AC Emerson, which are more tolerant to conditions causing the disorder (see Varieties). Since chlorotic plants are more sensitive to herbicides, care must be taken to apply herbicides under conditions that result in least injury.

Heat and Frost Canker

Cankers are caused by very high or freezing temperatures when the crop is in early stages of growth. While the damage is commonly inconspicuous, stands may be reduced by as much as 50%. Damage is usually most severe in thin stands on light soils (Photo 9-3). Low spots are more conducive to frost canker.

Symptoms: Frost cankers are similar to heat cankers in appearance. Affected plants are girdled at or near the soil line (Photo 9-4). The area below the constriction is usually thin and dry, while that above it consists of scar tissue which may appear swollen, rough and cracked. The scar tissue is brittle, and affected plants usually fall over. Less severely damaged plants may produce new shoots which grow to maturity, or they may topple over later in the season, turn yellow and die.

Control: The incidence of heat and frost canker is reduced by following recommended seeding practices to ensure good, vigorous stands. The practice of early seeding at a high rate has been shown to be effective on soils where these disorders can be a problem.

Herbicide Injury

Herbicide injury in flax can be grouped into three categories:

- Incorrect application or
- Herbicide residues in the soil
- Herbicide drift.

INCORRECT APPLICATION OF HERBICIDES

Flax has natural tolerance to many herbicides and although there are several herbicides that will cause injury to flax, they seldom kill the plant. Flax plants that have been injured from a herbicide treatment often show only slight symptoms. Injury from herbicides usually results in delays in flowering and/or maturity.

In addition to these general symptoms, there are some specific symptoms that can occur in flax with certain herbicides.

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- There is some risk of injury to flax from application of this herbicide on low organic matter soils, coarse textured soils and/or soils with a pH greater than 8, particularly if above-normal rainfall occurs within two weeks of application. Injury manifests as a thin stand as injured flax seedlings fail to emerge.

Bromoxynil/MCPA

- Bromoxynil/MCPA is commonly used to control broadleaf weeds in flax. Bromoxynil/MCPA should not be applied to flax crops if the daytime temperature exceeds 27°C (80°F) within two days prior to, or after the application. Under these high heat conditions, bromoxynil/MCPA causes height reductions and browning of the leaves, giving the flax plant a scorched appearance (Photo 9-5).
- Flax that recovers from this injury will have delayed flowering and maturity. Spraying in the evening may reduce the risk of flax injury. This injury can occur when bromoxynil/MCPA is applied alone or in tank mix with other herbicides.

MCPA

- MCPA is often used to control certain broadleaf weeds in flax. MCPA should not be applied to flax under hot or humid conditions. Flax treated with MCPA under hot or humid conditions will have a wilty appearance with bending in the stem and some height reduction. These symptoms result in delays in flowering and maturity. Applications of MCPA are preferably applied to flax prior to the 10 cm (4 in.) height.

Trifluralin

- Trifluralin herbicides for use in flax must be applied in the fall before the crop is sown. When seeding into ground treated with trifluralin, it is important to seed shallow to avoid crop injury. If flax is sown deep into the trifluralin-treated soil zone, reduced emergence and poor growth occur –resulting in a thin plant stand. Plants emerging from deep in the trifluralin zone will have swollen roots and will suffer from root pruning and therefore will be short, develop very slowly and have reduced yields.

UNREGISTERED HERBICIDES

Since flax has relatively good tolerance to many broadleaf herbicides, it has occasionally been treated with unregistered herbicides. However, as an increasing percentage of the flax crop is being utilized as a food crop, the use of herbicides not registered for flax is of growing concern. These herbicides usually cause delays in flowering and maturity, along with reduced yields.

HERBICIDE SOIL RESIDUES

Flax is susceptible to the residues from only a few herbicides. For specific information on the soil residual properties of individual herbicides, refer to the herbicide label or provincial recommendations.

Flax plants affected by herbicide residues in the soil are often stunted and have yellowing at the growing point (Photo 9-6). The severity of the injury to flax depends on when the herbicide was applied, the rate at which it was applied, and the soil type. To avoid the risk of injury from herbicide residues in the soil, carefully follow the recropping intervals identified on herbicide labels.

9-4–Heat and frost canker; plants have toppled over

9-5–Applying herbicide when the daytime temperature was too high, caused this bromoxynil/MCPA injury on flax

9-6–Flax plants affected by chlorsulfuron residues (Group 2) in the soil, one year after the herbicide was applied. Note the thin and stunted flax stand.

HERBICIDE DRIFT

Herbicide drift occurs when herbicides are applied in windy conditions, or when there is no wind and temperature inversions occur. Since flax shows good tolerance to many herbicides, there are only a few which commonly cause drift concerns. Glyphosate applied in the spring to fields adjacent to flax under drift-sensitive conditions can cause serious injury to flax. The extent of damage is dependent on the distance that the wind has carried the drift and the rate of herbicide used. Flax affected by glyphosate has a chlorotic growing point, and with higher rates the leaves may develop necrotic (dried brown) areas. At very low doses, glyphosate drift can cause a characteristic twist or kink in the stem of the flax plant that occurs at the location of the growing point at the time of exposure to glyphosate. In this case, no chlorosis or necrosis are observed.

Photos are courtesy of AAFC, and remain property of AAFC.

Production Tip

Choose a well-drained soil with no herbicide residue.

Chapter 10: Harvesting

When producers are evaluating flax harvesting systems, a number of factors should be considered including:

- existing equipment inventory of combine(s), header(s), windrower(s), and straw collection;
- residue management requirements;
- harvest system placement within an overall agronomic plan; and
- potential straw management for collection and fibre recovery;

Straight combining has generally become a preferred method of harvest for all Prairie crops wherever possible due, in part, to the availability of large, sophisticated headers, improvements in maturity uniformity of varieties, reduced labour and equipment inventory cost, and harvest time reduction.

Conventional Straight Combining

Flax harvesting can be accommodated within a straight combining system but its harvest may offer unique challenges and opportunities related to the tough, fibrous nature of the straw. Cutter-bar style headers can be used provided the sickle bar is in good condition and the flax straw is mature and dry. Cutter bars of combines or windrowers must be kept clean and sharp to ensure a smooth cut and to prevent accumulation of immature flax straw under the knife. Consult your local dealer or machine manual for recommendations regarding sickle knife designs that are best suited for cutting flax. Desiccation of the crop to force straw dry-down and reduce harvesting issues associated with weeds and immature straw could be considered as an alternative to waiting until the crop naturally matures or until a significant frost event improves the potential to cut the straw. Dry, mature straw and seed is essential if the combine is to properly separate the material without excessive seed or seed quality loss. However, either desiccation or waiting can impose economic risk due the cost of the spraying operation, crop trampling, or losses due to wind or rain.

Production Tip

Harvest the crop at the appropriate stage of maturity. Flax is considered to be fully mature when 75% of the bolls have turned brown.

Alternative Straight Combining

In plot and field scale studies conducted from 2006 until 2012, Agriculture and Agri-Food Canada (AAFC) compared the use of conventional straight combining to the use of a Shelbourne-Reynolds stripper header. This stripper header has a counter-rotating rotor containing stainless steel stripping fingers that strip seed from the crop as the combine moves the header forward in the field. After the grain has been stripped by the rotor, the grain and chaff are deflected back into a conventional auger and pan. The majority of the crop's straw is left standing in the field attached to the soil, reducing substantially the material entering the combine and leaving the straw relatively untouched and available for future collection or soil protection. For a more detailed description of this header, see:

http://www.shelbourne.com/3/products/1/harvesting/31_stripper-header.

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The results of demonstration scale field trials have shown that the use of the stripper header offers a number of opportunities and challenges when used in flax:

- Since much of the seed is threshed by the header and little straw is introduced into a combine, combine separation and harvest capacity can be improved or combine size reduced for a given header width.
- In demonstration trials conducted in 2007, flax seeded around May 1st was harvested by a rotary combine/stripper header as early as August 16th, when the seed was mature and dry and the straw still green. This reduced harvest risks associated with weather and time, eliminated the need for desiccation, and allowed the flax straw to rebound from being trampled making it available for collection. Normal harvesting with a conventional auger and a draper header occurred approximately six weeks later when the straw had matured and dried adequately.
- Stripper header rotor speed was increased over recommended to accommodate higher forward combine ground speed.
- The bull nose deflector needed to be positioned so that the bottom of the deflector was placed only a minimal amount into the crop canopy. This was especially critical in desiccated flax crops where embattlement of the standing crop was observed. A visual indicator placed on the bull nose assisted the operator to determine the correct deflector setting for the crop being harvested.
- The rotor height setting needed to be as low as practical and gauge wheels were added to assist the operator make this adjustment.
- Overall flax seed and straw recovery comparisons for the Simonson Farms Ltd. demonstration trials are contained in Table 10-1. No statistical significance can be derived due to the small number of samples, locations, and years involved in the trial.
- Recoverable fibre based upon hammer-mill fibre extraction technology showed that straw from stripper header harvesting had a 9% improvement in cellulose recovery over other harvest methods.

Production Tip

Avoid cracking the seed during harvest by using correct combine adjustments.

Yield Comparison 2005 to 2008 Simonson Farms Ltd.	Average Grain Yield (Kg/ha)	Grain Yield % of Draper Header	Average Straw Yield (Kg/ha)	Straw Yield % of Conventional Draper Header
Stripper header: Massey and Case IH combine data	1144	98	794	132
Auger header and Massey Combine	1253	108	783	130
Draper header and Case IH combine	1166	100	603	100

Table 10-1. Plot trials from 2008 to 2011 using the same Massey conventional combine compared a Shelbourne-Reynolds stripper header to a conventional Massey auger header at Indian Head and Swift Current, Saskatchewan. Seed recovery was lower for the stripper header (6.5% lower at P= 0.002) but straw recovery trended higher. This seed loss was verified to be predominately header loss through ground surface evaluations following harvest operations.

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Swathing

Flax is considered to be fully mature when 75% of the bolls have turned brown and swathing can be considered at this stage. Cutting or desiccating flax at an immature stage is not known to result in seed blackening, but yields will be reduced due to early termination of seed development. This will result in thin seeds of lower weight.

If re-growth occurs in the fall, cut the crop when the greatest amount of ripe seed can be obtained or consider desiccation at this time. Fall rains may cause weathering of the mature seed and frost may cause immature seed to turn black, resulting in grade reduction. Considerable frost damage occurs in immature seeds when temperatures drop to the -3˚ to -5˚C range (27˚ to 23˚F), while leaves are severely damaged at -4˚ to -5˚C (25˚ to 23˚F) and stems at -6˚ to -7˚C (21˚ to 19˚F).

When swathing, a stubble height of about 10 to 15 cm (4 to 6 in.) is recommended to hold the swaths off the ground and facilitate drying. Flax swaths can be rolled to prevent movement of the swath by strong winds.

Chemical Desiccation

Chemical desiccation may be used to accelerate drying of the crop and any weeds that may be present. It does not speed crop maturity, but will reduce the time from maturity to harvest.

Potential advantages from this practice are:

- earlier harvesting;
- elimination of the need for swathing;
- reduction in combining time;
- less wear and tear on machinery;
- cleaner seed;
- weed control; and
- reduction or elimination of the need for artificial drying.

A desiccant may be applied when 75% of the bolls have turned brown, which is the normal time of swathing. Generally, application of approved chemicals 7 to 14 days before the target harvest date should ensure best weed control and maximize harvest management benefits. Thorough weed dry down usually occurs in 10 to 14 days following application. Desiccated flax should be harvested as soon as possible after it is suited for cutting and threshing, to avoid capsule loss and weathering of the seed. For up-to-date information on the use and application of chemical desiccants, refer to the latest provincial recommendations or consult your local agronomist or provincial agricultural Agrologist.

Threshing

The combine must be adjusted correctly to minimize seed coat damage to flax and minimize unwanted losses due to the header operation or threshing. If seed is excessively dry, it becomes more susceptible to damage from high threshing cylinder speeds or tight concave clearances. When a stripper header is used, the material being separated by the combine is missing much of the straw and the opportunity exists for increased seed and chaff intake. Many of the settings

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Linseed oil is well-regarded as an excellent preservative for wood and concrete surfaces.

of the combine must change, including cylinder speed, concave clearance, fan speed/separator airflow, and sieve opening. If the seed is to be used for planting, greater care in threshing is required as seed with a damaged seed coat has reduced germination. It may be necessary to adjust the combine from time to time during the day depending on temperature, relative humidity and the condition of the flax. The manual provided with the combine should be consulted for correct settings and recommended adjustments for specific conditions or observations. Usually, early-sown flax is easier to thresh than late-sown flax because it has a better chance to mature under drier conditions.

The swath may be threshed when the leaves and stems are dry enough to separate in the combine and the seeds rattle in the boll, or when the seed has dried to the desired moisture level as indicated by a moisture meter.

Delayed combining of flax may result in weathered seed. Weathered seed often has a grey, dull cast and may turn black. Another risk of delayed harvesting is boll drop, where bolls break off the ripe plant and fall to the ground.

Flax is considered tough from 10.1 to 13.5% moisture and damp if over 13.5% moisture. Although flax seed is generally considered dry enough for storage at 10% seed moisture content, the crop may be harvested at higher seed moisture if drying facilities are available. For further information, refer to the Flax Storage section.

Although many recent combine models offer options to improve residue quality available for baling in general, flax fibre recovery of the highest quality may still be compromised. Producers who are planning to collect straw while using conventional headers with their combines should consult combine manuals, dealers, or internet resources to determine the best operational practises for their specific equipment.

Residue Management

Where flax residues are to be managed in the field, the combine, header, and residue disposal options are similar to those for cereals. Combine designs released by manufacturers over the past decade have considerable engine power and residue chopping/spreading capacity available to distribute chopped flax residue across the crop cutting width. Additionally, chemical desiccation or especially pre-harvest application of glyphosate, tends to make the straw more brittle and hence easier to chop and spread. Recent combine improvements and desiccation may reduce or eliminate the need for other residue management operations but may slow harvest due to the power needed for residue size reduction and spreading. If adequate residue treatment is not achieved, other residue treatment options should be considered to prevent issues with subsequent field operations.

Figure 10-1: Straw Buncher

Straw disposal by burning can be used to significantly reduce flax residue. A "straw buncher" has been developed to collect windrowed flax straw into piles that can be more easily and completely burned in the field (Figure 10-1). However, if the straw is removed by burning or baling, soil may become more vulnerable to erosion if summerfallow succeeds flax. Therefore, a cereal crop following flax is required to rebuild crop residues or continuous cropping should be used with a cereal as the next crop. Recent research has shown that none of the residue management methods appear to affect the yield of a succeeding crop of wheat.

Baled mature flax straw can be used for ruminant animal feed or animal bedding. However, green flax straw should not be fed or grazed as it is high in prussic acid. The danger of prussic acid poisoning is much higher if the immature flax is frozen.

Flax straw may contain between 10 and 22% fibre and represents a strong natural fibre of interest to the industrial sector for uses such as fibreglass replacement, composite plastic parts manufacturing, specialty paper production, and insulation. If producers wish to consider straw as part of their economic return from flax production, the complexity of flax harvest management for producers increases because straw quality, collection system type, and operation integration all may affect end use suitability, producer costs, and market returns. Fibre length and the quality of fibre retting are influenced by harvest system and variety. In trials conducted by AAFC, Biolin and SWM International, different options to increase retting and improve processing of flax straw were evaluated based upon flax straw remaining behind a stripper header. These included a number of conditioning, cutting, and packing operations designed to improve opportunities for retting bacteria and fungi to attack and partially decompose the flax straw in the time available following seed harvest. The straw was left in the field until spring and collected two weeks prior to when normal agronomic operations would commence for the specific location, with the results compared against standing flax straw overwintered then swathed and baled.

Production scale testing of spring baled winter retted flax produced cleaner, lower shive content, improved fibre length and fibre strength, than traditionally baled fall straw. Spring retted straw materially improved processor returns by increasing production rates, yields, and quality of fibre while reducing shive content level. The resulting fibre product had improved marketability characteristics for higher value applications.

The use of a forage macerator (super conditioner), while not showing improvements in retting success, showed promise as a bale densification device. In a demonstration scale evaluation, 180 cm (6') round bales of untreated straw weighed ~ 670 kg (1350 lbs) while 180 cm (6') bales of macerated straw weighed ~1000 kg (2200 lbs). This represented an improvement in bale density greater than 50%, allowing road transport to achieve or exceed legal load limits when macerated bales are the payload. This reduced transportation cost and provided more fibre per bale with potentially positive benefits for storage and processing for the fibre processor.

Flax Storage

Dockage can be reduced by controlling broadleaf weeds as well as grassy weeds, including volunteer cereals, during the growing season or through pre-harvest desiccation. If green weed seeds are present, they may raise the moisture of the flax seeds enough to cause heating and moulding. Removing this dockage before putting the flax into long-term storage is advisable. Freshly harvested seed can maintain a high respiration rate for up to six weeks before becoming dormant. As in other oilseeds and cereal grains, moisture migration will occur in stored flax seed. Even though the seed is binned with uniform moisture, high moisture spots can develop by moisture migration. This usually happens in fall and early winter, although it can also occur in the spring. This, coupled with mould growth can lead to heating. In general, stored flax requires more attention than stored cereals, so bins of flax seed should be inspected frequently for problem spots until the seed has cooled down. Whenever possible, it is recommended that flax seed should be cooled down after it is put into storage. See Figure 10-2 for more information.

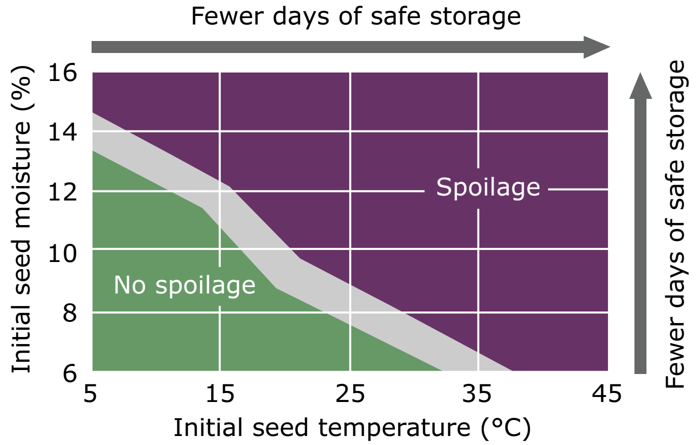

Figure 10-2: Flax safe storage moisture versus storage temperature (Canadian Grain Commission, 2013)

STORAGE INSECTS

Stored flax seed is not troubled by storage insects as frequently as cereal grains. This may be because flax does not provide a nutritionally optimal diet for many insects, mainly because of its high lipid and low carbohydrate composition. Insects that can occur in stored flax are the saw-toothed grain beetle, confused flour beetle, merchant grain beetle, and red flour beetle. Various fungus beetles and numerous mites can be found in seed that remains tough to damp in storage. Research in Manitoba has revealed that flax varieties vary in their susceptibility to the saw-toothed grain beetle.

The rusty grain beetle occurs occasionally in car lots of flax. However, it is suspected that this insect feeds on cereal admixtures in the flax. Research in Manitoba found that rusty grain beetles were not able to reproduce or complete development on flax. Granary weevils and rice weevils exposed to whole flaxseed all died.

The optimum temperature for rapid growth of insects is in the range of 30˚ to 35˚C (86˚ to 95˚F). Their activity is greatly retarded by temperature below 18˚C (64˚F). If the grain is cool and dry, insects will generally not thrive. However, flax may be put into storage at an acceptable moisture content and temperature, but pockets of high moisture and temperature can develop later through moisture movement on convection currents and heat production by mould respiration which would encourage insect activity.

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Chapter 11: Varieties

Varietal Development in Canada

Three major breeding programs develop flax varieties for Canada: the Agriculture and Agri-Food Canada (AAFC) program located at the Cereal Research Centre in Morden, Manitoba; the Crop Development Centre (CDC) program located at the University of Saskatchewan in Saskatoon, Saskatchewan; and the Saskatoon R and D facility of Crop Production Services Canada Inc. (CPS). Another breeding program targeting flax for crop diversification in Québec is active at CÉROM (Centre de recherche sur les grains), located in Saint-Mathieu-de-Beloeil. Some seed companies are also introducing cultivars from other countries.

Disease resistance to rust and wilt has been emphasized by all of these programs in order to manage disease effectively. Thus, all registered flax varieties are resistant to rust and must have moderate resistance to fusarium wilt. Breeding for disease resistance has been effective as the last outbreak of rust occurred in 1973.

Currently, flax varieties registered in Canada can be either brown or yellow seeded with high levels of alpha-linolenic fatty acid (ALA). Current Canadian linseed varieties have an oil content ranging between 45% and 50%, reported on a moisture-free basis. Linseed oil is composed of five main fatty acids: palmitic, stearic, oleic, linoleic, and linolenic (ALA). Linseed's high proportion of ALA (>50%) provides drying properties desired for the fabrication of paints, varnishes, and linoleum flooring coverings. Similarly, flax straw, in a partially or completely processed form, is used in the manufacture of fine papers. More recently, there is renewed interest for the use of straw fibre for industrial fibre products such as pulp sweeteners, geotextiles, insulation and plastic composites.

Flax baked goods are increasingly in demand as functional or health-promoting foods.

In addition to these industrial uses, new feed and food markets underpin market stability and fuel growth. **In 2014, flax was approved by Health Canada for a health claim linking eating ground whole flaxseed to lowered blood cholesterol levels, a major risk factor for heart disease.** The claim is only one of eleven approved in Canada. The omega-3 (ALA), fibre and antioxidants in flax are nutrients that keep us healthy. Seen as a health-promoting ingredient, premium quality flax is rapidly being absorbed into the expanding functional food markets. The consumer market for whole and milled flax seed and flax oil is also expanding. For more information on flax as a healthy food choice, check out 'healthyflax.org' website or the Flax Council of Canada website.

A high ALA content (68%) variety called VT 50 has been registered in Canada by CPS (www.cpsagu.ca). The trademark for the high ALA flax varieties is NuLin®. This high ALA oil may result in further food, feed and industrial market opportunities.

Flax in animal feeds could be an important contributor to animal performance and health. Omega-3 eggs have become a popular consumer choice. In the pork and beef industries, flax use in hog rations and cattle is being investigated for improved production. Meanwhile, flax processors have seen growth in the use of flax by pet food manufacturers. Flax in pet food formulations has been promoted as solving digestive and skin problems in dogs and cats.

In order to meet the fatty acid composition profile of the margarine industry, mutation breeding efforts led to development of varieties with major reductions in ALA levels (~3%). These flax varieties were known as Linola™ or solin. The fatty acid composition of solin oil is similar to other premium polyunsaturated oils, such as sunflower oil. Oils from such varieties have higher

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solidification temperatures that are suitable for the margarine industry. Unfortunately, the market niches for these specialty linseed varieties remain underdeveloped. As a consequence, solin varieties are no longer registered for production in Canada. The yellow seed coat trait was previously used as a phenotypic (grade) marker for solin. As commercial production of solin has ceased in Canada, the yellow seed coat has been decoupled from solin. Currently, yellow seed coat flax lines with traditional high ALA contents are being developed and commercialized in Canada.

AGRICULTURE AND AGRI-FOOD CANADA PROGRAM

Since the early 1900s, Agriculture and Agri-Food Canada and its predecessors have been active in developing new flax varieties for Canada and, in particular, for the Canadian Prairies. The initial program was located at the Central Experimental Farm in Ottawa and produced varieties such as Diadem, Ottawa 770B, Ottawa 829C, and Novelty. During the 1950s, this program was particularly active, releasing varieties such as Linott, Raja, and Rocket. The 1950s and 1960s also marked the beginning of an evolution and transition in flax breeding in Canada. A new program was initiated at the Indian Head Experimental Farm and the Winnipeg Cereal Breeding Laboratory. This led to the development of the variety, Cree. In parallel, a breeding program was established in the 1960s at the Fort Vermilion Experimental Farm and Beaverlodge Research Station, Alberta. This resulted in the variety Noralta, which was the predominant variety grown in northern Alberta and northern Saskatchewan. The AAFC breeding programs were eventually consolidated and moved to Winnipeg in 1960 and then later to Morden, Manitoba. Varieties from the AAFC program and released by the Morden Research Centre include Dufferin, McGregor, NorLin, NorMan, AC Linora, AC McDuff, AC Emerson, AC Carnduff, AC Lightning, Hanley, and Macbeth. Recent varieties released from the AAFC breeding program include AAC Bravo, Prairie Blue, Prairie Grande, Prairie Sapphire, Prairie Thunder and Shape.

Flax oil capsules are sold in health food markets.

The focus of the breeding effort at Morden has been to develop improved flax cultivars for the Prairies. Consequently, most of the cultivars developed have wide adaptation to Prairie conditions. The breeding program is now devoting its attention to the development of new cultivars with increased yield potential, decreased time to maturity, better lodging resistance, improved disease resistance, increased seed oil content and increased ALA content.

CROP DEVELOPMENT CENTRE (CDC) PROGRAM

The CDC flax breeding program develops cultivars for Western Canadian growers. A modest breeding program was carried out at the University of Saskatchewan from the 1920s through the 1960s, which produced the varieties Royal and Redwood 65. The program was enlarged in 1974 when the CDC initiated a flax breeding program that has produced 12 registered varieties. Commercially available cultivars include Vimy, CDC Bethune, and CDC Sorrel and more recently, CDC Sanctuary, CDC Glas and CDC Neela.

The main goal of the CDC flax breeding and genetics program is to increase the area of adaptation that flax can be grown successfully. It is also working to provide better genetics for improved agronomic performance and seed quality for the industrial, human health, and animal nutrition markets. The research program is striving to better understand the genetics of traits of economic importance in flax. The reduction in flax breeding activities announced by other organizations, including AAFC and CPS Canada, have made the CDC flax breeding efforts critical for the broader flax industry.

CROP PRODUCTION SERVICES (CPS) PROGRAM

In 1987, a flax breeding program was initiated by Biotechnica Canada in cooperation with Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) to develop solin (low ALA flax). These varieties were trademarked as Linola™. In 1990, United Grain Growers Ltd. (UGG) purchased Biotechnica's interest in the program and moved the program from Calgary, Alberta to the AAFC Morden Research Centre. Field evaluation was conducted by the UGG Rosebank Research Farm. The solin breeding program produced the following cultivars: Linola™ 947, 989, 1084, 2047, 2090, 2126, and 2149.

Following the acquisition of Agricore Cooperative Limited by UGG in 2006, the program was relocated to the Alberta Research Council/Alberta Innovates Technology Futures (ARC/AITF) Research Centre in Vegreville. Shortly thereafter, the Linola™ breeding program was shelved and a NuLin® (high ALA) program was established. This program was transferred to Viterra when the Saskatchewan Wheat Pool merged with Agricore United in 2007. After a few years, the program started developing brown and yellow seeded flax varieties with traditional levels of ALA. In 2011, the program relocated to the Viterra Research and Development facility in Saskatoon, Saskatchewan. CPS acquired the Viterra breeding program in late 2013. Varieties released from the recent program include NuLin™ VT 50, WestLin 70, WestLin 71 and WestLin 72.

The current program is focused on developing high yielding, earlier maturing, lodging resistant, enhanced quality yellow and brown seeded flax varieties adapted to Western Canada. Since 2010, CPS has worked on the Northern Adapted Flax Variety Development Project (NAFVDP) with the Saskatchewan Flax Development Commission, ARC/AITF, the British Columbia Grain Producers Association (BCGPA), Manitoba Agriculture, Food and Rural Development/Parkland Crop Diversification Foundation (MAFRD/PCDF) and AAFC. The NAFVDP is focused on developing flax varieties adapted to northern/shorter growing seasons and to develop best agronomic practices for these varieties.

CÉROM, CENTRE DE RECHERCHE SUR LES GRAINS

In 2000, a small breeding program was initiated in Québec with the intent of providing oilseed flax as an additional crop for Québec growers. Though flax was first introduced in Canada by the French settlers in the 1600s, this crop is no longer a major crop in Québec. However, flax may be a valuable crop rotation alternative, especially in more northern regions such as the lower Gaspé peninsula.

The initial germplasm for the program was sourced from the Crop Development Centre in Saskatoon, Saskatchewan and has been enriched by several sources of exotic germplasm from various countries. Both brown and yellow flax varieties are being developed. The focus is on adaptation to Eastern Canada, high yield, lodging resistance and enhanced quality. No varieties have been released yet, however, the program has reached maturity and several cultivars should be released soon.

Characteristics of Flax Varieties

The characteristics of current flax varieties registered for production in Canada are described in Table 11-1. Varietal yield performance is presented in Table 11-2. For more information on variety performance and suitability of varieties to your local area, refer to the Saskatchewan Seed Guide, Seed Manitoba, Alberta Seed Guide, Varieties of Grain Crops, your local retailer/agronomist or seed company.

Table 11-1. Characteristics of Flax Varieties

Variety[1] (Year of Registration)	Seed Colour[2]	Maturity[3]	Resistance to Lodging[4]	Seed Size[5]	Oil Content[6]	Oil Quality[7]		to[10]	
						Iodine Value[8]	ALA Content[9]	Wilt	Powdery Mildew
AAC Bravo (2012)	B	L	G	L	46.8	196.0	60.9	MR	MR
CDC Bethune (1998)	B	L	G	M	45.6	187.6	54.2	MR	MR
CDC Glas (2012)	B	L	VG	M	47.4	196.0	58.4	MR	MR
CDC Neela (2013)	B	L	G	M	46.5	198.3	60.7	MR	MR
CDC Plava (2015)	B	M	G	M	47.0	195.8	57.8	MR	–
CDC Sanctuary (2009)	B	L	F	M	45.3	188.2	56.2	MR	–
CDC Sorrel (2005)	B	L	G	L	44.2	195.0	58.8	MR	–
VT 50 (2009)	Y	L	G	M	48.8	210.3	67.8	MR	–
Prairie Blue (2003)	B	L	VG	S	45.9	191.0	56.8	MR	MR
Prairie Grande (2007)	B	M	VG	M	45.2	194.9	58.4	MR	MR
Prairie Sapphire (2009)	B	L	G	M	49.0	194.3	57.8	MR	MR
Prairie Thunder (2006)	B	M	VG	M	44.4	196.5	58.9	MR	R
Omega (interim 2015-17)	Y	L	F	M	44.3	184.7	51.8	MR	MR
Shape (2008)	B	L	G	L	50.2	196.8	59.1	MR	MR
WestLin 70 (2013)	B	L	G	L	46.8	198.4	60.8	MR	MR
WestLin 71 (2013)	B	L	VG	M	47.4	199.2	61.2	MR	MS
WestLin 72 (2014)	B	L	G	M	47.0	192.4	56.8	MR	MR

Based on data from Flax Cooperative Tests in the Prairie Provinces.
[1] Number in brackets refers to year registered.
[2] B = Brown; Y = Yellow
[3] E = Early; M = Medium; L = Late
[4] VG = Very Good; G = Good; F = Fair; P = Poor
[5] S = Small; M = Medium; L = Large
[6] Oil Content: Results are reported as percent, calculated to a moisture-free basis.
[7] Oil quality of flax is based on the amount of linolenic acid measure in the seed or as measured by iodine value calculated from the fatty acid composition of the seed. A higher iodine value and/or higher ALA content indicate a higher overall oil quality in the seed.
[8] Iodine value: Iodine number is calculated from the fatty acid composition
[9] ALA (alpha-linolenic acid): Percent of total fatty acid composition
[10] S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant

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Table 11-2. Relative Yield of Flax Varieties

Variety[1] (Year of Registration)	Soil Zone[2]		
	Black & Grey (long growing season)	Brown & Dark Brown	Black and Grey (shorter growing season)
CDC Bethune (1998)	100	100	100
AAC Bravo (2012)	105 (12)	96(12)	99(12)
CDC Glas (2012)	102 (7)	98(6)	103 (8)
CDC Neela (2013)	109 (6)	105 (7)	105 (7)
CDC Plava (2015)	–	–	106 (12)
CDC Sanctuary (2009)	98 (14)	105 (12)	93 (11)
CDC Sorrel (2005)	99 (13)	102 (10)	101 (9)
VT50 (2009)	102 (13)	101 (7)	–
Omega (interim 2015-17)	83 (6)	96 (4)	83 (1)
Prairie Blue (2003)	–	–	–
Prairie Grande (2007)	93 (13)	93 (10)	97 (12)
Prairie Sapphire (2009)	97 (14)	95 (11)	93 (11)
Prairie Thunder (2006)	102 (13)	98 (10)	98 (9)
Shape (2008)	96 (12)	91 (10)	93 (12)
WestLin 70 (2013)	97 (6)	94 (7)	99 (7)
WestLin 71 (2013)	94 (4)	100 (8)	95 (5)
WestLin 72 (2014)	113 (5)	106 (6)	103 (4)

Based on data from Flax Cooperative Tests in the Prairie Provinces

1 Number in brackets refers to year registered.

2 Number in brackets is the site years in Cooperative trials in the Prairie Provinces available for comparison with the check variety, CDC Bethune. The more site-years used, the more dependable the result. The check CDC Bethune is present in all site-years. Yield of varieties is expressed relative to CDC Bethune for the same number of site years. Because the number of site-years varies with varieties, yield performance of a variety can only be compared to CDC Bethune and not to other varieties.

Chapter 12: Flax Straw and Fibre

Past and Present Uses

Growing flax can present "the straw problem." Oilseed flax has a significant percentage of long tough stem fibres that decay slowly over time. This makes it difficult to incorporate flax straw into the soil after harvest since the fibres wrap themselves around and/or plug disks, wheels and seeder-shanks. In the past, the only way to cope with flax straw was to drop it in windrows after the combine and then burn it directly or harrow or rake it into piles and then burn it. More recently, straw choppers on new combines have been used to effectively chop and spread flax straw, if the straw was dry and relatively short or fibre content was relatively low due to drier growing season weather.

At the present time, there is one major commercial buyer and processor of Prairie flax straw, Schweitzer-Mauduit Canada, based in Winkler, MB. It extracts flax fibre for use in the production of paper for cigarettes and some plastic composite products. Schweitzer-Mauduit Canada also extracts shive (the non-fibre part of the stem) for bio-fuel, animal bedding and mulch. There are several much smaller buyers and processors. These include, but are not limited to, Biolin Processing based near Elstow, SK (50 km southeast of Saskatoon), a pilot processing facility operated by Alberta Innovates Technology Futures in Vegreville, AB, Synermulch in Calgary, AB, Erosion Control Blanket in Riverton, MB, and Urban Forest Recyclers Inc. in Swift Current, SK. There are also several hemp and biofuel processing facilities that, from time to time, buy flax straw to supplement their sources of raw materials.

Market News
Linoleum is widely recognized and recommended by architects and interior designers globally.

Existing and potential processors prefer tall, weed-free, contamination-free (i.e., no litter or items made with plastic) flax crops situated within 100 km of a processing plant or a processor's bale stack yard. In the past, Schweitzer-Mauduit Canada normally paid $5 to $10 per tonne for the straw, depending on the year and whether or not the straw could be baled in the spring. In addition, they usually arranged and paid for the baling, transport and storage of the straw.

Depending on the acreage planted and rainfall, the potential salvageable oilseed flax straw on the Prairies is 500,000 to 1,000,000 tonnes annually. The fibre content of oilseed flax straw usually ranges from 15 to 25%. As such, the annual potential pure fibre production from flax presently grown on the Prairies would be between 75,000 and 250,000 tonnes. Schweitzer-Mauduit Canada processes from 80,000 to 120,000 tonnes of straw annually. The vast majority of the presently extracted flax fibre is exported as 60–80% pure fibre. The total value of such flax fibre exports ranges from $8 to $18 million annually (i.e., 2 to 8% of the total value of flax seed exports). Emerging flax processors who are targeting more valuable markets for fibre and shive may be able to pay significantly more for good quality straw ($20–$80/tonne); however, it will take time before the volumes rise to significant levels.

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Reducing the Straw Problem

Managing flax straw may be mitigated by a number of agronomic and equipment tips, including:

1. Seed reasonably early. This generally results in shorter plants and will allow for earlier harvest under warmer, drier conditions;
2. Combine flax on hot, dry days. This will make it easier to chop and spread since cellulose-based fibres lose strength as they get drier;
3. Use a rotary combine with high rotor speed and tight concave settings. This will make it easier to chop and spread because the turbine is doing more of the work in breaking up the straw. Seed damage may be a concern under these operating conditions;
4. Buy and use after-market straw choppers that may be more effective for a given amount of engine power. This will make it easier to chop and spread the straw and easier to seed into the flax stubble next spring;
5. Use new hammers and sharp blades in an existing chopper and/or use one configured for 'fine cutting". This will also make it easier to chop and spread the straw and make it easier to seed into the flax stubble next spring.

Market News

Flax allows for a variety of marketing choices at any time of the year.

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Enhancing Possible Income from Flax Straw

Aside from the above conditions and methods, the other major way to deal with "the straw problem" is to find ways to use and/or sell the straw. There are several possible approaches to enhance possible income from flax straw. One approach is to try and find buyers for the flax straw that presently comes out of a combine. Such buyers are not plentiful and generally do not pay very much, but they do exist. The following list may help growers find local outlets for their straw.

1. Animal bedding–especially for dry cows living outside during winter;
2. Cattle feed–has the feeding value of slough hay so it is really only as a reserve feed when better feed sources are hard to get;
3. Duck nesting sites–Ducks Unlimited and some local hunting groups buy flax bales and pull them on the ice of shallow sloughs during winter. In spring the bales partially sink, but still provide safe little island nesting sites;
4. Linings for drainage ditches and road embankments–i.e., local governments often buy flax bales to limit the eroding forces of fast running spring melt water, heavy rains and/or wave action from large sloughs that come up to and/or over the edge of roads;
5. Ground firming–feedlots and oil well drilling companies sometimes buy flax straw and have it spread to firm up muddy alleyways and well drilling sites;
6. Shelter belt mulch–loose straw can be shredded and blown over young shelter belt trees to conserve soil moisture and reduce weed growth;
7. Straw bale buildings–non-traditional builders of houses, shops, garages, etc. often use small square flax bales for wall construction;
8. Wind breaks and shelters–round bales are stacked on end, with or without a narrow space between, to cut the wind for cattle and/or to hold back snow from roads or yards;
9. Bale burners–some people have built burners that can use large round bales to heat water that is then piped underground to heat homes, barns, shops, greenhouses and other buildings;
10. Golf course green covers–some golf courses buy and shred bales of flax straw over their greens to protect from winter kill;
11. Nursery plant insulation -some nurseries cover their perennials or tipped over container trees with a thick layer of flax straw in the fall to protect plants from cold air temperatures. In the spring, the straw is taken off and container trees are tipped upright again;
12. Insulation–some greenhouse and trailer home owners put small flax bales on the ground next to their buildings to reduce heat losses over the winter; and
13. Garden and orchard pathways -some owners spread flax straw in their pathways so staff and customers do not have to walk on muddy ground during rainy weather.

The second approach to possibly getting income from flax straw is to work with existing or potential processors to find ways to improve the quantity and/or quality of flax straw and/or of the fibre in the straw. The following are some conditions and practices that should help achieve this:

1. Warm weather with adequate rainfall from shooting to maturation stages;
2. Moderate levels of nitrogen fertilizer and balance of other nutrients needed for a realistic target yield based on soil test recommendations;
3. Do not use a desiccant unless deliberating trying to produce immature fibre with thinner, more flexible and usually higher value fibres;
4. Higher seeding rates combined with a narrower space between rows (tends to produce finer stems with higher fibre content. This also results in better weed competition and faster retting);
5. Practice good weed control including consideration of a soil residual herbicide like Authority®;
6. Use a fungicide like Headline® to reduce plant stress from pasmo and/or to prevent premature senescence. This increases the duration of fibre formation;
7. Combine flax on days when heat and/or dryness are not excessive;
8. Use a conventional or rotary combine with cylinder or rotor speeds and concave settings at the minimum settings required for good threshing;
9. Consult with potential end users to see if straw length and retting is important and/or valuable to them.

In some cases, processors will accept straw that has dropped out of the back of a combine but has not been through a chopper. In some situations, where straw is relatively tall, the end user may want the grower to use a stripper header or to straight cut as high as possible, to preserve the length of the straw and minimize the amount of straw going through the combine. The straw chopper would be still be used to chop and spread seed boll stalks and chaff. The standing straw would then be cut down at ground level in a way that leaves a thin even layer of straw covering the surface of the field. This could then be left to ret (by late fall or early spring). The retted straw would then be raked into rows and baled.

In some locations, tall straw left standing over winter will "weather" enough by spring that it will take on attributes similar to retted straw, however, the actual amount and type of weathering that takes place varies considerably with the type and duration of weather events that occur in a given winter (i.e., how much snow, how many freezing and thawing cycles, etc.)

The value of such straw to the farmer could vary from $20/tonne to $80/tonne, depending on the quality and quantity of the straw, processor end products and the proximity to the processing plant. Yields of straw could vary from 0.75 tonnes to 5.0 tonnes/ha (0.3 to 2.0 tonnes/acre) depending on growing season weather, agronomic practices, harvesting and post-harvest methods.

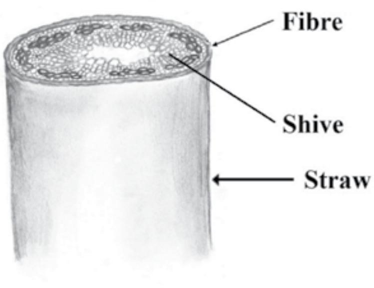

Figure 12-1–Cross-section of a flax stem about 8" above ground

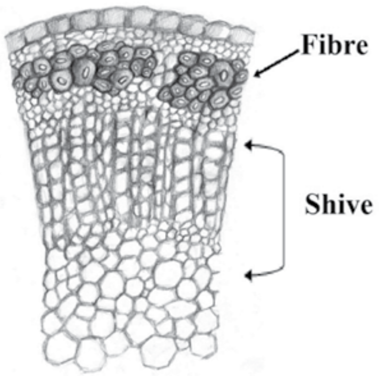

Figure 12-2–Stem cross-section showing position of fibre bundles

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Potential Future Developments

ALTERNATIVE AND NEW USES

Several developments are changing flax straw from a "burning issue" into a "growing opportunity." It is even feasible that, in the future, some growers will grow fibre flax (i.e., linen flax) instead of oilseed flax and receive the majority of their income from straw and not from seed. However, management and technical requirements will have to develop to optimize fibre value. Planting and processing costs will also have to significantly decrease if higher net incomes from flax straw are to be realized and if rural communities want more value-added processing of flax straw. The following paragraphs describe these opportunities, going from lowest value to highest value.

WHOLE FLAX STRAW

Bio-fuel–In certain circumstances, it can be profitable for farmers or a large user of fuel (i.e., large barn or greenhouse) to collect their own or neighbors' flax straw or shives and burn it in large scale burners. However, if the bales or shives have to be hauled a significant distance, the transport costs may overtake cost savings of using straw. Similarly, the transport costs for fuel pellets and logs made from flax straw or shives to major user markets (i.e., Europe) may quickly eliminate the profit potential. In addition, in Western Canada, coal and natural gas are alternative fuels, so in most cases, there is little financial incentive for large Western Canadian users of heat to consider burning flax straw or shive.

FLAX FIBRE

Pulp sweetners–The addition of extra strong fibre into a pulp mix is referred to as a "pulp sweetener." Since flax fibres are considerably stronger and longer than virgin wood fibres, a smaller amount of flax fibre can be used to replace virgin wood fibre used to strengthen recycled paper in pulp. This increases the percentage of recycled paper that can be used in the pulp. As recycled paper and tree-free paper become more popular, the use of flax fibre as a pulp sweetener is expected to increase.

Geotextiles and ground stabilization–Increasingly, road, railroad, mining operations and building sites require a mesh of fibre to reduce dust and erosion produced during construction and on-going operations. A mesh of fibre can be blown on (i.e., hydro mulching) or rolled out in a thick blanket-like material, called a geotextile. The use of flax fibres for geotextiles and ground stabilization is expected to increase, especially in areas where the end user is situated relatively close to flax-growing regions.

Insulation–In Western Europe, there are more than six companies producing flax-based insulation to compete with fibreglass. In Europe, the demand for flax fibre-based insulation is growing by more than 40% annually. The driving force behind this growing demand is due to:

1. The continued drop in the price premium for flax fibre insulation;
2. It is not itchy like fibreglass insulation;

3. Flax fibre insulation can be easily decomposed when its useful life is over;

4. Fibreglass will end up in a landfill; and

5. Flax fibres would be less harmful than fibreglass if inhaled during handling.

Plastic composites–Many everyday plastic products (i.e., car dash boards, sewer pipes) contain fibreglass to provide strength, reduce weight and/or reduce cost. Researchers have found that, in many plastic composite applications, flax fibres can replace fibreglass. Flax fibres are generally cheaper, lighter in weight, less abrasive and impart more springiness than fibreglass. In addition, flax fibres require less energy to manufacture and are easier to decompose or burn, than fibreglass.

The demand for flax fibres in plastic composites is growing by more than 50% annually in Europe and this trend has now started in North America. The largest users are automotive parts manufacturers, who are being pressured to make cheaper, lighter weight vehicles with lower gas consumption. There is also consumer pressure to use more environmentally friendly materials in the manufacturing process. This trend is spreading to other transport related industries (i.e., buses, trains, trucks, RVs, planes) for similar reasons. Some of this research is being conducted at the Composites Innovation Centre in Winnipeg, Manitoba.

Figure 12-3–3D image of a fibre bundle

Cottonized flax–The demand for cotton worldwide in 2014 was roughly 28 million tonnes and is growing by about 200,000 tonnes annually. Physically, the fibres in stems of flax are actually bundles of tiny fibres called "ultimate fibres". These ultimate fibres are roughly half to one-third the diameter of a human hair and, as such, are similar to the diameter and length of cotton fibres. Flax fibres absorb about 50% more moisture than cotton fibres. Hence, garments made from flax fibres will feel cooler and drier than cotton garments, especially on hot, humid days. Over 90% of the world's spinning and weaving equipment is designed to use fibres with the approximate length and diameter of cotton fibres. Researchers are looking at low cost ways to produce 'cottonized' flax. These methods include the use of specialized carding machines, enzymes, flash hydrolysis (steam explosion), high voltage jolting in water and ultra-sound in water. Breakthroughs have been made in all these methods and costs are rapidly falling to the point where cottonized flax could be blended much more extensively with cotton fibre to produce cooler, cost effective fabrics.

Long line flax for pure linen

Flax fibres have been used for over 5,000 years to produce yarn that can be woven into cloth and garments. The yarn and fabric made from flax fibres are called linen. Only in the last century in North America, has linen also come to mean fabric-based items used on tables and beds. In modern times, the fibres used to produce pure linen yarns are 50 to 100 cm (19.7 to 39.4 in.) in length, are easy to divide into finer fibres, yet are strong enough to be spun and woven without breakage. Such fibres must also be clean of all non-fibre components. These requirements cannot normally be met unless flax straw is retted. In addition to retting, most flax fibre crops are pulled out of the ground with special machines when the plants are still partially green and stems are laid on the ground in thin aligned layers. This allows for a higher yield of long, clean fibres that are finer in diameter and ret faster and more uniformly.

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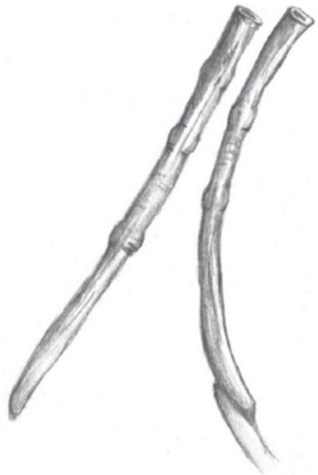

Figure 12-4–Flax ultimate fibres

Traditionally, pure linen yarn was uneven and could only be woven. This produced a fabric that was comfortable and long lasting, but wrinkled easily. In the last decade, spinners have finally found ways to make linen yarn even enough so that it can be knitted. This has allowed the production of linen garments that resist wrinkling. In addition, researchers have developed several chemicals that can be used to treat linen fabrics so they are wrinkle-resistant.

These developments have increased the demand for flax straw used for the production of pure linen yarn. With this opportunity, the net revenues generated by the grower producing fibre flax varieties are much higher than the returns expected when oilseed flax is grown. However, the management and capital requirements are also much higher.

Flax shives

When flax fibres are extracted from flax straw, the non-fibre parts of the stem, not including the seed, are normally referred to as shives. In oilseed flax, shives comprise between 70 to 85% of total straw weight. Thus shives are a major by-product of flax straw processing. Finding profitable end-uses for shives is an important consideration to ensuring the financial viability of a flax straw processing plant. In Europe and Asia, flax shives are often used to make particleboard. In North America, wood particles are generally so cheap that this is not a viable commercial use at this time. Currently, flax shives are often burnt as fuel or used as horticultural mulch. They are also increasingly used as horse, livestock and pet bedding. They can also be ground and used as a filler to reduce the weight and cost of certain plastic items.

Processors' requirements

It is expected that there will be a significant expansion in the size and number of firms processing flax straw on the Prairies. It is likely that at least some processors will pay significantly more for flax straw than what has been paid in the past. Quality standards for straw will be developed so processors can start selling flax fibres into higher value fibre markets. In such markets, flax fibres would compete with glass, cotton and synthetic fibres which have measurable and generally quite consistent properties. If flax fibres are to effectively compete in such markets, growers and processors must be able to produce straw and fibre with consistent quality and easily measured properties.

These properties include but are not limited to the cleanliness, length, fineness, strength and consistency of the fibres. The shives would be inspected for cleanliness, dust content, particle size and consistency. The straw would be evaluated for cleanliness, height, fibre content, degree of retting, average diameter and consistency. Ultimately, both growers and processors must be able to quickly identify straw, fibre and shive samples that are superior; must know how to influence various characteristics; and must receive sufficient financial incentives to produce the characteristics end users demand.

12

FIBRE GROWTH AND DEVELOPMENT

Like all plants, flax goes through sequential stages of growth and development (Chapter 4: Growth and Development). The following stages and timing of these stages are generalizations but will provide insight into various aspects of flax fibre content and quality. In the first 30 days after planting, the seed germinates, starts developing roots and produces a shoot a few inches high. Fibre cells start developing where the first true leaves emerge out of the stem. As such, there are no stem fibres in the stem from 2 to 5 cm (3/4" to 2") above the ground. Fibre cells are modified phloem cells and are found in a layer just beneath the waxy cuticle surface of the stem. When they form, they grow into tiny hollow tubes 3.7 to 5.0 cm (1.5" to 2") long with tapered pinched off ends and look microscopically much like drinking straws with pinched ends. (See Figures 12-1, 12-2, 12-3, and 12-4 for drawings of a flax stem, fibre bundles and ultimate fibres).

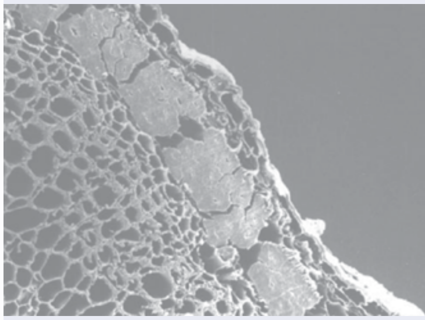

Figure 12-5–Microscopic image of the edge of an unretted flax stem

From 50 to 60 days after planting, the flax plant elongates and daily grows 1 to 3 cm and produces 2 to 4 new leaves. Each leaf is associated with one or more fibre cells. During this stage, the maximum number of fibre cells is determined and the fibre cells are often even finer in diameter than cotton fibre. The stem extension growth stage is followed by the flowering stage which lasts 15–25 days. Once flowering begins, flax plants seldom produce new fibres. When flowering is finished, the plant matures during the next 30 to 40 days and concentric layers of cellulose are deposited inside the hollow fibre cells, in a manner similar to hard water mineral build up inside copper plumbing pipes. These layers of cellulose can make the fibre cells much heavier, more solid and expand their girth as they push into neighboring fibre cells. Then, the flax plant starts drying down and turns from green to yellow to beige.

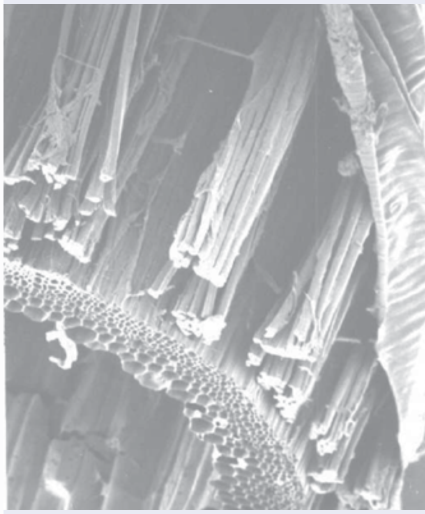

Figure 12-6–Microscopic image of the edge of a retted flax stem

As the flax plant matures, slippery, sticky pectin between the fattening fibre cells dries up and forms glue. This glues groups of fibre cells together to form a “bundle” of fibres which looks like a thread several times thicker than a human hair. To isolate a single “ultimate” fibre from a flax plant the dried up pectin and lignin must be removed. This pectin and lignin holds the fibre bundles to the rest of the plant and/or holds the fibres to one another within the bundle. Over the centuries, the most popular method to achieve fibre separation was to create conditions that allow microbe’s sufficient time to grow on flax straw and dissolve the pectin that is gluing the fibres and fibre bundles together. However, it is important that the microbes are not active for too long as they would start dissolving the cellulose in the fibres and weaken the fibres). This process is called retting (see Figures 12-5 and 12-6) and can be done in fields (field retting) or in water (i.e., water retting, river retting, tank retting, bog retting). After retting an optimal amount, the straw is dried and mechanical or manual methods are used to extract the fibres.

Growing season weather, agronomic practices and plant genetics (varieties) greatly affect the quantity and quality of fibre in a flax plant. Fibre quantity and quality depend on the interaction between genetics and environmental conditions during the life cycle of the flax plant. For instance, after a very dry hot summer on the Prairies, fibre content in standing unretted oilseed flax has been as low as 5%. Conversely after moist warm summers, fibre content in oilseed flax has been as high as 27%. For most years, oilseed flax straw has fibre contents between 15 to 25%.

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