Mountain States Oilseeds

FARMING FOR THE 21ST CENTURY

Growing FLAX

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Growing Flax

Flax Council of Canada

The Flax Council of Canada, established in 1986, is governed by a Board of Directors comprised of various representatives of the flax industry, including producers, exporters, manufacturers and grain companies. With this broad representation, the Council identifies opportunities and challenges for Canadian flax and flax products and acts as a catalyst for action. The Council's mandate is to develop and support markets that will lead to increased Canadian flax production and exports of flax and flax products. The Council initiates marketing, communications and research programs.

Saskatchewan Flax Development Commission

The Saskatchewan Flax Development Commission, established in May 1996, represents Saskatchewan's 15,000 plus flax producers. A check-off system (mandatory but refundable) enables the Commission to support research, communication and market facilitation activities to promote and enhance production and value-added processing of flax in the province. The Commission works in partnership with the flax industry and allied agricultural organizations to ensure quality flax and flax products worldwide.

Introduction

Flax

Flax belongs to the genus Linum, one of 10 genera in the family Linaceae. The genus contains more than 100 annual and perennial species. Cultivated flax belongs to the species, L. usitatissimum, and its varieties are of two types: one is grown for oil and the other for fibre.

In Canada, at present, oilseed flax is the main commercially produced crop. Yet, there is a growing trend back to natural fibres for both industrial applications and textiles. This trend will only continue as pressures increase to produce materials that are recyclable or decomposable. As a result, Western Canadian businesses are realizing the value of flax straw, and are developing technologies to handle oilseed straw and produce fibre from it for industrial purposes. The extraction and processing of fibre from existing flax straw residue and the dedicated planting of fibre flax will create new production and value-adding opportunities for Western Canadian flax producers.

Solin

Using advanced crop breeding techniques, researchers have developed from flax a new oilseed – solin. Solin oil contains less than 5% linolenic acid compared to more than 50% in flax oil, producing a light oil suitable for cooking. Canadian Grain Commission Standards specify that solin varieties have a yellow seedcoat.

Flax and Solin

Flax and solin are grown using the same agronomic practices. Any recommendations in the manual referring to flax will also apply to solin, unless otherwise stated

Crop Rotation

Flax is predominantly a stubble-sown crop in Manitoba. It is also increasing as a stubble crop in Alberta and Saskatchewan where currently more than 50% is grown on stubble. A broad spectrum of herbicides is available to control both broadleaf and grassy weeds, including volunteer cereals.

Following Canola or Mustard

Research in Saskatchewan has shown that flax sometimes does poorly after canola or mustard. This is due to toxic compounds in mature canola and mustard plants and their seedling residues. However, research in Manitoba has shown that flax yields on canola stubble were generally not affected, although small reductions occurred in some years. The problem is most evident where straw and trash from the previous canola crop have not been adequately spread on the soil surface. Canola straw should, therefore, be spread uniformly, and spring volunteer seedlings should be controlled at an early stage in order to minimize possible toxic effects. Seeding into untilled canola stubble can also minimize the problem.

The poorer performance of flax on canola stubble can also be attributed to mycorrhizae fungi which do not associate as strongly with canola roots as with flax roots. When flax is grown on canola stubble, the mycorrhizae populations tend to be lower. Mycorrhizae fungi, in their relationships to roots, will increase and improve nutrient uptake, especially phosphorus, a relatively immobile nutrient in the soil.

Following Other Crops

Flax does well after cereals or corn. It also does well after legume crops, but Rhizoctonia disease may be a problem. Flax does not do well after potatoes or sugar beets as the soil may be too loose and Rhizoctonia disease could also be a problem.

Flax does very well on alfalfa breaking as was observed by alfalfa producers in north-east Saskatchewan. Recent work at the Melfort Research Farm has demonstrated that flax will perform well on spring wheat and field pea stubble relative to canola stubble (see Table 1). Seeding flax on flax stubble will yield similar to flax on canola stubble. Seeding canola on flax stubble is preferable to flax on canola stubble.

Crop rotation of at least three years

between flax crops is recommended for controlling various soil-borne or stubble-borne diseases of flax (see Chapter 8 for the specific flax diseases).

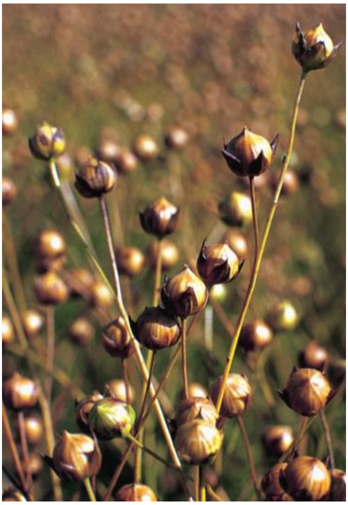

TABLE 1	
The effects of preceding crop on the yield of flax at Melfort, Saskatchewan for the period 1994-1997	
Preceding Crop	**Yield Index (% of spring wheat)**
Spring wheat	100
Canola	88
Field pea	103

From: A.M.Johnnston

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OTHER CROPS FOLLOWING FLAX

Information from Manitoba and Saskatchewan has shown that crops like spring wheat will yield well on flax stubble (see Table 2).

Soil Zones

Brown and Dark Brown Soil Zones

Flax is adapted to Brown and Dark Brown soils of the Prairies. With adequate weed control, the major factor influencing the yield of flax in a rotation for the Brown and Dark Brown soil zones is the availability of moisture. Because of its shallow rooting character, flax extracts 95% or more of its water from the top 71 cm (28 in.) of soil.

It appears that flax yields better on medium to heavy textured and fertile soils.
Although lack of moisture limits yields, it also allows for a high carry-over of nutrients. Therefore, it is important to fertilize according to soil test results in order to get optimum returns from the addition of fertilizer.

Flax leaves little residue on the land, thus increasing the risk of wind erosion if the land is summer-fallowed after a flax crop. Ideally, flax should be followed by a cereal in the rotation.

Black and Dark Grey/Grey Soil Zones

Flax fits into a rotation easily in the Black and Dark Grey/Grey soil zones across the Prairies, providing producers with an alternative to cereals and canola. Crop sequence studies at Melfort, Saskatchewan, have shown that flax produced higher yields on wheat and barley stubble than it did on canola, flax or oat stubble. Here, moisture is less of a yield-limiting factor than in the Brown and Dark Brown soil zones.

At Indian Head, Saskatchewan, wheat following flax showed no reduction in yield, therefore, making wheat the most acceptable crop to follow flax. Barley also performed well on flax stubble.

Seed and Seeding Practices

Flax usually does well on types of land suitable for wheat. It grows best on soils with high water-holding capacity and good inherent fertility. However, one disadvantage of heavy soils is their tendency to crust after heavy rains and interfere with the emergence of the seedlings. The use of zero tillage can greatly alleviate this problem. Flax does not thrive on sandy soils unless a large supply of moisture is available. Imperfectly drained soils may result in yellowing and stunting of flax. However, flax will usually outgrow this yellowing.

Poorly drained land, or land subject to excessive drought or erosion should not be sown to flax. Flax is moderately tolerant to salinity, provided that fertility levels are suitable and adequate moisture is available during germination.

Choice of Seed

Use good, preferably certified, seed of a recommended variety (see Photo 1). Certified seed is tested to ensure minimal weed content, genetic purity and good germination. Certified seed consistently yields better than cleaned seed and produces a higher net return from the crop. If farm-produced seed is used, it should be thoroughly cleaned to remove weed seeds and only sound kernels retained.

TABLE 2

The effects of preceding crops on the yield of spring wheat for the period 1982-1993 in Manitoba.

Preceding Crop	Yield Index (% of spring wheat)
Flax	116
Field pea	111
Spring wheat	100
Canola	108

From: From: Bourgeois and Entz. 1996. Can. J. Plant Sci. 76:457-459.

Seed Quality and Effect on Plant Stands

Reductions in stand must be expected when using untreated, damaged seed. Damaged seed is prone to decay by soil micro-organisms, and the seedlings that do emerge are weak and prone to develop seedling blight. Resulting stands will be poor, uneven, low yielding and lacking in vigour.

Seedlings produced from damaged seed may germinate very slowly and may be weak, or show a variety of abnormalities. Common abnormalities include 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.

Damaged Seed (See Photos 2 – 6)

Cracked, split or blighted seed is very common in samples of flax, regardless of where the crop has been produced. While cracked, split, or blighted seed generally occur together in the same sample, the amount of each varies with weather conditions and farm practices.

Cracked seed

Seed that may appear sound and whole to the naked eye may, in reality, be cracked when viewed under magnification (see Photo 2). Cracks, however small, provide entry for penetration and infection by soil micro-organisms. The amount of cracking varies with year and location and may range from a low percentage to as much as 50% or higher.

The seedcoat of flax is fragile, and cracked seed is the result of mechanical damage when flax is threshed at too high a cylinder speed, or when the seed is too dry. Large-seeded varieties are more prone to cracking than small-seeded ones.

1. Sound Seed

2. Cracked Seed

Split seed

Split seed refers to the condition when the two halves of the seedcoat have become separated at the small end with resultant exposure of the embryo (see Photo 3). Splits develop while the seed in the boll is still immature. This abnormality is more prevalent in varieties with a yellow seedcoat (e.g. solin varieties).

As in cracked seed, split seed is prone to attack by micro-organisms. Splits may be observed with the unaided eye, but the extent of the injury is evident only from inspection under magnification.

3-Split Seed

Blighted seed

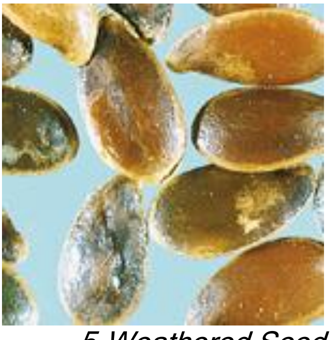
Blighted seed may be weathered and discoloured, or may be shrivelled (see Photo 4). Weathered seed often has a grey, dull cast, and may turn black, while the seedcoat often has a rough texture due to adherence of boll tissue (see Photo 5). Weathered seeds tend to adhere to each other in the boll, making threshing difficult at normal cylinder speeds.

Shrivelled seed results from diseases such as rust, pasmo, Fusarium wilt, or stem break and browning, which cause premature ripening. Shrivelled seed is often mouldy due to colonization by various saprophytic fungi.

4-Blighted & moldy Seed

Frozen seed

Black discoloration may be due to infection by species of Alternaria, or to freezing of immature seed. Frozen seed appears shiny black, as opposed to dull black for blighted seed (see Photo 6).



5-Weathered Seed

6-Frozen Seed

Seedbed Preparation

Conventional tillage

Flax must be seeded into moist, firm soil. Seedbed preparation begins in the previous season on either summerfallowed or cropped land. For summerfallow operations, the intent should be to control weeds and preserve the trash cover. For stubble land, the straw from the previous crop should be chopped when threshing, and straw and chaff spread uniformly.

Fall tillage

In certain areas where fall tillage is used, the land should be worked in such a way as to minimize soil drifting and provide effective snow trapping. If winter annual weeds, such as stinkweed, flixweed or shepherd's purse are present, they should be controlled with late fall or early spring applications of 2,4-D or MCPA at low rates.

7-Lodging

Spring tillage

Spring tillage before seeding, whether on summer fallow or on stubble land, should be shallow in order to maintain a firm seedbed, conserve moisture, and avoid bringing weed seeds up into surface soil where they may germinate. If deep tillage is necessary, packing before or after seeding may be required. Sow the flax soon after the land is worked, before the soil dries out and before weed seeds have a chance to germinate.

Minimum and zero tillage

Good post-emergent herbicides have made zero tillage viable for flax. Minimum and zero tillage practices are attractive because they provide protection from erosion, increase soil organic matter and improve moisture retention. In addition, they reduce crusting problems and sun scald, consequently improving stands of flax. Specialized seeding equipment, developed in recent years, is available for these practices.

Research at Indian Head, Saskatchewan has shown that flax is well adapted to minimum and zero tillage. In this study, minimum tillage was defined as one pre-seeding tillage operation just prior to seeding while conventional tillage involved one fall and one spring pre-seeding tillage operation. Over the 12 years of the study, flax grown with either zero or minimum tillage out-yielded conventional tillage by 13%. Water use efficiency was also greater with zero and minimum tillage, i.e. more flax seed was produced per unit of water used, even after taking into consideration that zero and minimum tillage will conserve more moisture.

Method of Seeding

Flax should be sown shallow, 2.5 to 4.0 cm (1 to 1.5 in.) deep, with a drill that places the seed at a uniform depth in rows 15 to 20 cm (6 to 8 in.) apart. Recent research has shown that up to 30 cm (12 in.) row spacing in zero tillage is acceptable. Depth of seeding trials at the University of Alberta have shown that seeding depths greater than 3 cm (1.2 in.) result in significant reductions to emergence and yield.

The most satisfactory results are achieved by using a drill equipped with press wheels which firm the soil around the seed. If a drill does not have press wheels, a soil packer may be drawn behind the drill, or the field may be packed in a separate operation.

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, has not been clearly defined. Studies at the University of Alberta have shown that deeper tillage results in poorer stand development but because this practice often leads to extensive tillering, there are not necessarily yield losses. The same effect was noticed with both pre-seeding packing and post-seeding packing. As a general rule, pre-seeding packing was beneficial even to land that also had post-seeding packing.

Dry land conditions

Seeds that are placed at a uniform shallow depth in firm, moist soil will germinate and emerge evenly and rapidly. Under dry soil conditions, it may be necessary to seed deeper than 4 cm (1.5 in.) in order to place the seeds in moist soil. However, deep seeding should be avoided whenever possible as emergence will be delayed, resulting in weak seedlings and reduced stands. Weak seedlings are more prone to injury from preplant incorporated herbicides. Furthermore, deep seeding increases the risk of a poor stand if heavy rain occurs before seedlings emerge and the soil crusts. Flax seedlings are less able to force their way through surface crusts than wheat seedlings. Harrowing, therefore, is occasionally necessary to facilitate emergence of seedlings.

Irrigated soil conditions

If irrigation is practiced and the soil is moist, broadcasting the seed followed by a shallow 3 to 4 cm (1.2 to 1.5 in.) cultivation and packing has been as successful as normal drilling or air seeding.

Rate of Seeding

In general, the seeding rate should be adjusted according to size of seed, germination percentage, soil fertility, or weediness. In tests conducted in Saskatchewan and Manitoba, flax showed little yield response to changes in seeding rate from 25 to 55 kg/ha (22 to 49 lb./ac.). A seeding rate of 30 to 45 kg/ha (27 to 40 lb./ac.) is recommended.

Higher seeding rates may be required for varieties with a yellow seedcoat (e.g. solin varieties), particularly if seed treatment is not applied. Excessively high seeding rates should be avoided where lodging may be a problem (see Photo 7).

On land under irrigation, seeding rates as high as 50 kg/ha (45 lb./ac.) can be used. However, if conditions for establishment are good, 33.6 to 39.2 kg/ha (30 to 35 lb./ac.) is adequate if weeds are controlled.

With irrigation, plant populations of 300 seedlings/m2 (30/ft.2) are adequate for optimum yield. It is extremely important to choose a variety that has a high level of resistance to lodging, since high soil moisture and fertility generally increase the potential for lodging.

Plant Stand

A seeding rate of 30 to 45 kg/ha (27 to 40 lb./ac.) results in approximately 500 to 800 seeds/m2 (50 to 80 seeds/ft.2). A seedling emergence rate of 50 to 60% is usually attained under

farm conditions.

According to Manitoba Crop Insurance, yields are not significantly affected by reduction in plant stands from 400 to 300 plants/m2 (40 to 30/ft.2), but yields generally tend to drop off as stands drop below 300 plants/m2 (30/ft.2). However, even at plant stands as low as 100 plants/m2 (10/ft.2), yields were reduced only about 20%, as extensive tillering compensated for the lower stands.

Reseeding

If seedling stands are thin, a decision must be made whether to reseed or not. Flax seedling emergence is sometimes poor due to damaged seed, soil crusting, seedling diseases, adverse weather conditions, deep seeding, herbicide injury, or other reasons. Generally, yields are lower the later the seeding date, and lower because of loss of soil moisture from additional tillage. The added costs of **reseeding must also be taken into** account.

Seeding Date

Early seeding

Early seeding of flax generally produces the best results, for flax is seldom damaged by light spring frosts. Plants just emerging are the most tender, but can withstand temperatures down to approximately -3°C (27°F). After the seedlings have passed the two-leaf stage and are hardened by exposure, they can withstand temperatures as low as -8°C (18°F) for a short time without damage. Unlike cereals, where the growing point of the seedling is protected under the soil surface, the growing point of the flax seedling is fully exposed above the ground and is more vulnerable to frost.

Moderate temperatures and ample soil moisture during flowering and seed development favour high yield, high oil content and high oil quality. Such conditions are more likely to occur with early seeding. As well, seeding in mid-May generally results in somewhat less lodging. High quality straw for fibre is also more likely to be obtained when flax is seeded early.

Late seeding

Late seeding of flax often results in much lower yields. Tests in Manitoba showed that compared to early seeding in May, a delay of seeding to June 1, June 10 and June 20 resulted in respective yield reductions of 7%, 29% and 52%. Late seeding also reduces oil content and seed size. Because green stems and second growth are more prevalent in a late-seeded crop, harvesting is more difficult. However, a delay in seeding of flax may be necessary if herbicides are not used to control early starting weeds such as wild oats, or when drought or excessive moisture have delayed field work. When seeding is delayed until after June 1, only early maturing varieties are recommended because of the risk of fall frosts. Flax varieties differ in their performance under conditions of late seeding.

Water Use and Irrigation

Flax is an excellent crop for irrigated crop rotation since it is not prone to Sclerotinia stem rot which affects canola, sunflower, peas, and beans. The major effect of irrigation on flax is to promote a second or third flush of flowers and to maintain adequate moisture for plant growth until all flowers have developed seeds.

In non-restricting soils (medium-textured soils that are amenable to lots of moisture), flax develops a short, branched taproot, encompassing a rooting zone of 1 m (39 in.). Root development is nearly completed by the flowering stage. On irrigated land, flax takes approximately 70% of its water requirement from the top half of the root zone.

Over the growing season, crop water use may be as high as 41 cm (16 in.). During the seedling stage, water use will range from 1 to 3 mm/day (0.04 to 0.12 in./day), rising to a high of 7 mm/day (0.28 in./day) during the flowering stage. The critical water requirement period for flax is from flowering to just prior to seed ripening. Therefore, to maximize yield and oil content, adequate soil moisture must be maintained during that period.

Monitoring moisture use by soil moisture sensors, crop water use models, or direct measurement of crop use, is important if adequate soil moisture is to be maintained. However, the last irrigation of flax should be completed by the second week in August to ensure that the seeds ripen. Extending the last irrigation past this time will encourage continued growth in the crop, increasing the potential for frost damage and a delayed harvest. It may be necessary to irrigate in the spring for the crop to germinate. Unless soils are very heavy, a light irrigation of 15 to 20 mm (0.6 to 0.8 in.) prior to seeding is preferred to irrigation after seeding which can cause crusting and cooling of the soil.

Fertilizer Practices

Soil tests and experience should guide fertilizer practices. Nutrient levels in the soil vary greatly among regions, with soil types, cropping history and fertilizer use. Provincial fertilizer bulletins should be referred to for general recommendations regarding fertilizer requirements, rates and placement. It is generally believed that relative to other crops, flax will not perform as well on low fertility soils, even when adequate amounts of inorganic fertilizers are used.

Placement Methods

Seed-placed fertilizer

Flax is very sensitive to seed-placed fertilizer with even low rates sometimes causing seedling injury. Some provinces recommend a low rate of phosphate- not more than 20 kg/ha (18 lb./ac.) of P2O5 - may be seed-placed, while others recommend that no fertilizer be placed with the seed of flax. Considerable research evidence has now shown that placement of phosphate 25 mm (1 in.) to the side and 25 mm (1 in.) below the seed is an effective method to improve phosphorus nutrition in the flax plant. Nitrogen (N) should not be placed directly with the seed.

As discussed in the next section, with the advent of direct seeding using a one-pass seeding and fertilizing system, recent work has shown that adding nitrogen to the phosphorus when placed to the side and below the seed does not change the benefits of that phosphorus placement.

Other placement methods

Pre-plant deep-banding of phosphorus (P), which is often a good placement method for other crops, is not effective for flax. Broadcasting and incorporation of P fertilizer for flax is relatively ineffective, with up to a fourfold increase in application rates required to achieve the same yield result as sideband placement. The performance of P placed with the seed in the wider bands behind hoe-type row openers is being evaluated.

With the rapid conversion to direct seeding, other placement methods are becoming commonplace. As a rule, with direct seeding, all the nutrients are applied during the seeding operation. With egards to nitrogen management, the practice of mid-row banding and side-banding is commonplace. The question of interest is whether or not adding all the nutrients, i.e. N-P-K-S together in a single band can have a negative effect on the response of those individual nutrients. 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.

Nitrogen

Flax often responds well to nitrogen (N) fertilizer application when available soil N is low. For flax seeded on stubble, 35 to 80 kg/ha (31 to 71 lb./ac.) of N should be applied unless more specific information, such as a valid soil test, indicates otherwise.

Select a rate from within the suggested range based on moisture conditions. Use the lower end of the recommended range when soil moisture is low and yield is expected to be limited by drought. Use the higher end of the recommended range when soil moisture is to be maintained near optimum. For flax seeded on fallowed land, the response to N fertilization is generally lower. The relative effectiveness of the various N sources, forms, placements and application times is the same for flax as for other annual crops. N should not be placed directly with the seed.

Phosphorus

Response of flax to phosphorus (P) fertilizers is less pronounced or consistent than for most other annual crops. The flax plant appears to prefer high soil P levels from P fertilization of preceding crops, as compared to the application of a high rate of P on the flax crop itself. Rates of up to approximately 35 kg/ha (31 lb./ac.) of P2O5 are recommended for flax on soils with low levels of available P, as long as the fertilizer is not placed with the seed.

Potassium and Sulphur

Deficiencies of potassium (K) and sulphur (S) can limit production of all crops. However, these deficiencies are much more limited in extent than those of N and P, and are usually associated with specific soil types.

Sandier soils of the Dark Grey/Grey soil zones, as well as organic soils, are most frequently deficient in K. Sulphur deficiency is slightly more extensive, and can occur on sandy to loam soils of the Black through Grey soil zones. On irrigated land there is normally enough sulphur in the irrigation water to meet crop requirements. Approximately 34 kg/ha (30 lb./ac.) of sulphur is added to the soil with each 30 cm (12 in.) of irrigation water.

Iron and Zinc

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

If a micro-nutrient deficiency is suspected, it should be confirmed through plant tissue testing. Following confirmation, measurement of response through small trial application should be undertaken before moving to full field scale application. Confirmation of a micro-nutrient deficiency is essential because research work has shown that applying micro-nutrients can depress flax yields if the nutrients were not truly deficient.

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 and available moisture. Flax is self-pollinating, but from 0.3 to 2% outcrossing may occur 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 (see Photos 8 and 9). Water stress, high temperature and disease can shorten any of these growth periods. Although there is a period of intense flowering, a small number of flowers may continue to appear right up to maturity. During the ripening process, under high soil moisture and fertility, stems may remain green and new growth may occur leading to a second period of intense flowering.

Growth Stages

There are 12 distinct growth stages (GS) in the development of a flax plant (see Fig. 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.

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 soil nitrogen is high.

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.).

Flowering

Flower opening begins shortly after sunrise on clear, warm days and petals are shed in the early afternoon. The flower parts, (petals, sepals and anthers) all occur in units of five (Fig. 2).

Flax varieties may be distinguished by the colour of the flower parts which can range from a dark to a very light blue, white or pale pink. The anthers are a shade of blue or are yellow. The style and filaments that bear the anthers are blue or colourless.

Ripening

The mature fruit of the flax plant is a 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. 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.

When ripe, the bolls of Canadian varieties are slightly gaping (Fig. 4), that is, the boll opens at the apex and the five segments separate slightly along the margin. The bolls rarely open so far as to allow the seeds to fall out.

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. Seed of different varieties ranges in colour from light to dark reddish brown or yellow. Mottled seed, a combination of yellow and brown on the same seed, is the result of external, environmental conditions and is not an inherited characteristic.

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 results in a reduced grade.

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8. Growth stage 5 - stem extension

9. Growth stage 6 - buds visible, and 7-first flowering

Weed Control

Weeds can be a serious problem in flax if left uncontrolled. Because flax does not shade the ground as much as cereal grains, weeds have an excellent chance to develop. Some weeds like wild buckwheat and red root pigweed are luxury users of nitrogen and will rob the flax crop of needed soil nutrients. Weeds not only compete with the growing flax crops to reduce yields, but also cause losses from dockage in seed shipments. Dockage amounts to thousands of tonnes annually and is charged directly against marketing costs.

Benefits of Early Treatment

Early removal of weeds is necessary to minimize crop losses caused by weed competition. Weeds in the seedling stage are more easily controlled by herbicides than at any other growth stage, and early treatment usually decreases the risk of injury to the flax crop. Risk of injury is also reduced by using correct water volumes, usually 110 l/ha (10 gal./ac.). The performance of many herbicides can also be affected by soil moisture conditions, air and soil temperatures, and other environmental factors.

Registered Herbicides

Many herbicides are available for the control of weeds in flax. Herbicides approved for flax are not necessarily approved for solin. As of 2001, only a limited number of herbicides are registered for use on solin. Additional herbicides are currently being evaluated for possible future registration. Contact your local agricultural representative or chemical company agent for information.

Herbicide Application Periods

There are three different herbicide application periods for the control of weeds in flax.

Pre-emergent

Pre-emergent herbicides include pre-plant soil-incorporated herbicides, and herbicides applied to weeds that emerge before the crop.

Post-emergent

Spring post-emergent herbicides (see provincial weed control guide for recommended product brands) are most effective when the weeds are in the seedling stage. These herbicides are applied after the weeds have emerged and the flax seedlings are 2 to 12 cm (1 to 5 in.) tall. Check the growth stages of both the crop and the 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.

Pre-harvest

Formulations of glyphosate registered (see provincial weed control guide for recommended product brands) for pre-harvest are applied when the flax is ripe, to control perennial weeds before the weed stems are cut when harvesting.

Weed Resistance to Herbicides

When choosing a product for weed control, records from previous years must be checked to ensure that the same herbicide (or members of the same herbicide group) is not used year after year on the same field. Frequent use of a herbicide group may lead to the development of resistance to that group of herbicides by a weed species.

Control of Volunteer Flax in Field Crops

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

There is no herbicide that will provide sufficient control, or even suppression, of volunteer flax in broadleaf crops. However, quinclorac herbicide provides excellent control of volunteer flax in wheat. Quinclorac provides control of cleavers and a new mode of action for green foxtail control. Products or mixtures that contain dichlorprop (see provincial weed control guide 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 have slightly more effect on the flax than 2,4-D amine or MCPA.

Because of the poor level of control likely to be achieved with herbicides, cultural practices are important in minimizing problems caused by volunteer flax. A competitive cereal crop managed for maximum competitiveness (early, shallow seeding; adequate, banded fertilizer; maximum seeding rate for the area) and treated with one of the herbicides mentioned above, should maximize the level of suppression.

Herbicide listings

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 local agricultural representative or weed supervisor.

Always read and follow label instructions carefully when using herbicides.

Field Insect Pests

Flax may be infested from the time of emergence to maturity by various insect pests. To keep damage low, fields should be examined regularly, and controls applied when infestations reach the economic threshold. The following species are potentially damaging but often occur in too low a number to cause economic loss.

Pests of Flax Only

Flax bollworm

Flax bollworm, Heliothis ononis (Denis & Schiffermiller), is a climbing cutworm. Flax is the only crop it attacks. The moths deposit their eggs in the open flowers, and the young larvae eat the developing seed within the boll (see Photo 10).

11. Flax bollworm (outside boll)

The older green and white striped worms leave the boll and complete development by feeding on other bolls from the outside (see Photo *11). Economic infestations of this* pest have been limited so far to west central Saskatchewan.

10. Flax bollworm (within boll)

Pests of Flax and Other Crops

Grasshoppers

Grasshoppers are a hazard to flax. Young grasshoppers may attack young plants and cause damage. However, more damage is done to the crop before harvest by the older, larger grasshoppers. They can quickly cause large numbers of bolls to drop by chewing through the more succulent portions of the stem below the bolls.

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Cutworms

Two subterranean species of cutworms, the redbacked, Euxoa ochrogaster (Guen.), the pale western, Agrotis orthogonia (Morr.), and the early cutworm, Euxoa tristicula, attack flax (see Photos 12 and 13).

12. Red-backed cutworm

The adult moths of these species lay eggs on the soil surface in weedy summerfallow fields during late summer. These eggs overwinter and the young larvae feed on flax seedlings in the spring. Cutworms usually remain below ground, cut off the young plants near the soil surface and draw them down where they are eaten. An average population of 12 redbacked cutworms/m2 (10/yd.2) can cause a 10% reduction in the yield of flax, and control should be considered.

Army cutworm

Larvae of the army cutworm, Chorizagrotis auxiliaris (Grote), damage flax and many other crops by feeding on foliage in the spring, and to a lesser degree, in the fall. It is an important pest in southern Alberta and, to a lesser extent, in southern Saskatchewan. Populations of 10 or more larvae/m2 (9/yd.2) can cause significant damage.

13. Early cutworm

Bertha armyworm

The bertha armyworm, Mamestra configurata (Walker), was a regular pest of flax before canola and mustard were grown on the Prairies (see Photo 14). However, since the widespread introduction of the Brassica crops, the 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, the flax can then suffer significant damage from invading larvae. When abundant, bertha armyworms cause serious damage by chewing through the stems below the bolls causing them to drop to the ground. Young bertha larvae are green but larger larvae are usually velvet-black.

14. Bertha armyworm

Beet webworm

The beet webworm, Loxostege sticticalis (Linnaeus), is a slim, active, dark-green caterpillar which eats leaves, flowers and patches of bark from flax stems and branches (see Photos 15 and 16). Localized areas can suffer severe damage.

Determine if a significant number of bolls are being damaged before applying control.

15. Beet webworm moth

16. Beet webworm caterpillar

Aphid

One species of aphid, Macrosiphum euphorbiae (Thomas), commonly occurs in flax and can significantly reduce yields (see Photo 17). Aphids fly into fields early in July, and reach peak densities in late July or early August. This pest uses its mouthparts to pierce and extract sap from stems and leaves. 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. At least 25 plants in different parts of the field should be checked for aphids to determine if the economic thresholds are exceeded. If no action is taken when aphids exceed the thresholds, 5-25% or more of the yield may be lost.

17. Aphids

Aster leafhopper/Tarnished plant bug

The aster leafhopper, Macrosteles quadrilineatus (Fbs.), and the tarnished plant bug, Lygus lineolaris (Palisot de Beauvois), can also damage flax (see Photo 18). These insects, like aphids, feed by sucking juices from the flax plants. Leafhoppers can carry aster yellows mycoplasm and also crinkle virus, and can infect the plants with these diseases while feeding. Tarnished plant bugs damage flax by feeding on the growing tips, which become distorted and die back. The damage from these insects is most serious on late-seeded crops.

18. Tarnished plant bug

Minor Pests of Flax

Climbing cutworm

A climbing cutworm, Polia lilacina (Harv.) has been widely distributed in flax fields in Saskatchewan and Alberta but apparently has not caused significant damage.

Zebra caterpillar

The zebra caterpillar, Ceramica picta (Harr.), is another species which feeds on flax as well as many other crop plants (see Photo 19). This is not normally a significant pest.

19. Zebra caterpillar

Wireworms

Wireworms, although often serious pests of cereal grains in the seedling stage, seldom damage flax (see Photo 20).

20. Wireworms

Variegated fritillary

The adults and larvae of the variegated fritillary, Euptoieta claudia (Cram.), have been recorded on flax (see Photos 21 and 22). However, this insect is usually not sufficiently abundant to cause economic damage.

Chemical Control of Insects

Current recommendations for chemical control of insects of field crops are published annually by most provinces. For more information on insects and their damage, and for up-to-date information on control, consult district agriculturists, agricultural representatives or provincial entomologists.

Labels on pesticide containers also provide essential information on application procedures and pesticide safety, and should be followed closely.

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

21. Variegated fritillary - adult

22. Variegated fritillary -larvae

Diseases

Historically, wilt and rust have been the diseases that posed a threat to flax production in Western Canada. Recently, the incidence of pasmo and powdery mildew has been widespread, particularly in Manitoba. They have caused localized disease epidemics. Maintaining the resistance to rust and wilt continue as objectives in developing new varieties. Breeding for resistance to pasmo and powdery mildew is also occurring.

Rust

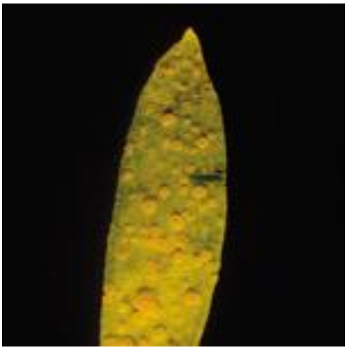
Rust is potentially the most dangerous disease affecting flax. It is a constant threat to flax production because it can survive locally and has the ability to produce new races that attack hitherto resistant varieties.

23. Rust; numerous orange uredia on leaves

The causal organism is Melampsora lini, a fungus that overwinters by means of teliospores on flax debris. Early infections may completely defoliate flax plants and reduce the seed yield and fibre 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

pustules develop on leaves, stems called uredia (see Photo 23). Rust and bolls but mostly on the underside of the leaves (see Photo 24). The pustules produce numerous urediospores which are airborne and cause new cycles of infections during the season. Spread and infections are favoured by high humidity during cool nights, warmer day temperatures, and vigorous plant growth. As the season progresses, the orange pustules turn black and produce overwintering teliospores (see Photo 25). The black pustules are most common on stems



24. Rust; on leaf of flax plant

25. Rust; orange (summerstage) and black (over-wintering stage) on flax boll

Control: Complete control is achieved by the use of rust-resistant varieties. All registered varieties 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 attack resistant varieties.

Additional safeguards include: destroying the plant debris, using certified and disease-free seed of a recommended variety, crop rotation, and planting the new flax crop in a field distant from that of the previous year.

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, and continues growth inside the water-conducting tissue. This interferes with water uptake, and warm weather therefore aggravates the disease. Recommended varieties are resistant/moderately resistant.

26. Fusarium wilt on flax seedings

Symptoms: Seedlings may be killed shortly after emergence while delayed infections cause yellowing and wilting of leaves, followed by browning and death of the plant (see Photos 26 and 27). 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, while the mycelia and spores survive for many years in debris of flax and other organic tissue. Wind-blown and run-off soil may spread the fungus from one field to another.

27. Fusarium wilt; dead (brown) and wilting (yellow) plants

Control: The most important control measure is the use of available resistant/moderately resistant varieties. Crop rotation of at least three years between flax crops maintains low levels of inoculum in the soil.

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 most susceptible to pasmo in the ripening stage. Epidemics, however, can occur early in the season when favourable, moist conditions prevail. Pasmo can cause defoliation, premature ripening and can weaken the infected pedicels resulting in heavy boll-drop by rain and wind. Depending on the earliness and severity of the infection, pasmo reduces the yield as well as the quality of seed and fibre. Most commercial varieties lack resistance to this fungus.

28. Pasmo; circular brown lesions on leaves

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Symptoms: Pasmo is characterized by circular and brown lesions on the leaves and by brown to black infected bands that alternate with green and healthy bands on the stem (see Photos 28 and 29).

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 favour the disease. Lodging favours the development of pasmo, because of increased humidity within the crop canopy, and results in patches of dead plants completely covered with the fungus.

29. Pasmo; alternating green and brown (infected) bands on the stem

Control: The best control is achieved by early seeding at the recommended rates to avoid high moisture conditions in the fall, using clean seed, treating seed with a fungicide, controlling weeds, and following a rotation of at least three years between flax crops.

Stem Break and Browning

Stem break and browning are phases of a disease caused by the seedborne and soilborne fungus Aureobasidium pullulans var. lini, also called Polyspora lini. This disease is of minor importance in Western Canada, however, some damage may occur 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, and the stem may break at this point when the plants are still young, or at a later stage (see Photo 30). Plants may remain alive after stem breakage, but any seed produced may still be lost in harvesting. 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 seedcoats 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 the bolls as well as the seeds, or may produce spores on the seed surface. However, affected seeds may remain viable.

30. Stem break and browning; plants often break at the canker that weakens the stem base

Control: Use of clean 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.

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. Yellow-seeded varieties (e.g. solin varieties) are more prone to cracking which renders them more susceptible to seedling blight and root rot than brown-seeded varieties.

31. Seeding blight

Symptoms: Blighted seedlings turn yellow, wilt and die. Infected seedlings may occur singly or in patches (see Photo 31). 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 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 proper combine settings. Treat the seed with a fungicide. Practice a 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. Provide a firm seedbed, and use recommended fertilizer and seeding practices to promote vigorous stands. Sow flax on second-crop land after cereals rather than on summerfallow.

Aster Yellows

The six-spotted leafhopper is the main vector which transmits the mycoplasma-like organism that causes aster yellows in flax, other crops such as canola and sunflower, and in some weeds. The disease occurs annually but commonly only traces occur in Western Canada. However, an epidemic in 1957 caused 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 (see Photo 32). All flower parts including the petals are converted into small, yellowish green leaves (see Photo 33).

Diseased flowers are sterile and produce no seed. The severity of the disease depends on the stage at which plants become infected and the number of insect vectors that carry the organism. The mycoplasma-like organism overwinters in perennial broadleaved weeds and crops, but most infections are carried by leafhoppers that migrate from the United States.

32. Aster yellows in the fields

33. Aster yellows. flowers are sterile

Control: Seed early to avoid the migrating leafhoppers in mid and late season. Seeding early also reduces the incidence and severity of aster yellows and its negative impact on yields.

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, by stunted growth and reduced tillering. Flowering may appear normal but seed production is reduced. Like aster yellows, crinkle is a disease of flax that depends for infection on transmission by the six-spotted leafhopper.

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

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 the yield and quality of seed. Some flax varieties are resistant to this disease.

Symptoms: The symptoms are characterized by a white powdery mass of mycelia that starts as small spots and rapidly spreads to cover the entire leaf surface (see Photos 34 and 35). Heavily infected leaves dry up, wither and die. Early infections may defoliate the flax plant and reduce the yield and quality of seed.

Control: The most economical control is through the use of resistant varieties. Early seeding will reduce the impact of this disease on yield losses by avoiding the early infections and buildup of epidemics.

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 fungicidal treatment. Occasionally, Sclerotinia sclerotiorum causes stem mould, stem shredding and breakage in heavily lodged flax.

34. Powdery mildew

35. Powdery mildew

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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.

37. Chlorosis; basal branching after terminal bud dieback

38. Heat and frost canker; plants have toppled over

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 (see Photos 36 and 37).

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 (see Photo 38). Low spots are more conducive to frost canker.

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36. Leaf chlorosis on flax plants

39. Heat and frost canker; stems at the soil line are girdled

Symptoms: Frost cankers are similar to heat cankers in appearance. Affected plants are girdled at or near the soil line (see Photo 39). 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:

1. incorrect application or application conditions
2. herbicide residues in the soil
3. 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.

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 (see Photo 40).

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 tankmix with other herbicides.

40. Applying herbicide when the daytime temperature was too high, caused this bromoxynil/MCPA injury on flax

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 (see Photo 41). 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.

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.

41. 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.

Harvesting

Flax may be harvested by straight combining or by cutting with a swather and threshing later with a combine. Straight combining is the preferred method if the crop is thoroughly dry and free of weeds. Swathing followed by combining has become popular because this method assures drier seed than with straight combining, particularly if the crop is not uniformly mature or if weeds are present.

Flax is considered to be fully mature when 75% of the bolls have turned brown. After this stage has been reached, the crop may be swathed. If regrowth occurs in the fall, cut the crop when the greatest amount of ripe seed can be obtained. Do not delay the harvest too long because fall rains may cause weathering of the mature seed and frost may cause immature seed to turn black, resulting in a reduction in grade.

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). 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.

Swathing

When swathing, leave a stubble of about 10 to 15 cm (4 to 6 in.) to hold the swath off the ground and facilitate drying. To prevent blowing of the swath by strong winds, flax swaths should be rolled. Swathed flax may be ready to combine after exposure to a few days of dry weather.

The swath may be threshed when the leaves and stems are dry enough and the seeds rattle in the boll, or the seed has dried to the desired moisture level as indicated by a moisture meter. Although seed is considered dry enough for storage at 10% moisture (Canadian Grain Commission, Official Grain Grading Guide, effective August 1990), the crop may be harvested at a higher seed moisture if drying facilities are available. Usually, early-sown flax is easier to thresh than late-sown flax because it has a better chance to mature under drier conditions.

Keep the cutter bars of combines or swathers clean and sharp to ensure a smooth cut and to prevent accumulation of immature flax under the knife. Gumming of the cutting parts can be reduced by frequent application of water or kerosene.

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;
- reduction or elimination of the need for artificial drying.

A desiccant may be applied after 75% of the bolls have turned brown, which is the normal time of swathing. Studies at Morden, Manitoba have shown that yields are reduced if applications are made too early. For instance, swathing or desiccating at the 25 to 50% brown boll stages, reduced yields by an average of about 10% and 5% respectively, due to premature termination of development of some of the seed.

Desiccated flax should be harvested as soon as possible after it is ready, to avoid capsule loss and weathering of the seed. For up-to-date information refer to the latest provincial recommendations, or consult your local agricultural representative.

40. Sample of No. 1 Canada flax seed (magnified)

41. Sample of No.2 Canada flax seed. This seed shows the rime or scabbing which occurs in years with a wet harvest. This condition is not considered damage as long as the seed is otherwise sound.

42. Sample of heated to binburnt flax seed. Dark tan, orange or dark brown pulp is indicative of heat damage. Severely heated seeds are often accompanied by a heated odor.

Threshing

It is important that combine adjustments are correct for threshing flax. The seedcoat of flax is easily broken during threshing, particularly if the cylinder speed is too high and the seed is very dry. Damaged seed has reduced germination. If the seed is to be used for planting, great care in threshing is required. Yellow-seeded varieties are more susceptible to seed damage because of their thinner seedcoat.

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.

Management of Straw

There are several methods of handling flax straw. Recent research has indicated that none of the methods appear to affect the yield of a succeeding crop of wheat. However, if the crop residues are removed by burning or baling, it must be kept in mind that the soil will become more vulnerable to erosion if summerfallow succeeds flax. Therefore, an additional cereal crop following flax is required to rebuild crop residues. Where continuous cropping is practised, rebuilding crop residue becomes less of a concern.

Storage of Seed

The percentage of flax grading Canada #1 is frequently very high, but dockage is often up to 10% (see Photos 40 and 41). Dockage can be reduced by controlling broadleaf weeds as well as grassy weeds – including volunteer cereals. 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.

Heated flax

Stored flax requires more attention than does stored wheat. Freshly harvested seed can maintain a high respiration rate for up to six weeks before becoming dormant. This, coupled with mould growth if the relative humidity of the air in the spaces between the seeds rises above 70%, can lead to heating. Once flax starts heating in a pocket, the heat will spread quickly - possibly throughout the entire bin. For this reason, flax seed should be cooled down after it is put into storage. Flax seed can be safely stored at seed moisture levels of 10% or lower.

Tough flax contains from 10.1 to 13.5% moisture; damp flax is over 13.5% moisture (Canadian Grain Commission, Official Grain Grading Guide, effective August 1990).

Each year some heated flax seed shows up in the delivery system (see Photo 42). A wet harvest or an early fall frost will increase the percentage of heated flax. If aeration equipment is not available, bins of flax seed should be inspected frequently for problem spots until the seed has cooled down. Flax seed has an airflow resistance very similar to Polish-type canola (B. campestris). Periodic checking is necessary to detect the development of hot spots.

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.

Storage insects

Stored flax seed is not troubled by storage insects as frequently as cereal grains. Insects that can occur in stored flax are: 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 carlots of flax. However, it is suspected that this insect feeds on cereal admixtures in the flax.

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.

Solin

The Canadian Grain Commission has established official grade tables for solin which are different from those for flax. It is important that admixtures of canola, mustard and especially flax are avoided during production, storage and transportation of solin. There are three main differences between flax grade tables and solin grade tables: For solin there are:

1. tighter limits on damaged seed
2. more categories for inseparable seed
3. slightly tighter limits for heated seed.

Varieties

Varietal Development In Canada

Three major breeding programs develop flax and solin varieties for Canada. These are the Agriculture and Agri-Food Canada program located at the Morden Research Centre in Morden, Manitoba; the Crop Development Centre program located at the University of Saskatchewan in Saskatoon, Saskatchewan; and the Agricore United program at the Morden Research Centre. Additionally, some seed companies are introducing cultivars from other countries. Disease resistance to rust and wilt has been emphasized by all the programs in order to keep these problems under control. Thus, all registered flax and solin varieties are resistant to rust and must have moderate resistance to fusarium wilt. Since 1973, when the last outbreak of rust occurred, the resistance to flax rust has continued to hold.

All flax varieties registered in Canada are brown-seeded and have high levels of alpha-linolenic fatty acid (ALA). Solin varieties, with less than 5% ALA, produce polyunsaturated edible oil similar to sunflower oil and, in Canada, must have yellow seed. Unregistered yellow-seeded flax varieties, with high levels of alpha-linolenic acid, are grown under contract for use in edible products and for the health food market.

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 at the Central Experimental Farm in Ottawa 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 as a new program was initiated at the Indian Head Experimental Farm and the Winnipeg Cereal Breeding Laboratory, which led to the development of the variety Cree. As well, in Alberta, in the 1960s, a breeding program was conducted at the Fort Vermillion Experimental Farm and

Beaverlodge Research Station, producing the variety Noralta, the predominant variety grown in northern Alberta and Saskatchewan.
The breeding programs were eventually consolidated and moved to Winnipeg in 1960, finally moving to Morden, Manitoba where they still exist. The varieties Dufferin, McGregor, NorLin, NorMan, AC Linora, AC McDuff , AC Emerson, AC Carnduff and AC Lightning have been released by the Morden Research Centre.

The focus of the breeding efforts 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 devoting its attention to the development of new cultivars with increased yield potential, decreased time to maturity, better lodging resistance, chlorosis tolerance, improved disease resistance and improved seed quality by increasing seed oil content and ALA content.

Crop Development Centre Program

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 Crop Development Centre (CDC) initiated a flax breeding program. It has since produced seven cultivars: Vimy, Somme, Flanders, CDC Normandy, CDC Valour, CDC Arras and CDC Bethune. Other varieties produced at the Crop Development Centre include Andro (tissue-culture-derived) and CDC Triffid (first transgenic flax cultivar). Both of these varieties have now been deregistered and are not commercially available.

The breeding program is developing varieties for Western Canadian conditions, with particular emphasis on Saskatchewan. Improved yield potential, earlier maturity, good agronomic performance, disease resistance, quality characteristics, greater seed weight and lodging resistance are some of the breeding objectives. The Crop Development Centre is also developing varieties of solin.

Agricore United

In 1987, a solin breeding program was initiated by

Biotechnica Canada in cooperation with Australia's Commonwealth Scientific & Industrial Research Organisation to develop low ALA flax, subsequently known as solin. In 1990, United Grain Growers Ltd. (UGG) purchased Biotechnica's interest in the program and moved the program from Calgary to the Agriculture and Agri-Food Canada Morden Research Centre and the UGG research and evaluation farm at Rosebank, Manitoba. This breeding program has produced the solin cultivars, LinolaTM 947, 989 and 1084. Overall the program is committed to the development of varieties with superior agronomic performance and disease resistance as well as enhanced quality (value) characteristics. The characteristics of flax and solin varieties currently registered for Canada are described in Tables 3 and 4, respectively. Varietal yield performance is presented in Tables 5 and 6, respectively. For more information on the varieties recommended in a particular area, refer to provincial recommendations, which are published annually.

Uses for Flax

The Canadian commercial flax crop satisfies the diverse needs of a wide group of end users. The flax breeding programs support flax market development by focussing on quality characteristics tailored to particular business and consumer markets.

Industrial Uses

The natural qualities of flax make it a desirable oil and fibre commodity for manufacturers seeking alternative solutions to chemical- and plastic-based products. Thus, flax is exported primarily as raw seed for crushing into linseed oil. From the oil, manufacturers create environmentally friendly products such as linoleum flooring, and also some paints and stains. Similarly, flax straw, in a partially or completely processed form, is used in the manufacture of fine papers and, more recently, for industrial fibre products such as the interior panelling of some cars.

Food Uses

In addition to these industrial uses, new feed and food markets underpin market stability and fuel growth. Seen as a health-promoting ingredient, premium quality flax is rapidly being absorbed into the expanding functional food markets. Functional foods are those food products which have been fortified with a healthful ingredient, or which are promoted because of a healthy ingredient. Flax, with its high alpha-linolenic fatty acid content, ample fibre, and cancer-fighting lignans is a unique functional food. To serve these markets, “super-clean” (judged 99.9% pure) whole seed and packaged milled seed is sold to food manufacturers. The consumer market for whole and milled flax seed, and cold-pressed flax oil is also expanding.

Feed Uses

Flax in animal feeds could be an important contributor to animal performance and health. In the pork and beef industries, flax use in hog rations and cattle feed 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.

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 shovels. 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 the largest new combines have been used to effectively chop and spread flax straw, if the straw was relatively short. The straw has also been used as animal bedding, duck nesting sites, lining for drainage ditches, horticultural mulch or as a fuel source in “bale burners.”

Traditionally, the major commercial users and buyers of prairie flax straw have been two flax straw processing companies based in Winkler, Manitoba, which extract flax fibre for use in the production of specialty papers (i.e., paper for cigarettes, currency, bibles, prayer books, artwork, stock and bond certificates, etc.). In recent

years, a flax straw processing plant was also set up in Canora, Saskatchewan. In addition to extracting flax fibre for use in specialty paper production, this plant produces fibres to replace the fibreglass presently used to make automotive parts like dashboards
and headliners.

Processors look for 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. Processors normally pay $5 to $10 per tonne for the straw, depending on the year and whether or not the straw can be baled in the spring. In addition, the processing plant usually arranges and pays for the baling, transport and storage of the straw.

Depending on the acreage planted and the rainfall, the potential salvageable oilseed flax straw on the Prairies is 500,000 to 1,000,000 tonnes annually. With fibre content ranging from 8 to 40%, this means that the potential pure fibre production from the flax presently grown on the Prairies would be between 100,000 and 250,000 tonnes annually. The three commercial processors mentioned above process from 150,000 to 250,000 tonnes of straw annually. The vast majority of the extracted flax straw is exported and the total value of such flax fibre exports would range from $20 to $30 million annually (i.e., 10 to 15% of the total value of flax seed exports).

Potential Future Developments
Alternative and new uses

Several developments are changing flax straw from being seen as a "problem" into a new "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 the straw and not from the seed. However, management and technical requirements, and planting and processing costs will also increase if higher net incomes from flax straw are to be realized and if rural communities want more value-added processing of flax straw.

Whole flax straw

Bio-fuel - Several companies and individuals are developing large scale burners for flax straw that have automated feeding systems for flax bales. With these systems flax straw becomes physically easier to use as a fuel source for large commercial users of heat like greenhouses, alfalfa dehydration plants, hog barns, potash mines and hospitals.

Flax straw has a per tonne heating value similar to soft coal and thus has a heating value greater than other crop residues. Flax straw is not only cheaper than conventional fuels; it is also a carbon neutral fuel. This means that the flax plant takes carbon from the air during the growing season to produce the straw. When this straw is burnt, carbon, in the form of carbon dioxide, is released into the air, where it can, once again, be used the following year in the production of straw. When conventional fuels are burnt, they release carbon into the air that has been stored for millions of years and hence increase the carbon dioxide content of the present day atmosphere.

Flax fibre

Pulp Sweetners - When paper is recycled, it must be re-pulped before it can be made into paper. Each time paper is recycled, it loses some of its strength. In many applications, paper strength is important and often 20% or more of strong virgin wood fibre must be added to recycled paper pulp to give it the necessary strength. 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 the virgin wood fibre used to strengthen recycled paper pulp. This means that the percentage of recycled paper in the pulp can be increased.

As recycled paper and tree-free paper become more popular, the use of flax fibre as a pulp sweetener is expected to increase.

Geotextiles - Increasingly, road, railroad and building sites require a mesh of fibres to reduce the levels of dust and erosion that are produced during construction. Such geotextiles are especially needed where bare earth is placed into a highly sloped position (e.g., road construction in the mountains, highway overpasses).

In addition, geotextiles are finding increasing use in horticultural applications as mulch and/or a weed barrier. At the present time, it is common to use synthetic fibres (e.g., nylon) and/or coconut fibres for such geotextiles. There is growing pressure to find alternative fibres for use in geotextiles in inland areas where the freight costs for nylon and coconut fibre products are relatively high. Thus, the use of flax fibres for eotextiles can be expected to increase in the future, especially in areas where the end user is situated relatively close to flax-growing regions.

Insulation – When flax fibres are only processed to a limited extent, they remain quite stiff and coarse. When they are more aggressively processed, they can be turned into quite soft, fine fibres. A combination of coarse and fine flax fibres can be blended and processed to produce insulation batts with similar insulating properties to the fibreglass batts now commonly used to insulate walls and ceilings. Cost-effective, environmentally friendly chemical treatments are used to give flax insulation resistance to burning and to rodent and insect infestations. In Western Europe there are more than four companies producing flax-based insulation to compete with fibreglass insulation. These factories are relatively small scale operations and hence have higher production costs than large scale fibreglass insulation factories. In spite of this higher cost, the demand for flax fibre-based insulation is growing by more than 40% annually in Europe. The driving force behind this growing demand is the awareness that flax fibre insulation can be easily decomposed when its useful life is over, whereas fibreglass will end up in a landfill, a situation that many European consumers no longer tolerate.

Plastic Composites - Many everyday plastic products contain fibreglass to give strength, reduce weight and/or reduce cost. When plastic resin is combined with another material, the resultant product is called a plastic composite. Tractor fenders, car dashboards, decking, fencing materials, sewer pipes and septic tanks are but a few examples of products that are being made from plastic composites. Researchers have found that, in many plastic composite applications, flax fibres can be used in place of fibreglass. Flax fibres are generally cheaper, lighter in weight and impart more springiness than fibreglass. In addition, flax fibres take 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. By far the largest users are automotive parts manufacturers who are being pressured to make cheaper and lighter weight vehicles with lower gas consumption and use more environmentally friendly materials in their construction. Fibreglass comes in many grades and prices. At the present time, flax fibre is able to substitute only for lower grade, lower priced fibreglass. This is mainly because the flax straw processors buy is quite inconsistent. It will take time for processors and growers to learn the management techniques needed and make the necessary capital investments to produce more consistent, higher-grade types of flax fibre. As quality improvements take place, an increase in demand, and a corresponding increase in the average price of both the fibre and the straw can be expected.

Cottonized Flax - The demand for cotton worldwide in 2000 was roughly 20 million tonnes and is growing by about 200,000 tonnes annually. Physically, the fibres in the stems of flax are actually bundles of tiny fibres called "ultimate fibres" (see Fig. 5, 6 & 7). These ultimate fibres are roughly 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 and most synthetic fibres are extruded so they can be easily used in the cotton system of textile manufacturing.

Over the years, the above factors have led to the development of mechanical processes which attempt to break down flax fibre bundles into ultimate fibres to produce a flax based fibre that could be spun on the cotton equipment. Such flax is generally referred to as cottonized flax. In the past, the mechanical systems used to produce cottonized flax created large amounts of dust and waste fibres and could only use relatively expensive flax fibres that were properly retted. This led to a final cost of cottonized flax that was considerably higher than cotton. Hence it had only very limited demand in several small markets. However, researchers are looking at alternative ways to produce cottonized flax that minimizes the waste and produces a more consistent, lower cost fibre. These methods include the use of enzymes, flash hydrolysis (steam explosion) and ultra-sound. Breakthroughs have been made in all of these methods and costs are rapidly falling to the point where cottonized flax could compete with cotton fibre. Hence, there is growing potential to build processing plants that can produce cottonized flax. The demand for flax fibre for this end use is large since the cotton market is so huge and cottonized flax garments are more comfortable to wear than pure cotton garments.

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 turned into garments. The yarn and fabric made from flax fibres are called linen (only in the last century has linen also come to mean fabric-based items used on tables and beds). In modern times, the fibres used to produce linen yarns are 50 to 100 cm (19.7 to 39.4 in.) in length and 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 the flax straw is retted.

Retting refers to any of several methods that allow flax straw to be rotted to the point where the fibre can be easily separated from the straw but not to the point where the fibre becomes weak. At the present time in North America, all the commercially grown flax is based on oilseed varieties which have been bred to be short and produce high yields of seed. Under good growing conditions, taller varieties of oilseed flax could be retted and used to make linen. However, private companies and researchers in several areas of North America (including the Canadian Prairies) are now trying to grow and ret fibre flax varieties. These varieties are taller, have a higher fibre content and a lower seed yield than oilseed flax varieties. Traditional linen spinners in several overseas countries have assessed the quality of the fibre produced from these trials and have found the fibre produced to be acceptable for traditional linen spinning.

Traditionally, pure linen yarn was uneven and could only be woven. This produced a fabric that was very comfortable and long lasting but one that wrinkled very easily. However, in the last decade, spinners have finally found ways to make linen yarn even enough so that it can be knitted. This, in turn, has allowed the production of linen garments that do not wrinkle easily. 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 that could be used for the production of pure linen yarn. It will take investment funds, further agronomic research and trained management to develop this market. The net revenues that can be generated by the grower and straw processor by growing fibre flax varieties are much higher than the returns that can be 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 make up from 70 to 85% of the total straw weight and in fibre flax varieties the shives make up from 50 to 75% of the total straw weight. Thus shive is a major by-product of flax straw processing plants. Unfortunately, to date, flax shives have not found many high value end uses. In Europe and Asia, flax shives are often used to make particleboard but wood particles are generally so cheap in North America that this is not a viable commercial use at this time. Flax shives are often burnt as fuel or used as horticultural mulch. They are also increasingly being 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.

On the Prairies many of the flax shives are simply spread back on the farmland from which the flax straw was collected.

Processors' requirements

It is expected that, in the next decade, there will be a significant expansion in the size and number of firms processing flax straw on the Prairies. In the future, it is likely that at least some processors will pay significantly more for flax straw than what they are paying now. Those that pay high prices for straw will only pay a premium for the straw that meets a variety of quality requirements. Such quality standards for straw will be put in place so processors can start selling flax fibres into the higher value fibre markets. In such markets, flax fibres must compete with glass, cotton and synthetic fibres which have measurable and generally quite consistent proper ties. If flax fibres are to effectively compete in such markets, growers and processors must be able to produce consistent straw and fibre with easily measured properties.

STRAW AND FIBRE QUALITY

Research has begun on examining how specific varieties, agronomic practices and harvest methods affect the quantity and quality of both oilseed and fibre flax straw and fibre grown under prairie conditions.

In addition, American and Canadian fibre specialists and industry labs are working with the American Society for Testing and Materials (ASTM) to develop industry accepted methods that will be used throughout North America to test and qualify the characteristics of flax fibre, shives and straw that are important to processors and end users. These methods include rapid measurement systems using near-infrared machines similar to that presently used to test protein in wheat. Characteristics include the cleanliness, length, fineness, strength and consistency of the fibres; the cleanliness, dust content, and particle size and consistency of the shives; and the cleanliness, height, fibre content, degree of retting, average diameter and consistency of the straw. Ultimately, both growers and processors must be able to quickly identify which straw, fibre and shive samples are superior; must know how to influence various characteristics; and must receive sufficient financial incentives to produce the characteristics for which end users will pay.

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TABLE 3

Characteristics of Flax Varieties

Variety (Year of Registration)	Maturity [b]	Height [c]	Resistance to Lodging [d]	Seed Size [e]	Oil Content [f]	Oil Quality: Iodine Value [g]	Oil Quality: ALA Content [h]	Resistance to Wilt [i]	Resistance to Powdery Mildew [i]
CDC Arras (1998)	M	M	G	ML	45.2	188.6	55.8	MR	MS
CDC Bethune (1998)	ML	MT	G	M	45.6	187.6	54.2	MR	MR
AC Carnduff (1996)	ML	MT	G	L	45.3	193.4	57.8	MR	MR
AC Emerson (1994)[a]	M	M	F	ML	44.2	196.5	58.9	R	R
Flanders (1989)	ML	M	FG	SM	45.6	191.0	56.8	MR	MR
AC Lightning (2001)	ML	M	G	L	46.6	189.4	54.6	MR	R
AC Linora (1991)	ML	M	FG	M	44.9	193.2	57.0	R	MS
Linott (1966)	ME	M	F	M	41.8	191.0	na	MR	S
AC McDuff (1993)	L	MT	VG	M	46.7	184.8	55.3	MR	R
McGregor (1981)	L	MT	VG	SM	43.3	190.0	54.3	MR	R
NorLin (1982)	M	M	G	M	42.8	190.0	56.2	MR	MS
NorMan (1984)	M	M	F	M	43.8	184.0	na	MR	S
CDC Normandy (1995)	M	M	FG	M	44.7	192.6	58.0	MR	MS
Somme (1989)	M	M	F	M	42.5	185.1	58.3	MR	S
Taurus (2000)	ML	M	G	M	44.6	183.9	52.4	MR	R
CDC Valour	ME	M	PF	ML	45.0	192.0	57.6	MR	S
Vimy (1986)	M	MT	P	ML	45.7	191.0	57.1	MR	MS
AC Watson (1995)	M	M	G	ML	45.7	195.3	54.6	MR	R

Based on data from Flax Cooperative Tests in Prairie Provinces

- **a** AC Emerson is the only registered variety with chlorosis tolerance.
- **b** E = Early; M = Medium; L = Late
- **c** M = Medium; T = Tall
- **d** VG = Very Good; G = Good; F = Fair; P = Poor
- **e** S = Small; M = Medium; L = Large
- **f** Oil Content: Results are reported as percent, calculated to a moisture-free basis.
- **g** Oil Quality - Iodine: Iodine number is calculated from fatty acid composition.
- **h** Oil Quality - ALA (alpha-linolenic acid): Percent of total fatty acid composition
- **i** S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant

TABLE 4

Characteristics of Solin Varieties

Variety (Year of Registration)	Maturity [b]	Height [c]	Resistance to Lodging [d]	Seed Size [e]	Oil Content [f]	Oil Quality: Iodine Value [g]	Oil Quality: Linoleic Acid Content [h]	Resistance to Wilt [i]	Resistance to Powdery Mildew [i]
Linola™ 947 (1993)	L	MT	G	SM	47.6	144.4	71.5	MR	R
Linola™ 989 (1995)	ML	MT	VG	M	46.2	145.2	72.9	MR	R
Linola™ 1084 (2000)	ML	MT	G	SM	45.4	142.2	71.4	MR	R

Based on data from Solin Cooperative Tests in Prairie Provinces

- **b** E = Early; M = Medium; L = Late
- **c** M = Medium; T = Tall
- **d** VG = Very Good; G = Good; F = Fair; P = Poor
- **e** S = Small; M = Medium; L = Large
- **f** Oil Content: Results are reported as percent, calculated to a moisture-free basis.
- **g** Oil Quality - Iodine: Iodine Value is calculated from fatty acid composition.
- **h** Oil Quality - Linoleic Acid: Percent of total fatty acid composition.
- **i** S = Susceptible; MS = Moderately Susceptible; MR = Moderately Resistant; R = Resistant

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TABLE 5

Yield Performance of Flax Varieties

Variety	Soil Zone[a] Black	Soil Zone[a] Brown & Dark Brown	Late Seeding[b]
NorLin	100	100	100
CDC Arras	105 (22)[c]	105 (23)[c]	99 (12)[c]
CDC Bethune	114 (22)	106 (23)	99 (12)
AC Carnduff	111 (21)	105 (21)	98 (12)
AC Emerson[a]	100 (21)	101 (21)	102 (10)
Flanders	104 (60)	103 (62)	95 (31)
AC Lightning	105 (21)	100 (22)	110 (12)
AC Linora	104 (55)	103 (56)	104 (29)
Linott	92 (27)	85 (29)	106 (16)
AC McDuff	102 (30)	99 (33)	93 (17)
McGregor	103 (54)	99 (55)	88 (26)
NorMan	103 (27)	99 (29)	85 (12)
CDC Normandy	102 (26)	104 (27)	105 (15)
Somme	99 (54)	102 (55)	99 (27)
Taurus	109 (21)	103 (22)	103 (12)
CDC Valour	97 (19)	102 (21)	103 (11)
Vimy	91 (66)	97 (68)	96 (34)
AC Watson	100 (19)	104 (21)	107 (11)

a See Soil Zones of Western Canada, page 8.
b Data from tests sown generally after June 1.
c Number in brackets is the actual number of site years, in Cooperative trials in the Prairie Provinces, 1985 - 2000, available for comparison with the check variety, NorLin. The more site-years used, the more dependable the result. The check NorLin is present in all site-years. Yield of varieties is expressed relative to NorLin in the same number of site years. Since the number of site-years varies with varieties, yield performance of a variety can only be compared to NorLin but not to other varieties.

TABLE 6

Yield Performance of Solin Varieties

Variety	Soil Zone[a] Black	Soil Zone[a] Brown & Dark Brown	Late Seeding[b]
Linola™ 947	100	100	100
Linola™ 989	106 (13)c	105 (14)c	114 (7)c
Linola™ 1084	103 (14)	106 (14)	113 (8)

a See Soil Zones of Western Canada, page 8.
b Data from tests sown generally after June 1.
c Number in brackets is the actual number of site years, in Cooperative trials in the Prairie Provinces, 1985 – 2000, available for comparison with the check variety, Linola 947. The more site-years used, the more dependable the result. The check Linola 947 is present in all site-years. Yield of varieties is expressed relative to Linola 947 in the same number of site-years. Since the number of site-years varies with varieties, yield performance of a variety can only be compared to Linola 947 but not to other varieties.

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Harvest and Combine Tips

(Best internet source of information http://www.flaxcouncil)

When to start Harvest

- Flax harvest should begin when seed moisture is at 8%.
- Under irrigation, we had had the best experience with swathing . Swathing will allow you to harvest approxiamately 2 to 3 weeks early with better quality.
- Dessicants can also be used with good success. Usually 20 days after the application of a dessicant harvest can start.
- Dryland fields usually ripen even and can be harvested on the stump.
-

- Flax is more difficult to harvest than small grains; however, flax does not shatter or lodge as easily. Because of green weeds and uneven ripening, flax is usually windrowed and allowed to dry before combining. It may be combined standing if it is relatively weed free and appears to be uniform in maturity. Flax is ready to harvest when 90 percent of the bolls have turned brown. The seed should be under 9% moisture before combining.

- Flax is usually ripe when the stems turn yellow, the bolls turn brown, and the seed can be easily threshed. In wet summers the stems may remain green and the plants continue to flower long after the early bolls are ripe. Under such conditions flax should be harvested when all but the very late bolls are ripe. It is important to harvest soon after it is mature because weeds usually become a greater problem. If left standing for a long period of time, the seed quality for oil purposes may be seriously reduced.

- Adjust the combine cylinder speed (800–1300 RPM) and cylinder concave clearance (1/16–1/4") to avoid cracking and yet remove all the seed from the bolls. A sharp cutter bar is necessary when combining direct. Adjustment in the cleaning is important to minimize losses. A sieve with an opening of 1/16 to 3/16" is suggested. Careful loss evaluation will aid in refining these adjustments.

- Flax seed over 11% moisture usually cannot be stored safely for extended periods. Top market prices are usually based on 9% moisture. Flax should be left in the windrow to dry until the seed reaches this moisture level. Seed containing large amounts of green weed seed and inert matter should be cleaned before storing.

- If the straw is to be marketed, it should be baled and stacked when thoroughly dry. The straw should be fairly weed free if the highest prices are to be obtained.

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FLAX IRRIGATION GUIDE

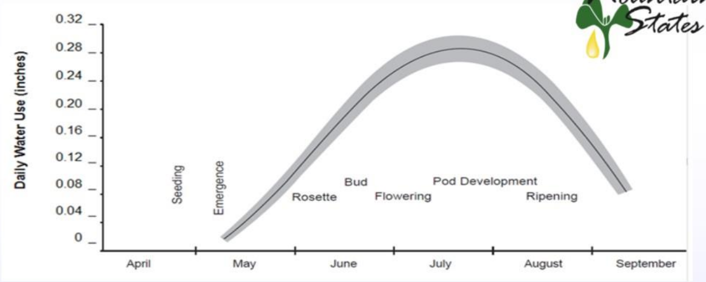
Flax is an excellent crop for irrigated crop rotation since it is not prone to Sclerotinia stem rot which affects canola, sunflower, peas, and beans. The major effect of irrigation on flax is to promote a second or third flush of flowers and to maintain adequate moisture for plant growth until all flowers have developed seeds.

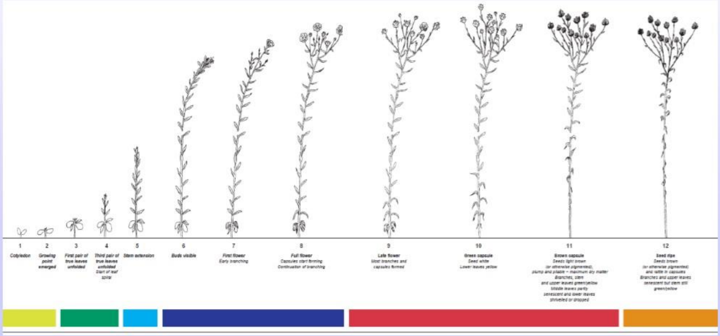
In non-restricting soils (medium-textured soils that are amenable to lots of moisture), flax develops a short, branched taproot, encompassing a rooting zone of 1 m (39 in.). Root development is nearly completed by the flowering stage. On irrigated land, flax takes approximately 70% of its water requirement from the top half of the root zone.

Over the growing season, crop water use may be as high as 41 cm (16 in.). During the seedling stage, water use will range from 1 to 3 mm/day (0.04 to 0.12 in./day), rising to a high of 7 mm/day (0.28 in./day) during the flowering stage. The critical water requirement period for flax is from flowering to just prior to seed ripening. Therefore, to maximize yield and oil content, adequate soil moisture must be maintained during that period.

Monitoring moisture use by soil moisture sensors, crop water use models, or direct measurement of crop use, is important if adequate soil moisture is to be maintained. However, the last irrigation of flax should be completed by the second week in August to ensure that the seeds ripen. Extending the last irrigation past this time will encourage continued growth in the crop, increasing the potential for frost damage and a delayed harvest. It may be necessary to irrigate in the spring for the crop to germinate. Unless soils are very heavy, a light irrigation of 15 to 20 mm (0.6 to 0.8 in.) prior to seeding is preferred to irrigation after seeding which can cause crusting and cooling of the soil.

Mountain States Oilseeds





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Registered Herbicides for flax Production

Bison	.0.9 pt/A	Broadleaf Weeds	Apply when flax is 2-8 inches tall Do not apply during or after bud	Do not apply above 85*F.Apply to susceptible weeds that do not exceed 4 leaf stage or 2 inches in height or 1 inch in diameter.
Bronate	0.9 pt/A	Broadleaf Weeds	Apply when flax is 2-8 inches tall Do not apply during or after bud	Do not apply above 85*F.Apply to susceptible weeds that do not exceed 4 leaf stage or 2 inches In height or 1 inch in diameter.
Buctril	1pt/A	Broadleaf Weeds	Apply when flax is 2-8 inches tall Do not apply during or after bud	Do not apply above 85*F.Apply to susceptible weeds that do not exceed 4 leaf stage or 2 inches
Moxy 2E	1 pt/A	Broadleaf Weeds	Apply when flax is 2-8 inches tall Do not apply during or after bud	Do not apply above 85*F.Apply to susceptible weeds that do not exceed 4 leaf stage or 2 inches In height or 1 inch in diameter.
Poast	0.5-1.5pt/A	Annual Grasses	Prior to bloom. Grass weeds 2-8 inches tall.	Apply with 1 qt/A crop oil to Actively growing grasses.
MCPA	0.25-0.5 pt/A	Broadleaf Weeds	Apply when flax is 2-8 inches tall Do not apply during or after bud.	Use a minimum of 8GPA for Ground rig or 3 GPA for aerial.
TreflanHFP	2-4 pts/A	Broadleaf Weeds Grasses	Fall or Spring incorporation may preformed ibefore planting	Use higher rates on fine texture soils. Incorporate withi9n 24 Hours of application. Keep Spring tillage depth shallower than fall applications.
TreflanTR-10	5-10lbs/A	Broadleaf Weeds Grasses	Apply and incorporate in the in the fall between Oct-15 and Dec 31. Spring application Before planting when soils are Warm enough to germinate seed.	Use higher rates on fine texture soils. Spring incorporation should be shallow.

** When using MCPA, Buctril, Bison, Bronate, and Moxy severe leag burn will happen if temperatures are Above 85*F.

**Trifluralin at 1 to 2 pt/A or 10 to 12 lb 10G/A may be fall applied for foxtail and broadleaf weed control on fields to be planted to flax. Granular formulations may be applied to standing stubble; use liquid or granular formulations when residue will not interfere with incorporation. Seed flax less than 1.5 inches deep into a moist seedbed. Registration for shallow spring application is being pursued. To maximize crop safety, if in-corporated shallow-seed deep, or if incorporated deep-seed shallow.

This bulletin serves as a guideline for production. Conditions may vary in individual fields. Good agronomic practices should always be followed by the grower to ensure the maximum potential. (Best internet source of information http://www.flaxcouncil)

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Flax Production Tips

(Best internet source of information http://www.flaxcouncil)

Adaptation

- *Flax does well after cereals or corn.*
- *Flax yields better on medium to heavy texture fertile soil with high water holding capacity. Soil must be well drained.*
- *Crop rotation of at least three years between flax crops is recommended.*
- *Flax can be grown in medium to high elevations with shorter growing seasons*

Seeding and seeding Practices

- *Use good, preferably certified, seed. Reductions in stand can be expected when using inadequate seed. Poor or uneven emergence result in lower yields and plants that lack vigor.*
- *Flax seed bed must be moist and firm.*
- *If irrigation is present applying seed to the surface of the ground and a harrowing plus water usually results in good emergence. Flax should be sown shallow. Use a disc drill with 6 to 7 inch spacing is preferred. Place the seed 1/2 to 1 inch from the surface in moist ground.*
- *Dryland seeding rate should be 25 to 35 pounds per acre. The higher seeding rates have a better chance for taller plants with better branching and higher yield.*
- *Irrigated seeding rates should be 45 to 60 pounds depending on the quality of seed.*
- *Early seeding generally produces the best results on dryland provided good weed control can be accomplished.*
- *Later seeding with warm soils under irrigation will result in higher yields with uniform emergence.*
- *Emerging plants can withstand 27 degrees F. At the two leaf stage, flax plants can with stand 18 degree F.*

Fertilizer Recommendation Rates

- Flax requires about the same soil fertilization program as small grains. Apply lime to maintain soil pH in the 6.0 to 6.5 range. Follow soil test recommendations for phosphorous and potassium fertilizer applications where soil tests for P and K are low (L) or very low (VL).
- Stands of flax will likely be reduced if combined total rates of N, P_2O_5 and K_2O applied with the seed exceed 20 lbs./acre.
- Under irrigation phosphate is especially important for early and strong root development.
- Nitrogen and sulfur work together and their ratio of 1:1 units applied is a good recommendation.

Weed Control

- *There are both pre-emergence and post emergence chemical available to use. Treflan is the recommended pre-emergence chemical. Bronate is the preferred post emergence chemical. Consult the Mountain States Oilseeds herbicide tips for fine tuning your weed control program.*

This bulletin serves as a guideline for production. Conditions may vary in individual fields. Good agronomic practices should always be followed by the grower to ensure the maximum potential.

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