



Flax

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History

Flax (*Linum usitatissimum* L.) is an ancient crop grown for seed and oil and for the strong fiber produced in its stems. The plant was domesticated approximately 7,000 years ago. The ancient Egyptians produced fabrics from flax including linen, which they used to wrap their dead for embalming.

Flax was introduced to North America by the earliest European settlers and has been produced in the U.S. and Canada since then. It was grown as early as 1617 in Quebec and moved across the continent with settlers in the 1800s. Flax was always one of the first crops settlers planted as they broke prairie sod throughout the upper Midwest, Great Plains, and Canadian Prairies.

Although it was once grown throughout the United States, the majority of domestic oilseed flax is currently produced in the Dakotas and Minnesota, primarily because it is a crop that matures rapidly under cool, short-season growing conditions. Large-scale production of oilseed flax still occurs in the Canadian Prairies.



Oilseed flax in bloom.

Fiber flax has been produced commercially for centuries in northern and eastern Europe, but the highest quality fiber is produced in cool coastal areas. Fiber flax was brought to Oregon in 1843, and the Willamette Valley was a major producer of high-quality flax fiber from the late 1800s until about 1960. Mechanical harvesters and improved processing machinery developed by the USDA in Corvallis in the 1940s ushered in the age of efficient mechanization for fiber flax.

Following World War II, European fiber flax growers rapidly adopted the machinery developed in the United States.

The advent of synthetic fibers in the late 1950s as well as development of easier-to-grow and more profitable crops like grass seed hastened the decline of the Oregon fiber flax industry. Belgium, France (Normandy), and the Netherlands are the primary fiber flax producing countries today.

Description

Flax is an annual herbaceous plant that can be grown as a winter annual in mild climates. Flax plants grow from 12 to 48 inches high. The flowers have five petals and form a five-celled boll that can contain up to 10 seeds. Flowering continues until plant growth stops.

Distinct varieties have been developed for oilseed and fiber flax. Oilseed flax varieties tend to be short, highly branched plants bred to maximize the number of flowers per unit area. Fiber flax varieties are tall, unbranched plants that are grown at very high density to maximize fiber production.

Although flax generally is planted as a spring crop, a few winter-hardy varieties have been developed that allow fall planting in many areas. Winter varieties tend to be intermediate between oilseed and fiber types, and may offer the opportunity to produce high oilseed yields and better quality fiber than traditional oilseed varieties.



Flax flowers.

Uses

Oilseed flax

Currently, oilseed flax is more economically important than fiber flax. Most world flax production is for linseed or flaxseed oil, flaxseed meal, and flax straw. Flax seeds are an excellent source of oil, containing from 40 to 45 percent oil.

The fatty acid profile typically found in linseed oil is shown in Table 1 (page 3). The distinguishing characteristic of linseed oil is the high linolenic acid (18:3) content (> 50%). The fatty acid composition of sunflower is shown for comparison.

Linseed oil was the only class of flaxseed oil until 1990, when low linolenic-acid flax cultivars were developed. Low linolenic-acid flax cultivars are called linola or solin flax.



Table 1. The fatty acid content of linseed, low linolenic acid flaxseed (linola or solin), and sunflower oil.

	16:0 ^a	18:0	18:1	18:2	18:3
Oil source	----- % -----				
Linseed	5.3	3.1	16.2	14.7	59.6
Solin flax	9.5	4.6	15.6	65.3	2.1
Sunflower	6.0	4.0	16.5	72.4	0.0

^a Fatty acid profiles show the percentage of each fatty acid component in a vegetable oil. The first number in the notation at the top of each column in the profile (e.g., 18:3) indicates the number of carbon atoms in the fatty acid. The number after the colon indicates the number of double bonds in the fatty acid. Although fatty acid profiles vary somewhat from sample to sample, they are generally used to characterize vegetable oils from particular species or varieties of plants.

Industrial uses

Because it contains high levels of linolenic acid, linseed oil is highly reactive and oxidatively unstable. As a result, linseed oil goes rancid (oxidizes) more rapidly than most other seed oils. Many of the industrial uses of linseed oil, however, rely on the chemical properties of linolenic acid. Linseed oil is a drying oil, which rapidly changes to a hard, tough, elastic substance when exposed in a thin film to air. It is used in paints, resins, varnishes, printing inks, and linoleum. Linoleum is a mixture of solidified linseed oil mixed with gums and cork dust or wood flour. Although it fell out of favor for many years, linoleum production has increased recently because it is considered a “green” building material.

Historically, the straw residue from oilseed flax was considered a waste product, and most oilseed flax straw is still burned in the field. But, fiber from oilseed flax straw makes strong, high quality paper (U.S. currency, tea bags, bible paper). In Canada, oilseed flax straw is gathered to central locations, processed through a hammer mill to remove most of the woody stem core, and baled for shipment to paper mills.

Recent research has led to renewed interest in industrial uses for flax straw and fiber.

- Flax straw is a carbon-neutral fuel that burns cleanly and has the same heating value as soft coal.
- Because paper fibers lose strength each time they are recycled, adding small amounts of flax fiber to paper pulp greatly increases the strength of recycled paper.
- The automotive and aerospace industries are using flax fiber to replace fiberglass in a wide range of fiber-reinforced composites, due to its high performance and light weight. Flax fiber also takes much less energy to produce than fiberglass and is biodegradable.
- Demand for flax fiber in composites is currently growing by 50 percent per year in Europe, and American manufacturers are investigating industrial uses of flax.



Nutritional uses

Although normally thought of as an industrial oil, linseed oil is a rich source of essential fatty acids and is the richest natural source of linolenic acid, an omega-3 fatty acid that may reduce the risk of heart disease. Increasing interest in healthy lifestyles and diets has created growing markets for both conventional and organically grown flax seed and flaxseed products.

Linola or solin flax oil, due to its low 18:3 content, is more oxidatively stable than linseed oil. The fatty acid composition and chemical, physical, and storage properties of solin oil are close to those of sunflower and other important edible oils.

Flaxseed meal is a good source of dietary protein. Most flaxseed meal is fed to animals. Whole flax seeds are used in cereals, breads, and other baked foods. Flax seed is also an excellent source of soluble and insoluble dietary fiber: the dietary fiber content of flax seeds is 25 percent. Eating foods rich in soluble fibers can reduce blood serum cholesterol.

Fiber flax

Fiber flax cultivars produce long fiber (line fiber, in the trade) and short fiber (tow). Long fiber is spun and woven to produce very high-quality linen fabric. Linen is used to make fine clothing, sheets, tablecloths, and other household goods. Linen yarn is used to make the very finest lace.

Short fiber generally is blended with cotton or wool and spun into yarn to make a wide variety of apparel, upholstery, and carpet fabric. The recent development of wrinkle-free linen/cotton blends has been particularly popular because they feel cool in hot, humid climates and need no ironing.

The by-products of fiber flax processing are shives and seeds. Shives are the woody core of the flax stem separated from the fibers. In Oregon flax mills, shives were burned to heat the water. Since the 1950s, shives have been used to make strong, lightweight particleboard panels in Europe. Shives are also extremely absorbent and can be used as animal bedding or to absorb liquid spills.



Fiber flax stems after high-density planting.

Adaptation

Climate

Oilseed flax is widely adapted to a broad range of soil and environmental conditions. Cool temperatures after flowering tend to increase oil (particularly linolenic acid) content. As a result, flax oil yield and quality are generally better in higher latitudes.



Fiber flax also will grow in many environments; however, cool weather conditions during crop development are essential to produce high-quality fiber. The best quality flax fiber generally comes from temperate regions (near 45° latitude) with a strong coastal climatic influence.

Soil

Flax generally does best on well-drained soils with good water-holding capacity, such as silt-loams and clay loams. Flax does not tolerate poorly drained soils well. Surface crusting on heavy soils can retard germination and interfere with good crop establishment. Do not plant flax on sandy soils unless plenty of moisture is available.

Cultural practices

Most flax varieties are spring planted. Flax is cold-hardy to about 25°F, and frost damage has rarely been a problem with spring seeding.

Because flax will germinate and grow under relatively cool conditions, winter flax can be planted later in the fall than other oilseed crops. In dry fall planting conditions, this may be a significant advantage over crops like canola that are more sensitive to planting date.

Fiber flax typically is sown from mid-February through mid-April in Oregon.

Seedbed preparation

Under conventional tillage, flax should be sown in a firm, moist seedbed. A clean, firm, smooth seedbed is vital for flax production, especially fiber flax.

With the development of effective herbicide programs, direct seeding has become viable for oilseed flax. In Canada, direct seeding improves both yield and water use efficiency in flax production compared to conventional tillage.

Seeding rate

Seeding rates and optimum stand densities for oilseed and fiber flax differ greatly. Oilseed flax typically is planted at a rate of 30 to 40 lb of seed per acre. The optimum stand density for oilseed flax is about 30 plants per square foot.



Flax seed.



Fiber flax seed normally is planted at 100 to 150 lb/acre, depending on seed size and germination rate. The optimum stand densities for fiber flax are 175 to 200 plants per square foot. Fiber flax seeding rates are commonly adjusted to take into account 1,000-seed weight and germination rate of each seed lot.

Seeding depth

Plant flax seed shallow, in the range of ½ to 1½ inches deep.

Row spacing

Use conventional grain drills to plant oilseed flax in rows 6 to 8 inches apart. Use press wheels or some other mechanism to firm the soil over the seed behind the planter.

To increase plant density, plant fiber flax using a unique planter and technique known as underground broadcasting. V-shaped planter shoes are pulled through the soil just below the soil surface while spreader plates randomly distribute the seed underground. The result is bands of uniformly distributed seed placed at uniform depth and at high seed density.

Variety selection

Most oilseed flax varieties that are readily available in the United States were developed at North Dakota State University or in Canada. Performance information for many varieties is available at <http://www.ag.ndsu.edu/pubs/plantsci/smgrains/a1049-10.htm>. Agronomic descriptions of North Dakota State University varieties are available at <http://www.ag.ndsu.nodak.edu/aginfo/seedstock/varieties/VA-FLAX.htm>.

Solin oilseed flax varieties were developed in Canada. They are not currently available in the United States.

Many excellent fiber flax varieties were developed in Oregon in the mid-1900s, but modern European fiber flax varieties have much higher fiber content (approximately 30 percent vs. 15 percent). They also are more disease- and lodging-resistant than earlier varieties.

Fertilizer

Nitrogen

Oilseed flax responds well to moderate nitrogen application. Excess nitrogen application stimulates vegetative growth and increases disease susceptibility and lodging. Eighty pounds of N per acre is the maximum amount normally applied. Most recommendations subtract available



soil-test nitrate-N and N available from previous crops from the base rate of 80 lb N/acre to arrive at an application rate.

Fiber flax has a moderate to low requirement for nitrogen and is prone to lodging at high nitrogen rates. Once lodged, fiber flax is extremely difficult to harvest. Traditional fiber varieties such as ‘Cascade’ were grown with a maximum of 40 lb/acre of available nitrogen. Newer European varieties use 70 to 75 lb/acre of available nitrogen, and growers rarely apply more than 50 lb/acre of nitrogen.

Phosphorus and potassium

Phosphorus and potassium applications are not generally made for flax except in cases of extreme soil deficiency.

Zinc

Flax is sensitive to zinc deficiency, and applications of zinc sulfate are common in Europe. Zinc-deficient plants are chlorotic, and the primary terminal bud may die. Liming prior to planting a flax crop appears to increase problems with zinc deficiency. No zinc deficiency symptoms in fiber flax have been reported in Oregon.

Weed control

Oilseed flax is a relatively poor competitor with weeds, especially when planted on wider row spacing. There is a wide variety of herbicides that can provide effective control of both grass and broadleaf weeds; however, many are registered for use only in Canada.

Although high-density fiber flax is quite competitive, weed control is very important during its early development. Several herbicides currently registered for use on oilseed flax in the U.S. can also be used in fiber flax production. MCPA causes rapid curling to the tips of the flax stems, but the plants will recover within a few days.

Pest management

Diseases

The most serious fungal diseases of flax are Fusarium wilt (*Fusarium oxysporum* f. sp. *lini*), flax rust (*Melampsora lini*), and pasmo (*Septoria linicola*). While these were extremely serious diseases in the past, careful use of crop rotation and the development of varieties resistant to Fusarium and rust have greatly reduced the impact of plant diseases in flax production.

Treat flax seed with fungicides to help control seedling diseases.

Insects

Insect pests are rarely a problem in flax production. The most widely cited insect pests of flax are cutworms, wireworms, aphids, grasshoppers, aster leafhopper, tarnished plant bug, and beet webworm. Most can be



controlled or reduced using cultural practices, insecticides, and crop rotation.

Harvest

Oilseed flax

Modern oilseed flax varieties have very little seed shattering and can be harvested by direct combining or by swathing and field drying before threshing with a combine. Swathing is commonly used in Canada to ensure uniform drying of fields with uneven maturity or weed control problems. To enhance drying when swathing flax, leave 4 to 6 inches of stubble to keep the windrow off the ground. Mature oilseed flax straw is readily cut with a sickle bar; however, immature flax is very difficult to cut and can rapidly dull a sickle bar.

Flax seed moisture must be 10 percent or less before storing seed.

Fiber flax

Fiber flax is harvested by pulling rather than cutting. Specialized machinery uses rubber belts that pull and then lay the crop down in windrows with the stems oriented perpendicular to the swath.

Depending on variety and weather conditions, flax is ready for pulling 85 to 100 days after planting. Pull the crop when about $\frac{2}{3}$ of the leaves have fallen and the stems are $\frac{1}{2}$ to $\frac{2}{3}$ yellowed. At this point, the seeds are still somewhat immature, but fiber quality is highest.

Following pulling, fiber flax must be retted to allow clean separation of the fiber from the stems. Retting is the microbial breakdown of pectins that bind the fiber bundles together within the flax stems, allowing easy mechanical separation of the fibers. Retting requires adequate moisture and temperatures high enough for microbial activity. The key to producing high-quality fiber is to halt the retting process before the continued breakdown of cellulose weakens the fibers.

Most of the fiber flax produced today is field retted. Previously, both European and Oregon flax was retted by submerging flax bundles in tanks of water over several days or weeks. Since World War II, most European production has moved toward field retting to save cost and avoid problems of water pollution.

To do field retting, lay the pulled flax in windrows behind the puller, exposing the flax to dew and rain. Depending on temperature and moisture, retting usually takes 2 to 4 weeks under good conditions. Be sure to turn the windrows to expose both sides to moisture and promote uniform retting. Specialized, self-propelled machines turn flax at about 1.6 acres per hour. You may need to turn windrows two or three times depending on weather conditions.



Bale dry, retted flax straw for storage and processing using modified round balers that insert strands of baling twine between each layer of flax. Round bales allow the windrows to be unrolled into the processing machinery as a continuous ribbon, greatly reducing hand labor.

Moisture content of flax straw should not exceed 16 percent. If flax bales become wet, the retting process will continue, usually degrading fiber quality.

Yield

Dryland spring oilseed flax with adequate moisture can yield 2,000 to 3,000 lb of seed per acre. Winter oilseed flaxseed yield without irrigation usually ranges from 1,800 to 2,400 lb/acre.

Total biomass yield (seed and stems) after field retting of fiber flax averages about 6,000 lb/acre in the Willamette Valley. Approximately 30 percent (2,000 lb/acre) can be extracted as useful fiber, and about 15 percent (900 lb/acre) is seed. The remaining biomass is mostly shives, unrecoverable fiber, and chaff.

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