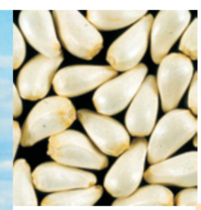
Safflower Production on the Canadian Prairies: revisited in 2004



Agriculture and Agri-Food Canada
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Canada

Safflower Growers Check List

Field Selection: Previous crop not safflower, canola, or mustard.

Weed Control: Trifluralin or Ethalfluralin as ppi; Sethoxydim if needed, for post-emergent annual grass or cereal control.

Seed Bed Preparation: A good firm seed bed is very important for even seed depth and plant emergence.

Seeding Rate: 33.6 to 39.2 kg/ha (30 to 35 lb/ac) on dryland.

Seeding Depth: 1 inch or to moisture. ***CAUTION:*** do not seed too deep.

Harvest: Moisture content below 13%.

Drying: Aeration drying preferred but a grain dryer can be used. If the farmer does not have these facilities available he can combine the crop when it is dry.

Storage: Crop is dry at 9.5%.

Tips for good safflower stand establishment:

- Use high quality seed.
- Treat seed with Thiram® 75% WP, especially if damping-off is likely.
- Seed into warm soil, at least 5°C (41°F).
- Seed between April 20th and May 10th.
- Use a high seeding rate to compensate for seedling losses.
- Seed shallow (1.9 to 3.8 cm; 0.75 to 1.5 inches deep) to encourage quick emergence.
- Seed into a firm moist seedbed.
- Rotate with cereals to avoid disease build-up in the soil.
- Seeding Rates: 32 to 40 kg/ha (30 to 35 lb/ac).

Things to avoid when seeding safflower:

Poor seed quality: Cracked, diseased, sprouted, mouldy, frosted seed may have low viability. Using poor seed increases problems with seed rots, seedling blight and damping off.

Cold wet soil: Cool temperatures delay emergence. High moisture levels in the soil encourage some disease organisms that reduce emergence. Soil puddling increases losses from root rot. Avoid planting in very heavy soil and soil that drains poorly.

Heavy soils: Crusting prevents emergence and/or stresses the emerging seedling. If crusting occurs, light harrowing may break the crust enough to allow the seedlings to emerge.

Deep seeding: Safflower has a large seed, but when seeded too deep, its emergence is poor.

Wireworms and cutworms: These insects can create a considerable amount of damage by chewing and thus destroying germinating seeds and seedlings.

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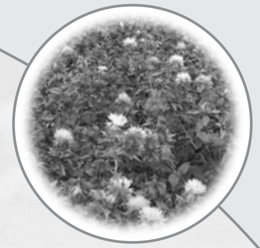

Safflower Production on the **Canadian Prairies: revisited in 2004**

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Canada

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Foreword

The objective of this production guide is to give farmers and extension workers the information they need to make safflower a viable alternate crop in the Canadian Prairies.

While safflower production area has not increased over the past twelve years, some important research directions have resulted in updated information being available and a consideration of new potential production for new potential uses of this crop. These we have incorporated in this 2004 version. Also, we found various errors in our earlier, 1992 version: and corrected these. We trust that this publication will be of value to experienced growers and to those growing the crop for the first time.

While the original intent of the 1992 version was to make it available to Canadian prairie growers and extension personnel, it became apparent, with requests for copies we received from across Canada, USA and beyond, that via the 'Web' it could be made available to anyone interested. As the previous version appeared on our AAFC-website as http://res2.agr.ca/lethbridge/safflo/part1_e.htm in English and as http://res2.agr.ca/lethbridge/safflo/part1_f.htm in French, and is receiving considerable traffic on the 'net', we plan to make this version available in this form, to readers around the world again, replacing the older version with this newer one.

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Introduction

Safflower (*Carthamus tinctorius* L.) is a thistle-like annual plant mainly grown in dry hot climates as an oilseed or birdseed. It has many red, orange or yellow flowers on bushy plants. Flower heads are on the ends of stiff branches, with 15 to 30 seeds developing within each head (Pic. 1). The seed is about the size of plump barley, either white or brownish and white with grey, brown or black stripes. The crop is seeded and harvested with the same equipment as is used for cereal grains.

Safflower was originally grown in the Middle East and south Asia for the red/orange pigment in the flower petals which was used for colouring rice and bread, and for dyeing cloth. After synthetic aniline dyes took over this market in the 1800's the crop was grown as an oilseed.

Traditionally, the oil has mainly been sold in the health food market because it is unsaturated having high linoleic and oleic acid levels. With increased health consciousness in recent years, the oil quality has become a more general health issue to a large sector of our population. At present, India is the major producer of safflower, but there is a small but significant safflower industry developing in other countries.

Safflower in Canada

Prior to 1985, safflower was generally considered a risky crop to grow in Western Canada. Weeds were often a major issue as safflower is a poor competitor early in the season and there were no herbicides available. With the release of Canadian varieties beginning in 1985, and with several pesticide registrations, safflower production is now more dependable.

Safflower production in western Canada has focused on the southern production region in Alberta and Saskatchewan adjacent to the 49th parallel. The recent annual acreage in this area has fluctuated between 810 to 2,025 ha (2,000 to 5,000 acres) per year. Historically, in the early 1990s this area has grown as much as 6,480 ha (16,000 acres) with most of the safflower production of the early 1980s taking place in Manitoba. US varieties were grown, largely on contract. After devastating crops in the mid 1980s, resulting from early fall frost, sclerotinia head rot and alternaria blight, on the highly susceptible and late maturing US varieties, Manitoba acreage dropped to near nil in recent years.

Most Canadian safflower today is marketed on the spot marketplace where price, quality and delivery options are determined at the time of delivery or sale. A good safflower crop should yield 1,650 kg/ha (1,500 lb/ac) (37.5 bu/ac) on dryland and 2,200 kg/ha (2,000 lb/ac) (50 bu/ac) on irrigation. Birdseed markets generally range from 31 to 57 cents per kg (14 to 26 cents per lb) with oil values at a discount to the birdseed market. Oilseed markets will also discount the grower price by the additional freight cost associated with moving this low density product to the oil crushers in the USA.

The birdseed marketplace has evolved over time with more and more of the USA production being dedicated to this premium marketplace as the safflower oil marketplace in Japan as diminished in size.

Varieties

Varieties developed at Agriculture and Agri-Food Canada (AAFC) - Research Centre, Lethbridge:

Saffire (Mündel *et al.,* 1985a) was released in 1985, as an early maturing (Pic. 2, compared to S-208), sclerotinia head rot resistant, white seeded variety. Saffire is the first Canadian safflower variety. The seed colour and size make this a good birdseed variety. Oil content averages 32%, too low for the main oilseed market. Flowers are yellow to deep orange in full bloom, largely depending on environmental factors, turning to deep orange to red on dry-down (Pic. 3).

Varieties *continued*

AC Stirling (Mündel *et al.,* 1992) was released in December 1991, as a dual-purpose birdseed/oilseed variety. AC Stirling averages somewhat higher oil and yield than Saffire, but its maturity averaged five days later than Saffire (Table 1). Sclerotinia resistance is somewhat less than that of Saffire. Flowers are yellow (Pic. 4). This variety was deregistered by 2002 as the oil demands changed and the later maturity made it too risky to grow.

AC Sunset (Mündel *et al.,* 1996) was released in November 1995, with yields slightly more than Saffire (around 5%), with similar early maturity, and oil levels equivalent to those of AC Stirling (Table 1). Sclerotinia head rot resistance is as good as for Saffire. Flower colour is orange to red. The white seed colour and size also make this a desirable birdseed.

Today the oil marketplace focuses on high oil (over 38%) and high oleic acid varieties. None of the Lethbridge-developed varieties can be used for the commercial oilseed market. However, because of their white seed, they remain attractive to the birdseed market.

Safflower germplasm line developed at AAFC-Lethbridge, Research Centre, but not officially registered:

Lesaf 496 is a high oleic safflower germplasm line with oil around 40% and oleic acid around 70%, maturing almost as early as Saffire. This line is also suitable for the birdseed market, having white seed. This germplasm line has shown some promise for transformation, and for being adapted to the southern Canadian prairies.

US varieties - not registered for use in Canada:

S-208 is a US variety, developed in the late 1960s by SeedTech in California. It is generally too late maturing for the Canadian prairies (Table 1) and highly susceptible to sclerotinia head rot. S-208, a linoleic oil variety, has been a dual purpose variety, averaging 37 to 38% oil (in years with late killing fall frost), before the change to high oleic oil varieties. Yield in disease-free environments with late fall frost, is comparable to that of Saffire. Flowers are yellow in full bloom turning orange in post-bloom.

Centennial (Bergman *et al.,* 2001) is a linoleic, high oil US variety, developed at the Eastern Agricultural Research Center, Montana Agricultural Experiment Station, Sidney, MT, USA, in cooperation with the Williston Research Extension Center, North Dakota Agricultural Experiment Station, Williston, ND, USA, released in 1991. It is generally too late maturing for the Canadian prairies, even later than S-208, and highly susceptible to sclerotinia head rot. Yield, in disease-free environments with late fall frost, can be greater than that of Saffire. Flowers are yellow in full bloom turning orange in post-bloom. It has been of interest because of its ability to be transformed.

Specialty uses of unregistered varieties/lines

With commercialization of safflower products arising from transgenic plants, it is expected that some form of contract registration for such materials will be offered to some growers.

Table 1. Comparison of four safflower varieties in Alberta and Saskatchewan for yield, maturity and oil (Safflower Cooperative Registration Test, 1990, 1991, 1994, 1995 and 1996).

Variety	Yield (T/ha)	Days to Maturity (DTM)	DTM Range	Oil (%)
Saffire	2.3	128	122 - 137	30.4
AC Stirling	2.4	133	124 - 140	32.5
AC Sunset	2.4	128	119 - 135	32.4
S-208	1.9	138	128 - 147	33.6
No. of Sites	31	10		18
Years	All	1994, 1996		1994 - 1996

Notes: 1992 and 1993 had early fall frost, affecting all varieties at most locations; thus data from these years are not included.

Utilization

Worldwide, the primary use of safflower is for edible oil, some is used for birdseed, a small amount goes for industrial uses and the meal or whole seed is fed to dairy cattle. Medicinal uses of safflower have been important in countries such as China and India, and have potential in Canada in the future, as do cosmetic uses.

Birdseed

The safflower seed is mainly used for wild birds (Peterson, 1996). It also caters to racing pigeons, parrots, other pet birds, gerbils, hamsters and to commercial small animals such as chinchillas. Normally the birdseed market commands a premium over the oil market. Most Canadian produced safflower is for the birdseed market.

Seed must meet stringent standards to qualify as birdseed.

Sample: Seed must be uniformly snowy white and large (called bold in the trade) (Pic. 5) and free from pappus (bristles at the end of the seed) (Pic. 6). Seed with the brown stripes of some oilseed varieties (Pic. 7) or with mould or staining from disease or wet harvest weather is not acceptable.

Bushel weight: Only well filled seed, at least 47.5 kg/hl (38 lb/bu), is wanted. The average is 50 to 52.5 kg/hl (40 to 42 lb/bu).

Purity: The standard purity is 99%. Wheat or high levels of Russian thistle seeds or any other inseparable admixture mixed in the sample can make safflower very difficult to clean and hard to market.

Edible Oil

A health-conscious population in developed countries has created the most significant market for safflower oil as salad oil, margarine and cooking oil. Safflower is considered a wholesome oil because of its high polyunsaturated fatty acid level. It therefore commands a premium price among edible oils and currently is priced out of the industrial oil market.

The oilseed market demands seed with over 38% oil. Factors that cause premature senescence (death) of the leaves and bracts and shorten the seed-filling period tend to lower oil levels. The Japanese market prefers levels over 40% and has generally purchased safflower from California where oil levels tend to be high. The actual oil content of the de-hulled safflower seed is relatively constant at 59 to 64%.

High oleic safflower varieties have become dominant in the international trade since late 1995. These may contain 75 to 80% oleic acid. This oil is comparable to olive oil, it is stable when heated, and is used primarily as a high-quality frying oil particularly for special snack frying, e.g., potato chips. It is also used in the production of baby formulas and cosmetics. Mono-unsaturates, such as oleic safflower oil, tend to lower blood levels of LDL ('bad' cholesterol) without affecting the HDL ('good' cholesterol) (Smith, 1996). High oleic safflower varieties, which have been developed in the USA, are well situated to take advantage of the market for mono-unsaturated oils such as olive and canola oils as health foods.

A high proportion of the fatty acids in older safflower varieties is linoleic acid. Premiums may be paid in specialty markets for high linoleic acid oil. The cool climate of the Canadian Prairies may be an advantage in producing this type of oil. However, it is a disadvantage that our Canadian safflower varieties have a lower total oil content when produced in this growing area. Safflower oil produced in California, from the typically older, 'linoleic' varieties, is usually about 73% linoleic acid compared to about 78% in Montana and 80% or more in Canada.

Livestock Feed

The full-fat oilseed safflower (at 16-18% protein) or the meal left after oil extraction (at 24% protein) may be used as a livestock feed.

Safflower meal is a high protein by-product remaining after extraction of the oil from safflower seeds. Meal from de-hulled seeds is a high quality protein supplement similar to canola meal, but with slightly more protein and energy. It is suitable for all classes of cattle (Bottger *et al.,* 2002), sheep (Dixon *et al.,* 2003) and swine and poultry (Raj and Kothandaraman, 1981).

Most commercial safflower meal includes hulls. This results in a medium protein (25% CP) meal that is high in fibre content (50% ADF). The fibre content of this meal is too high for most swine and poultry diets (Lennerts 1989).

Hulled safflower meal is comparable to dried brewers' grains as a feed for ruminants, although the fibre is less digestible. Limited information indicates that safflower meal is relatively high in ruminal bypass protein, making it a good alternative protein supplement for lactating dairy cows.

At present, Canadian producers are not likely to have access to safflower meal, but they may be able to use the whole seed in rations.

Full-fat safflower seed has a high fibre content which limits its use in all but special-situation diets for swine and poultry. Whole safflower seeds are, however, a good source of fat for lactating dairy cows (Stegman *et al.,* 1992). The composition of whole safflower is roughly comparable to cottonseed, being slightly higher in fat and lower in protein content. The composition of safflower varies, like any feed, with variety and growing conditions. Feed analyses are important before incorporating safflower into dairy cow diets.

Safflower seed can be rolled, along with barley, when mixing rations, although processing is not necessary for ruminants such as cattle and sheep, as the hull is easily broken during chewing.

An oxidized flavour may develop in the milk if cows are fed more than 2 to 3 kg/day (4.4 to 6.6 lb/day) of high linoleic acid safflower. This flavour can be eliminated by increasing the level of dietary vitamin E.

Safflower Forage

In Canada, safflower would be useful as a forage crop only in situations where the seed could be predicted to be of inferior quality such as after an early frost.

Vegetative safflower has been made into good-quality silage (Weinberg *et al.,* 2002) and could be used as a livestock feed, although seed yield and quality of the seed would be greatly reduced.

Hay from safflower cut after blooming is likely best suited as feed for sheep and goats. Full-bloom safflower hay was superior to alfalfa-grass hay for mature ewes pre-breeding as an increased proportion of safflower-fed ewes subsequently lambed (89.7 vs 80.1%; Stanford *et al.,* 2001). The increased fertility of the ewes is likely related to the use of safflower forage as a treatment for infertility in parts of Asia. Feeding safflower seed does not improve livestock fertility (Bottger *et al.,* 2002). To improve utilization, safflower hay should first be chopped. Mouth irritation due to spines was not observed in sheep, although safflower-fed sheep sorted through their feed and rejected more low-quality high-fibre stem material than did the alfalfa-fed animals.

For cattle, safflower forage should be made into silage unless harvested prior to spine development. Compared to sheep and goats, cattle are more susceptible to mouth ulceration and have less ability to select the most nutritious feed particles.

Once fully mature, safflower has little value as a forage, as all nutritional value is in the seed.

Industrial Oil

Safflower produces a drying oil, intermediate between soybean and linseed oils. Non-yellowing drying paints, alkyd resins in enamels, and caulks and putties are made with safflower oil.

Salinity Control Crop

Safflower can help prevent the spread of dryland salinity. It is a long season crop, so it extracts water from the soil for a longer period than cereal crops. The long taproot can draw moisture from deep in the subsoil. Safflower, with its long season and deep roots, uses surplus water from recharge areas which otherwise would contribute to the development or expansion of saline seeps.

Medicinal and Cosmetic Uses

Global uses

The whole plants, flowers, seeds, and oil have a wide range of medicinal uses in different countries. A 'tea' from safflower foliage is used to prevent abortion and infertility by women in India and Afghanistan (Weiss, 1983). Flowers are used as tonics for a multitude of conditions in China, such as dilation of arteries, reduction of

Utilization *continued*

hypertension, increase of blood flow, thus oxygenation of tissues (Anonymous, 1972). Seed decoctions are used with sugar as laxative in Pakistan, for flushing out urinary tracts in Kashmir, and ground up and mixed with mustard oil, to reduce rheumatic pains in Bangladesh (Knowles, 1965). The oil is used in Iran to treat liver and heart ailments (Knowles, 1965) and in charred state in India to treat sores and rheumatism (Weiss, 1971). Numerous other uses, specially medicinal of different safflower components, are outlined in the book by Li and Mündel (1996).

Genetic modification

The genetic modification (GM) of crop plants for use as protein factories has been pursued for nearly a decade as a potential method of meeting the high volume demands made on the pharmaceutical industry. A Calgary-based company, SemBioSys Genetics Inc., has found safflower to be a very attractive host for the production of high value proteins such as pharmaceuticals and industrial enzymes. SemBioSys genetically transforms safflower tissue so that the proteins of interest will accumulate in the seed of the mature transgenic plant. The patented Stratosome" Biologics System involves the genetic attachment of commercially viable target proteins to oleosin, the primary protein coating the oil-containing vesicles (oilbodies) of the seed (Fig. 1). This attachment allows the target protein to be purified along with the oilbody fraction which floats to the surface of a ground seed/water slurry upon centrifugation (Fig. 2) (van Rooijen *et al.,* 1992). This initial purification step gives the system a favourable process advantage over other transgenic plant systems. In addition to the purification advantage of the Stratosome" Biologics System, the attachment of proteins to the oilbodies of safflower has been shown to stabilize intracellular accumulation of foreign proteins as well as providing a useful attachment matrix and delivery benefits for downstream applications.

The uncontained, outdoor production of so-called molecular farming crops such as SemBioSys' GM safflower offers the potential for economical, huge-scale production of pharmaceuticals and industrials but, understandably, must be regulated for proper material confinement. The Canadian Food Inspection Agency (CFIA) (in Canada) and the United States Department of Agriculture (USDA) (in the USA) have placed a host of restrictions on the numerous crops that are used for molecular farming purposes but many of the features possessed by safflower make it a lower risk production platform. Several inherent agronomic qualities such as a low tendency to weediness, low seed dormancy and the large degree of self-pollination translate into a system that is much easier to confine so that target products don't mingle with food or feed. The role that safflower plays in North American agriculture also lends benefits to its use as a pharmaceutical factory. Safflower is not a major food or feed crop in North America, acreages are relatively low and there are no weedy relatives with which it can cross to produce fertile hybrids. As the tiny molecular farming industry grows in North America, safflower has been receiving increasing attention as a host crop with great appeal.

Cosmetic uses

In addition to the use of GM safflower for molecular farming applications, SemBioSys has discovered the cosmetic allure inherent in the native oilbodies of the safflower seed. An aqueous emulsion of non-transgenic safflower oilbodies forms a milky cream referred to as the DermaSphere" Ingredient System. The system has numerous potential applications in the dermal and personal care industries. Much attention has been paid to this potential as evidenced by a May 2004 license agreement executed by SemBioSys and personal care giant, Lonza, Inc.

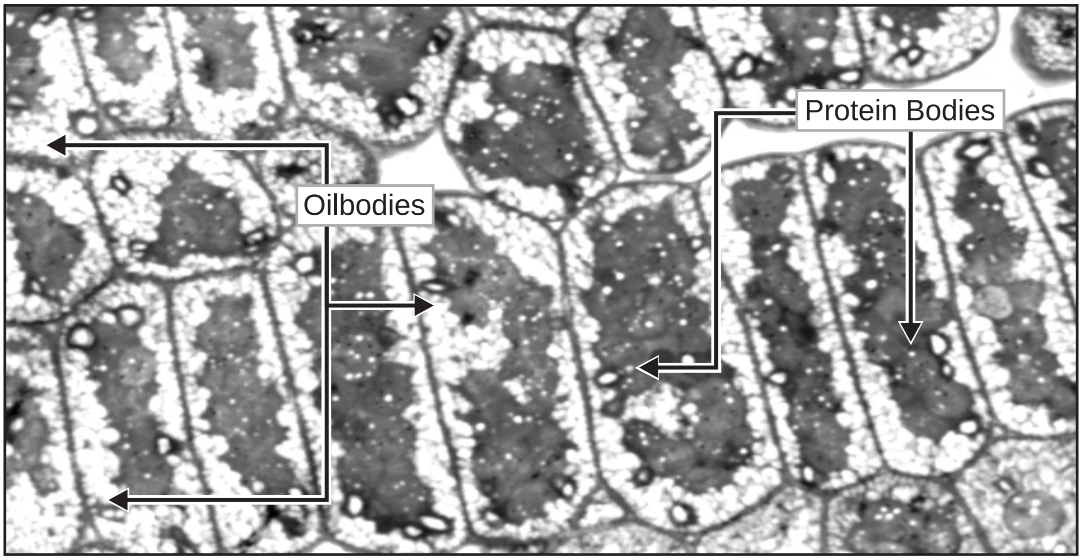


Figure 1. Oilbodies and protein bodies in cells of safflower seed.

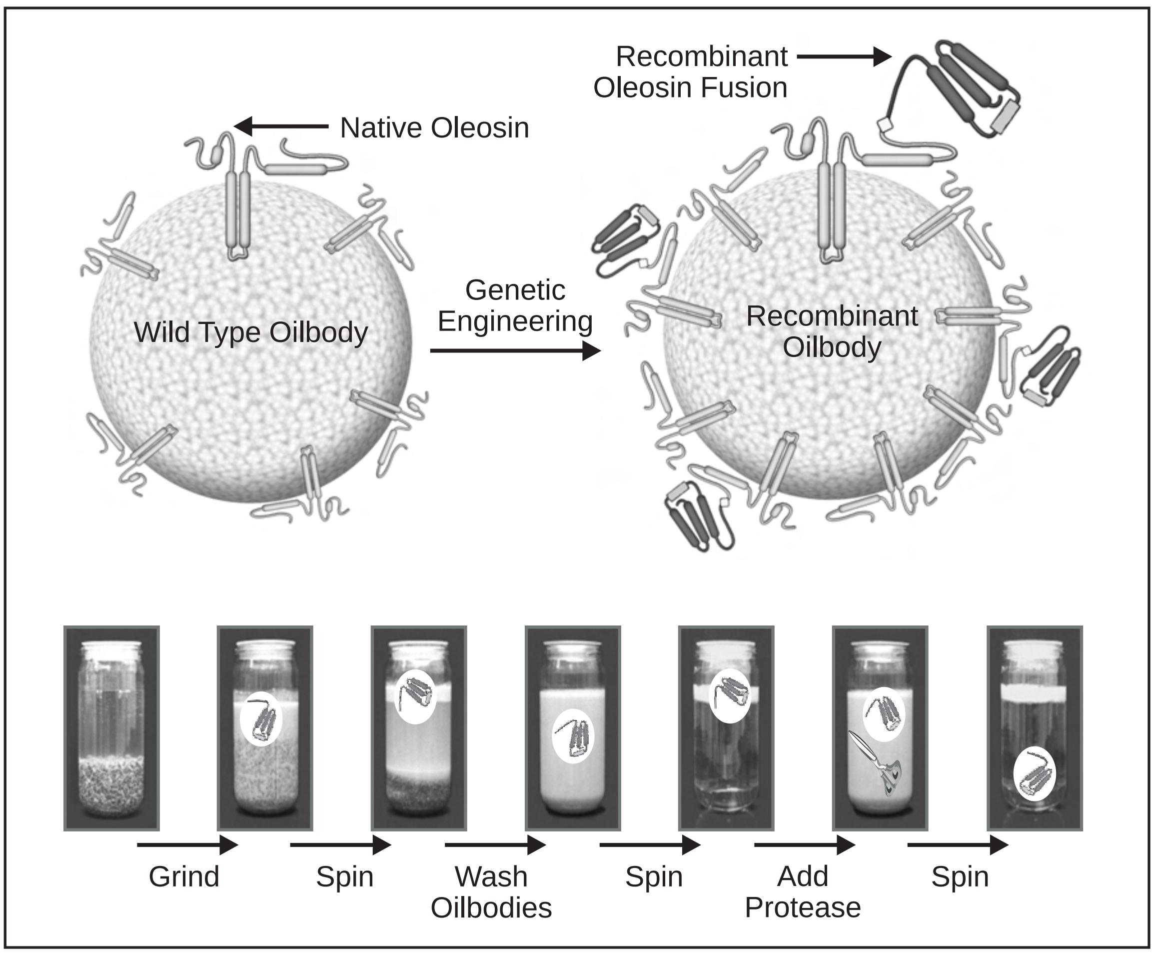


Figure 2. Recombinant oleosin attachment and purification schematic.

Safflower Plant

The glossy, white seed germinates in one to three weeks, depending on soil temperature and moisture. After germination, a slow-growing rosette stage develops and a tap root penetrates deep into the soil. Stems then elongate quickly, forming sturdy branches 45 to 75 cm (18 to 30 inches) high. At the end of each stem is a flower head enclosed by miniature leaves called bracts.

The bloom stage lasts 14 to 21 days, depending on stand density, available moisture and variety. Flowering starts on the central stem and spreads outwards. Each head flowers over several days, with the flower developing from the outside towards the centre.

Developed heads each contain from 15 to 30 or more seeds. The seed matures within 30 to 35 days of flowering. It takes about two more weeks to dry the crop for harvest. Safflower is ready to harvest when most of the leaves have turned brown and only a hint of green remains on the bracts of the latest flowering heads. Mature seeds are white and rub freely from the least mature heads.

Growth stages for assessing the crop (Fig. 3): To make a field estimation of growth stage, look at several areas of the field. Consider only healthy plants. Safflower has potential to compensate for thin stands. However, if emergence is less than 50% consider ploughing up the crop and replanting with safflower, if before mid-May, or a shorter duration broad-leaved crop.

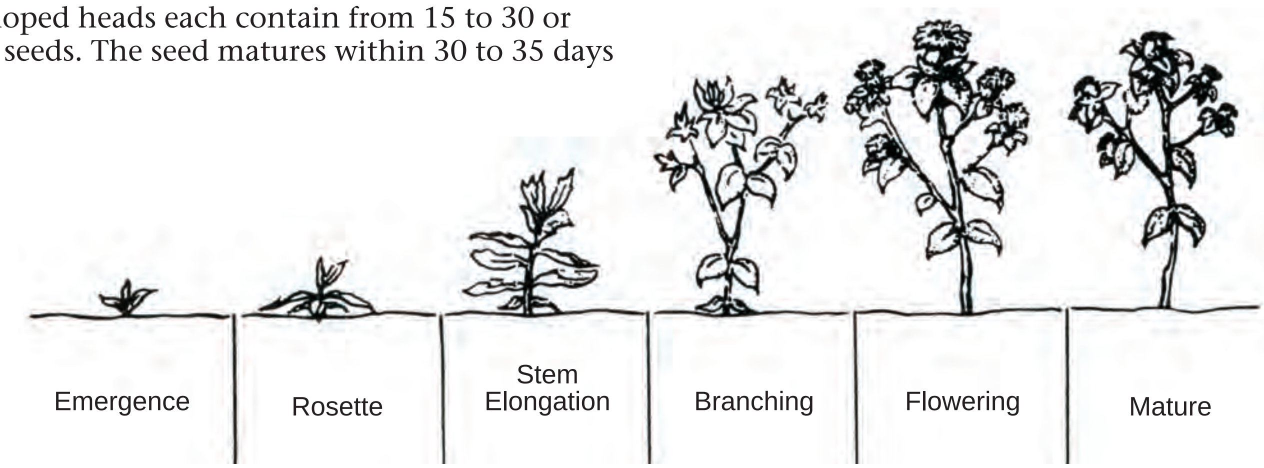


Figure 3. Growth stages of safflower.

Areas of Adaptation

A map of areas of potential adaptation for the current safflower varieties in the Canadian Prairies is shown in Fig. 4. Major soil zones involved in Alberta include the dark brown and brown soil zones (Clayton *et al.,* 1977). In Saskatchewan, the dry brown, dark brown, and moist dark brown soils, as well as the black soils in the south eastern region of the province (from slightly north of Fort Qu'Appelle, east and south to the Manitoba border) (Henry and Harder, 1991) are included. In Manitoba, mainly the black soil zone region with lower cropping-season precipitation, from Brandon south to the Canada/US border and west to Saskatchewan, are included.

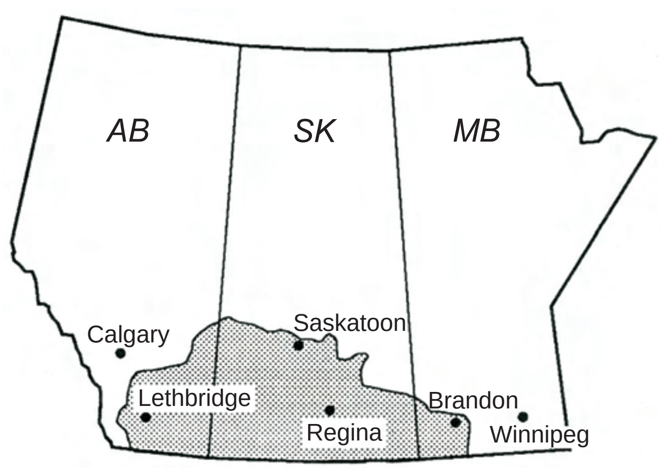


Figure 4. Areas of adaptation for safflower.

Areas of Adaptation *continued*

Other factors to consider include risk of killing fall frost, soil moisture reserves, risk of leaf or head diseases (e.g., Sclerotinia head rot and Botrytis head rot; Alternaria blight) associated with high precipitation and/or humid conditions from flowering onwards.

In general, seed safflower only in areas with a growing season of 127 to 130 days. In these areas, a crop seeded on May 1 should be mature by the end of the first week in September. Production is safest where the average date of the first killing frost (-2°C; 28.4°F) is September 20 or later. This allows two weeks leeway for unusually early frosts or late maturity in wet years. Under irrigation, grow safflower only in the longest season areas since irrigation can delay maturity by 10 to 14 days.

As a general rule of thumb, do not plant safflower in areas where seeding cannot be completed by mid-May.

Production Requirements

Water

Safflower has deep roots that can tap stored subsoil moisture or seepage (Table 2). Therefore, yield depends on accessing deep soil moisture in addition to growing-season rains. Also, safflower is a long season crop, so it can use late-season rainfall. These qualities, rather than true drought tolerance, allow it to produce well in dry areas, and to endure periods of drought.

In areas with few hot, dry winds, and with adequate pre-plant soil moisture, 300 mm (12 inches) of rainfall or irrigation can produce excellent yields. Yields are closely tied to moisture levels, and spring moisture is more valuable than growing season precipitation.

Safflower's ability to convert moisture into grain yield is lower than that of wheat.

In Saskatchewan trials, when moisture and growing season precipitation were good, safflower performed as well or better on stubble as it did on fallow. When soil was dry in the spring and growing season precipitation was below normal, stubble yields were much lower than fallow yields. Oil content was also lower on stubble.

Safflower is intolerant of high moisture. Wet soils reduce emergence, and waterlogging of the soil for even short periods reduces stands and yield, especially if temperatures are high.

High rainfall promotes leaf diseases and head rot. During flowering, prolonged rainfall interferes with pollination and seed-set. Moist conditions during flowering or the kernel-filling period promote Sclerotinia and Alternaria head rots and various leaf disease, which lead to yield reductions, and discoloured seed. Persistent rain at maturity causes seed to germinate in the head.

Both Saffire and AC Sunset lack good resistance to Alternaria leaf spot, a serious and common disease. Discolouration of the seed due to Alternaria results in downgrading for the birdseed market.

Table 2. Relative rooting depth and soil water use by various dryland crops (Montana, 1976-78).

Crop	Rooting Depth (m)	Soil Water Use (% of Safflower)
Safflower	2.0 - 2.4	100
Brown Mustard	1.8	88
Sunflower	2.0	82
Winter Wheat	1.8	81
Barley	1.5	77
Turnip Rape	1.7	68
Flax	1.7	67

Production Requirements *continued*

Temperature and Frost-free Period

Safflower is tolerant of low temperatures as a seedling, during the rosette stage, prior to stem elongation. At flowering, it is susceptible to extremely high temperatures, which can sterilize the pollen, and it is susceptible to frost during kernel filling.

In the rosette stage, the growing point is protected so most varieties can stand temperatures as low as -7°C (20°F). The first few leaves emerging after a frost may show injury, but the plant recovers and grows quite normally.

A hard frost during elongation can cause substantial damage. Even if the plant generates new branches at or near ground level, maturity is greatly delayed.

During the kernel filling period, frost dramatically lowers yield and oil levels. The oil content of late-maturing cultivars such as S-208 can be 40% in a long frost-free year, but can drop well below 34% with an early frost. If late planting is combined with an early frost, the oil content can drop below 20%. For late-maturing varieties, this can occur as frequently as 7 years out of 10. Thus none of such varieties are registered for growing in Canada.

High humidity, combined with high temperatures at flowering reduces seed set, particularly if temperatures are 32°C or more early in the morning. However, the generally relatively cool mornings during flowering on the prairies tend to promote good seed set.

Heat Unit Accumulation

In general, Saffire and AC Sunset need about 2,150 Corn Heat Units (CHU) (Major *et al.,* 1976) to mature. The most secure production is in areas that receive 2,100 CHUs 7 years out of 10.

Wind

Fully grown safflower is extremely wind-resistant, with few losses from lodging or shattering. Wind combined with heavy rain or hail during the bud stage or flowering may cause some lodging.

Hail

In the rosette stage, safflower is little damaged even by severe hail. Once stems start to elongate, hail is more damaging. Hail just before formation of flowers and secondary branches can do a great deal of damage. Damaged stems often produce new buds and branches but these mature late and are prone to frost damage. Also, damaged stems may be bent and weakened so that wind breaks them off.

Soil

Safflower needs fairly deep, well-drained soils. A dense subsoil, plough pan or an impermeable layer retards root growth. Highest yields are obtained on sandy loams with good water holding capacity at depth.

Safflower does poorly on light, sandy soils without good moisture reserves deeper down. On these soils, it quickly depletes the soil moisture and suffers moisture stress during the kernel filling period.

On heavy, clay soils that are prone to crusting, emergence may be reduced and higher seeding rates will be needed.

Salinity

Safflower is rated as moderately salt-tolerant and it can produce profitable crops on saline soils. It is slightly less tolerant of salinity than barley but more tolerant than wheat. Plants affected by salinity tend to be shorter, with darker green foliage and thinner stems, than those grown in non-saline soil.

Salinity reduces germination, delays emergence, and depresses crop yield. Safflower stands tend to be irregular. Safflower seedlings are less than half as salt-tolerant than at later growth stages. When the salt concentration, measured in electrical conductivity is 14 dS/m, safflower yield is cut by about half. Emergence time is doubled at about 7 dS/m. Some varieties are less affected by salinity than others.

Production Requirements *continued*

Under saline conditions, the number of seeds per head does not change, but there are fewer heads per plant, and each seed weighs less. The oil content of the seed may be reduced by up to 60%, depending on the variety. No change as a result of salinity has been detected in the chemical composition of the oil.

Safflower is particularly tolerant of sodium salts. Sodium, as distinct from salinity, has been found to stimulate early growth of safflower, providing ample potassium is present.

Safflower needs more water and roots to a greater depth than most other crops, so it may be a good choice to dry out recharge areas and lower water tables associated with salinity. Its rooting depth is less in areas with replenishing shallow groundwater.

Field Selection

Cropping History

Separate safflower from other broadleaf crops to minimize disease problems. A four-year rotation is the minimum. In particular, do not follow safflower with safflower. A number of disease organisms affecting safflower are carried over in the soil and on shattered seed. There is a great risk of diseases which cause stand and yield loss if safflower follows safflower in a rotation. Crops such as sunflower, bean, mustard and canola are highly susceptible to several of the same diseases, particularly sclerotinia diseases and leaf spot. Keep these crops separated from safflower in the rotation.

Safflower can follow winter or spring wheat, however it may be difficult to separate volunteer wheat kernels from the safflower. If adequate soil moisture is available, safflower can be followed by barley or spring wheat.

Topography

Avoid land with poorly-drained depressions, as safflower cannot tolerate wet soil. Excessive soil moisture leads to root rot and stand losses.

Soil Moisture

As long as the soil is moist to a depth of 60 to 75 cm (24 to 30 inches) at seeding time, a reasonable safflower crop can be expected. Safflower needs more moisture to germinate than cereals, and seed must be placed in, not just on, the moist layer of soil.

Soil Conservation

After harvest, safflower leaves only a small amount of crop residue to hold the soil against erosion. It is important to preserve these crop residues, especially if the field is to be fallowed.

Safflower draws more soil moisture and from greater depths than cereals, and it uses the moisture from late season rains (August, early September), leaving the soil dry for the next crop. Recrop safflower stubble only if there has been sufficient recharge of soil moisture. If safflower stubble is to be fallowed, as may be necessary in dry areas, cultivate as little as possible to preserve trash. Planting between shelter belts or grass strips, or seeding barrier strips (e.g. flax) may be advisable.

Nutrient Requirements

Safflower nutrient requirements increase with increasing yield. Safflower removes 5, 1.2 and 3.8 kg/ha of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) for every 100 kg of seed produced.

Safflower can take up moisture from a depth of up to 1.8 m (6 ft). Residual soil nitrogen, which has accumulated below the root zone of cereal crops, can be partially recovered by deep-rooted safflower.

Soil Testing

Soil analysis is the only way to accurately assess fertilizer needs. Soil samples could be taken randomly from 15 to 25 locations of the field or taken from specific benchmarked locations within a field (Kryzanowski, 2004). Sampling depth is important. The 0-15 cm (0-6 inches) is needed to assess soil phosphorus (P) and potassium (K) analysis, and then determine recommendations. Soil analysis to at least 60 cm (24 inches) depth is important for N and sulphur (S) analysis for both dryland and irrigated soils especially for the deep-rooted safflower.

Fertilizer Amounts

Nitrogen (N)

This is generally the most limiting nutrient to crop production in Western Canada. It is taken up in greater quantities than any other nutrient. Soil fertility trials show N application increases the yield and the protein content of safflower seed, but it also lowers the oil content.

On summerfallow, good yields can often be achieved with minimal N fertilizer, if soil test N levels are medium to high. Data from Montana (Fig. 5) indicate that safflower can yield up to 2,200 kg/ha (2,000 lb/ac) on summerfallow if soil and fertilizer N totals 110 kg/ha (100 lb/ac). The soil must be wet to 90 cm (36 inches) in spring and growing season rainfall normal to above average to achieve this potential.

Moisture must be carefully balanced with available N to obtain good yields without delaying maturity and risking unacceptable losses due to frost or disease. Above normal moisture allows the crop to utilize more N and results in higher potential yield.

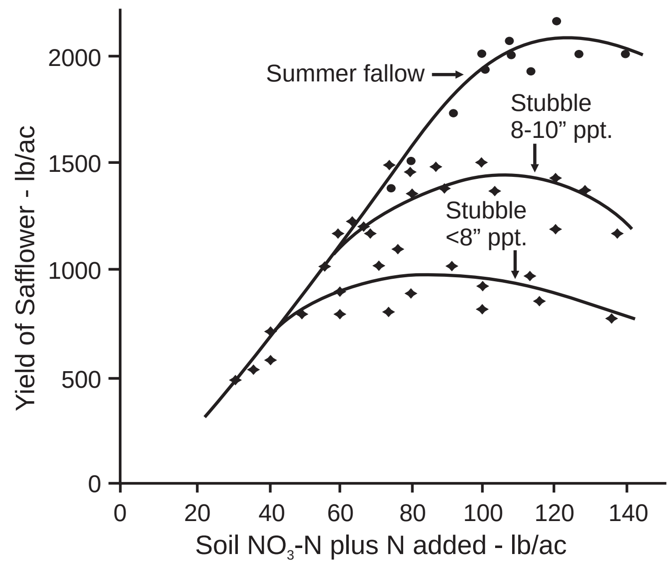


Figure 5. Effect of nitrogen on safflower seed yield (Montana).

On summerfallow, in the brown and dark brown soil zones of Western Canada, 20 to 40 kg/ha (18 to 36 lb/ac) of N fertilizer is normally adequate.

Some years, safflower yields almost as well on recropped land as on summerfallow, when spring soil moisture is very good. On continuously cropped land, the top 60 cm (24 inches) of soil generally contain about 20 to 30 kg/ha (18 to 27 lb/ac) of nitrate-N. If soil is wet to 100 cm (40 inches) then 80 to 90 kg/ha (72 to 81 lb/ac) of N fertilizer would be adequate for optimum yield. If soil is wet to only 60 cm (24 inches) 50 to 60 kg/ha (45 to 56 lb/ac) N is sufficient and if only 30 cm (12 inches) is wet apply 20 to 30 kg/ha (18 to 27 lb/ac) N. It is important to remember that potential safflower yield is correlated closely with soil and fertilizer N and also to soil moisture.

Generally on irrigation, 70 to 120 kg/ha (63 to 108 lb/ac) N is required because some N is usually present in the soil. One or two fertigation applications at 20 kg/ha (18 lb/ac) during the growing season may be worthwhile when high fertilizer N levels are used on sandy soils.

Phosphorus (P)

Phosphorus is often limiting in Western Canada soil although many soils now have sufficient residual fertilizer P levels that are generally adequate for most crops.

Nutrient Requirements *continued*

P is critical to early maturity and high yields. A lack of P may delay maturity. For dryland soils testing low in soil P, apply up to 30 to 40 kg/ha (27 to 36 lb/ac) of phosphate (P_2O_5) with the seed. On soils testing medium, apply 18 to 27 kg/ha (20 to 30 lb/ac) of phosphate. On soils that test high for P, either apply no P fertilizer or apply 15 to 20 kg/ha (13 to 18 lb/ac) of phosphate for a starter effect. Under irrigation, put 25 to 35 kg/ha (22 to 31 lb/ac) with the seed. These amounts will ensure that P will not limit safflower yields and soil P levels will be maintained.

Potassium (K)

Western Canadian soils generally have adequate K to meet crop needs. Safflower uses relatively large amounts of K, but the clay minerals in the soil release enough K to maintain the supply. Sandy soils may not be able to supply K and fertilization with K may be economical on such soils.

A soil test shows whether K fertilizer is needed. Generally, when soil test K levels are less than 280 kg/ha (250 lb/ac) in the 0 to 15 cm (0 to 6 inches) depth using the ammonium acetate extraction method, then K_2O application should be considered. Since K is relatively immobile, responses are greatest when it is banded.

Sulphur (S)

is present at high levels in most subsoils in the brown and dark brown soil zones. Sulphur is rarely needed in dryland situations. Since irrigation water contains more than enough S to meet crop needs, fertilizer S is unnecessary for irrigated safflower.

Micronutrient

Deficiencies have not been observed in safflower fields in brown and dark brown soils in Western Canada. Micronutrient deficiencies most often occur in cool, wet springs on sandy soils with low organic matter and high pH. Safflower's response to micronutrient fertilization has not been fully investigated.

Kinds of Fertilizer

The choice of fertilizer product should be governed by the cost per unit of each nutrient and the relative convenience in using the product.

Rate, Placement and Time of Application of Fertilizer

Fall fertilization may be very effective or it may be disastrous, depending on soil type, the form of N fertilizer used and how it is applied.

Spring banded N is better than spring broadcast and incorporated N but at times the differences are small (5%). Spring broadcast N is generally better than fall broadcast N. Fall broadcast is the least effective method of application and its efficiency declines with the length of time a soil is waterlogged. Fall banded N is as effective as spring banded N except when soils are waterlogged for an extended period in early spring, as is typical of cooler, more northerly areas.

Because N is present in, or transformed into, mobile nitrate forms that move to the plant roots with soil water, there is little advantage to placing it with the seed. Germination can be reduced when too much N is placed with or near the seed. Generally, do not put more than 20 kg/ha (18 lb/ac) N in the seed-row. Spiking in anhydrous ammonia, banding or broadcasting and incorporating granular N are all effective. Normally, late fall banded N is the most effective and eliminates the concern of fertilizer application before seeding which can result in loss of valuable seedbed moisture in the spring.

Phosphorus is relatively immobile in the soil and should be placed with or near the seed to maximize uptake. Up to 40 kg/ha (36 lb/ac) of phosphate (P_2O_5) can safely be seed-placed.

P can also be banded with N fertilizer. If more than 80 kg/ha (72 lb/ac) of N is banded, P in the band will be less available to the crop. In this case, band P separately or place it with the seed.

Even with optimum placement, P uptake efficiency is generally less than 35%.

Weed Control

Safflower is a poor competitor with weeds (Pic. 8). Weeds can cut safflower yields by up to 75% depending on the species and numbers of weeds (Blackshaw *et al.,* 1990a, 1992).

Safflower seedlings grow slowly, remaining in the rosette stage for 3 to 4 weeks after emergence. Weeds can easily become established during that period. Later in the season, many weeds are taller than the crop, effectively shading it.

Safflower is mostly grown on dryland on the prairies. The problem weeds under these conditions are usually Russian thistle, kochia, wild buckwheat, wild oat, stinkweed, flixweed, lamb's-quarters, and redroot pigweed. Perennials like Canada thistle and sowthistle may also be problem weeds.

Preventing Weed Problems

- Use weed-free seed.
- Seed fields that are relatively free of weeds.
- Use clean, weed-free machinery and vehicles.
- Do not apply manure containing viable weed seeds to land where safflower will be seeded.

Cultural Control Methods

- Use tillage when weeds are vulnerable to drying out on the soil surface.
- Grow a competitive crop and use appropriate herbicides the year before seeding safflower.
- Hand-weed small patches of new weeds that are new to the farm.
- Mow or till weed patches to prevent viable seed production.
- Seed to get a vigorous stand of safflower that can compete effectively with weeds.
- If weeds emerge before safflower, uproot them with spike tooth or coil spring harrows.

Chemical Weed Control

- Paraquat or glyphosate will effectively kill weeds prior to seeding safflower. This is especially important if seeding safflower on crop stubble from the previous year. Caution: Phenoxies, such as 2,4-D or dicamba, applied close to seeding time may injure safflower.
- Trifluralin and ethalfluralin are registered for use in safflower. Both are applied pre-plant and incorporated. Both herbicides control a variety of grass and broadleaf weeds (Blackshaw *et al.,* 1990a). Ethalfluralin may be more effective in controlling Russian thistle and kochia. Follow application and incorporation guidelines provided in provincial crop protection guides.
- Sethoxydim is registered for in-crop postemergence control of annual grass weeds (including volunteer cereals) in safflower (Blackshaw *et al.,* 1990b).
- Use herbicides in conjunction with other sound control practices. Follow label directions at all times.

Seeding

Land Preparation

Safflower needs a seedbed free from clods but not so fine it will seal after a rain. Avoid working the seedbed too much before seeding, as this may dry out the soil and lead to emergence problems. Safflower is particularly sensitive to being seeded into dry soil.

Seed Quality

Use high quality seed. It should be bright white, well-matured, with large kernels and high bushel weight. To minimize disease carried within the seed, choose seed produced in a dry area.

Seeding *continued*

The seed should have a good germination rate, as lower rates are associated with poor seedling vigour, which can lead to problems with seedling blight. As with all crops, a pure, uniform seedstock will provide the foundation for high yielding and high quality production. Freedom from, and protection against, seedborne diseases improves emergence and overall crop health.

Seed Treatment

Thiram® (75% WP), offers some protection against seed rots and damping-off caused by soil- and seed-borne fungi. Seed treatments have very limited effects against Alternaria, which is carried inside the seed.

Damping-off is the loss of seedlings. It is mainly caused by soil-borne micro-organisms and occasionally seed-borne Alternaria. Seed into well-drained soils to reduce damping-off. Avoid fields which have had severe damping-off in the past.

Do not grow safflower in fields where wireworms and cutworms are expected to be a problem. No insecticide is registered for control of either insect on safflower seed or seedlings. Rotate with insecticide-treated cereals.

Seeding Date

Safflower should be planted during the last week of April or the first two weeks of May. See Tables 3 and 4 (Mündel *et al.,* 1994a). Delays in seeding decrease days required to reach maturity. An early-maturing variety such as Saffire, has yields which tend to be stable across seeding dates to mid-May; while later maturing varieties, such as S-208, have more variable yields. When killing fall frosts do not occur until late September or early October, S-208 can yield more than Saffire. Yield and quality of safflower crops seeded after May 15 are often at great risk from fall frosts, with the maturing process being arrested, resulting in reduced yields (Fig. 6). Later seeding also frequently results in seed filling occurring at a time when soil moisture is low. Early April seeding is not beneficial in many years as practically no germination occurs at 2.5°C (36.5°F), but there is almost complete germination at soil temperatures over 5°C (41°F).

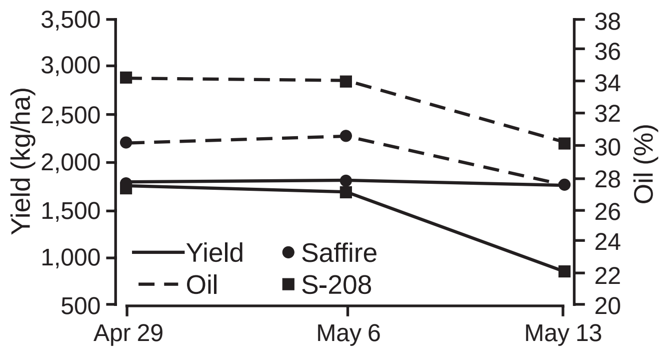


Figure 6. Planting date effect on yield and oil for Saffire and S-208, 1987 at Lethbridge, AB.

Table 3. Effect of seeding dates on days to emergence, maturity, heat unit accumulation, yield and oil content for Saffire (Lethbridge, 1991).

Seeding Date	Emergence (days)	Maturity (days)	CHU*	Yield (kg/ha)	Oil (%)
April 9	21	147	2270	1525	33.1
April 15	22	142	2285	1581	32.9
April 23	19	134	2250	1477	32.4
April 30	15	129	2251	1461	32.8
May 8	10	122	2241	1416	32.7
May 16	10	115	2179	1006	32.7

*CHU = corn heat units.

1. Cross-section of safflower head, showing seeds

2. Late (left) S-208 and early (right) Saffire

3. Saffire in bloom

4. AC Stirling flowering head

5. Saffire seed - 'bold' white

6. Seed with pappus

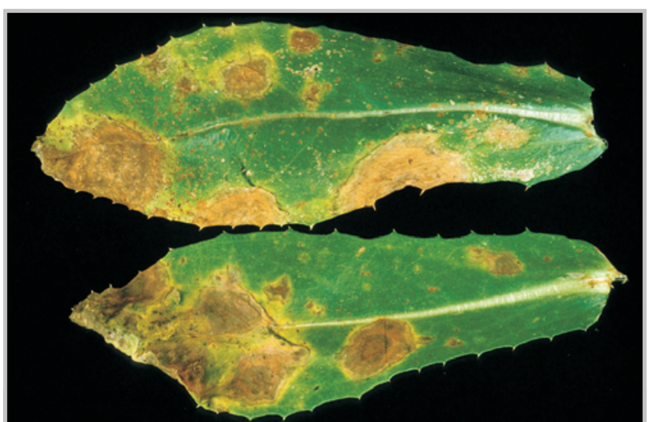
7. Seed with striped hull

8. Weedy and weed-free safflower plots

9. Spore-producing mushrooms of *Sclerotinia sclerotiorum*

10. Safflower heads infected with sclerotinia head rot

11. Assortment of sclerotia of *Sclerotinia sclerotiorum*



12. Alternaria leaf blight on safflower

13. Alternaria infected safflower seeds (dark regions) (left), and healthy seeds (right)

14. Safflower rust on leaves with light (left) to heavy (right) infection

15. Damping-off and seedling blight in safflower field

16. Safflower seedlings: healthy seedling (left) and infected with seedling blight (4 on right)

17. Wireworm stages

18. Army cutworm

19. Pale Western cutworm

20. Red-backed cutworm

21. Two-striped grasshopper

22. Lygus bug

23. Severe grasshopper damage on safflower plant

24. Clear-winged grasshopper feeding near top of safflower stem

25. Combining safflower

Seeding *continued*

Table 4. Effect of seeding dates on yield and days to maturity for Saffire and S-208 at Lethbridge from 1987 to 1990.

		Yield (T/ha)		Days to Maturity	
Year	Seeding Date	Saffire	S-208	Saffire	S-208
1987	April 29	1.8	1.7	140	146
	May 6	1.8	1.7	134	137
	May 13	1.8	0.9	138	142
1988	April 25	3.0	2.6	127	140
	May 4	2.8	3.0	120	135
	May 13	2.5	2.3	120	139
1989	May 5	1.1	1.1	121	126
	May 11	1.2	1.2	120	126
	May 17	0.9	0.8	117	122
1990	May 3	1.8	3.2	123	136
	May 11	1.5	2.5	120	130
	May 17	1.6	2.7	118	128

Seeding Rate

Seedling losses are often as high as 50%, so although 28 kg/ha (25 lb/ac) had been recommended in the past, some growers seed 34 kg/ha (30 lb/ac). However, studies carried out at various prairie locations, show that seeding rates from 32 to 40 kg/ha (30 to 35 lb/ac) result in the highest yields from southern Alberta to southern Manitoba (Table 5 shows southern Alberta results) (Mündel *et al.,* 1994b). A seeding rate of 7.5 kg/ha (6 lb/ac) produced low yields. Days to maturity, test weight, and oil content varied only slightly across all these seeding rates. Allowing for some losses from seedling blight and deep placement this rate should form a thick enough stand to compete with weeds and mature evenly. Too high a seeding rate (40 to 45 kg/ha [35 to 40 lb/ac]) may increase damping off and other diseases in wet years, and may lead to premature drought stress in dry years. Under irrigation, seeding rates may be up to 45 kg/ha (40 lb/ac). Figure 7 shows the effect of seeding rate on yield using narrow 15 to 23 cm (6 to 11 inches) and wide 30 to 46 cm (12 to 18 inches) rows at various prairie locations in 1987.

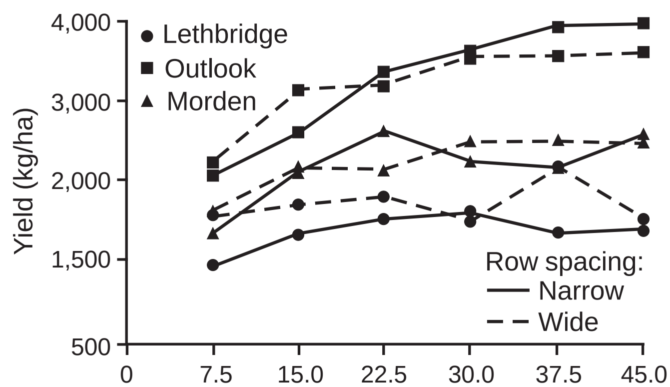


Figure 7. Seeding rate (in kg/ha) effect on yield at narrow and wide row spacings at Lethbridge, AB, Outlook, SK and Morden, MB.

No particular row width seems to have a general advantage. If a yield advantage occurs, it is generally in the narrow (15 to 23 cm; 6 to 9 inches), compared to wide (30 to 45 cm; 12 to 18 inches) row spacings. Most safflower is seeded at the narrow row spacings with the common seed drills. These narrow row plantings may help the safflower crop compete better with weeds and give a more uniform stand.

Table 5. Effect of seeding rates on yield of Saffire at 5 southern Alberta sites from 1989 to 1991, seeded at 23-cm (9-inch) row spacings.

	Seeding Rate - kg/ha (lb/acre)					
	7.5 (6)	15 (13)	22.5 (20)	30 (27)	37.5 (27)	45 (41)
Yield - kg/ha (lb/acre)	1293 (1164)	1592 (1433)	1741 (1567)	1763 (1587)	1827 (1644)	1827 (1644)

Seeding Depth

The best seeding depth for safflower is 2 to 3.5 cm (0.75 to 1.5 inches) into a well-packed, moist soil. Safflower, because of its hulled seed, needs more moisture than a cereal grain to germinate. For this reason, safflower must be placed into rather than on top of the moist soil layer. Seeding into a dry seedbed may result in thin stands with reduced yield potential.

The seed must not be placed too deeply. Safflower is very sensitive to deep seeding, particularly if the soils are wet. Deep seeding extends the period during which the seedling is exposed to damping-off pathogens, which can lead to uneven stands.

Seeding Equipment

Disc drills, hoe drills and air seeders have been used successfully to seed safflower. Good seeding practices achieve a uniform, shallow seeding depth and place and pack the seed into moist soil. Safflower seed is about the same size as a barley seed, and similar settings can be used. However, the seed runs through grain drills faster than barley or wheat, and some adjustment is needed. Cup calibrations on most drills are the same as for barley but set as if the seeding rate were 32 to 40 kg/ha (30 to 35 lb/ac).

Post-Seeding Cultivation

Hard rain on a newly seeded field may cause crusting. Safflower seedlings, which are not very tough, may not emerge. Packers, seed drills, and/or harrows can be used to break the crust.

Stand Assessment

Safflower can compensate for poor emergence by extra branching, extra heads and more seeds per head. If gaps in a row are less than 50 cm (20 inches), yield reduction will not be major. Very poor stands can recover to produce adequate yields. Uneven, thin stands have more weed problems and mature later, increasing the risk of frost damage.

Assess your stand as early as possible to give yourself the widest possible choice of crops if reseeding is necessary. Assess the stand in several parts of the field: e.g., for 32 ha (80 acres) check three representative areas. At each spot, count the number of plants in a square metre (yard). Also check the gaps in rows. If there are fewer than 30 plants per square metre (25 plants per square yard) at the rosette stage, or if the spaces between plants in rows are more than 50 cm (20 inches), the yield potential of the crop is probably less than 1,100 kg/ha (1,000 lb/ac). Reseeding safflower is an option if this is done before mid-May. After May 15, mustard or canola may be a wiser choice of crop to seed.

Irrigation

Requirements

Irrigation can be worthwhile in years when moisture prior to flowering and seed filling is limited. Southern Alberta experience with irrigation versus dryland safflower production shows a long-term yield advantage of 670 to 880 kg/ha (600 to 800 lb/ac) from irrigation, if properly managed. Even one irrigation at the bud stage will almost double yields on sandy soils.

Irrigation of safflower requires moderation: excessive water application, particularly when combined with high nitrogen levels, results in delayed maturity and increased disease. Irrigation early in the season, before the bud stage, can delay maturity by as much as 5 days and irrigation during the bud stage can delay maturity by a further 10 days. Irrigation much beyond flowering will increase the risk of Sclerotinia head rot (not a major concern with current Canadian varieties) and Botrytis head rot, as well as Alternaria leaf blight.

When irrigating safflower, keep the soil at 60 to 75% of field capacity once the crop has formed a rosette and weed control is complete. If necessary, irrigate for the last time in early August, before the end of flowering. This replenishes the soil profile and the crop can mature using the available soil moisture. Any further irrigations delay maturity and increase the risk of frost damage.

Irrigation Regime

There are two most critical crop stages to consider when irrigating:

1. Pre-plant (fall) irrigation: Good sub-soil moisture early ensures good branching and bud formation.
2. Bud stage: Saturate the soil profile to 60 cm (2 ft) to ensure good seed set.

Irrigation after full bloom ensures good kernel fill and high oil levels. However, if soil moisture is abundant, this irrigation should be avoided: the risk of delaying maturity is high.

Safflower fits in well where the irrigation system is unable to keep up with a high moisture use crop and limited irrigation maximizes the efficiency of the system.

Higher seeding rates, up to 56 kg/ha (50 lb/ac) can be used in irrigated crops. Seed as early as possible, to allow for the delayed maturity.

High N levels, either applied or residual in the soil, in combination with irrigation, delay maturity of the crop substantially. Applied N levels on irrigated safflower should rarely exceed 67 kg/ha (60 lb/ac).

Diseases

Safflower is susceptible to many diseases caused by fungi, bacteria, viruses, or disorders due to environmental stresses. The genetics and the mode of inheritance of disease resistance and tolerance in safflower are not well defined in most cases. In the time since the first version of this bulletin was released in 1992, the focus of pest management has shifted towards environmentalism, emphasizing the importance of sustainability and reducing the reliance on the use of chemical pesticides for the control of plant diseases. Thus, the use of environmentally sound methods for management of crop diseases such as breeding for disease resistance, biocontrol, crop rotation and other cultural methods have become increasingly important in this new environmental protection era. Nevertheless, with currently no active breeding programs on safflower in Canada, since 1997, certain chemical pesticides may still be required. They must be used judicially and coupled with crop rotation and other cultural methods.

The fungal diseases Sclerotinia head rot, Alternaria leaf blight, rust, and damping-off or seedling blight, are common and they may cause serious losses to safflower, especially in years with above-average rainfall.

General Disease Control Strategies

There is only one fungicide (Thiram®) registered for seed treatment on safflower in Canada; therefore, cultural practices must be the main disease control strategy. These include the following measures:

- **Choose a well-adapted, disease-resistant cultivar.** Under high moisture conditions, such as under irrigation in Alberta and rainfed in much of Manitoba, growing varieties with resistance to Sclerotinia head rot and Alternaria leaf blight is particularly important. Saffire and AC Sunset have good resistance to Sclerotinia head rot; both are susceptible to Alternaria blight. Alternaria-resistant cultivars are not available for the Canadian prairies.
- **Choose clean, healthy-looking seed** with a high germination rate, preferably produced in a dry area with low disease levels. Seed having high germination generally results in seedlings with high vigour, able to resist seedling blight organisms. Disease-free seed reduces the risk from Alternaria leaf blight.
- **Plant shallow into a well-prepared seedbed.** This promotes quick emergence and reduces the risk of seedling blight of safflower.
- **Do not plant safflower after safflower or other broadleaf crops,** such as sunflower, pulse crops, mustard or canola, to reduce the risk of sclerotinia head rot, leaf spot, rust, seedling blight and root rot. Seed safflower and follow with cereal crops, grasses or summerfallow.
- **Fertilize and control weeds.** Use recommended rates of fertilizer to promote growth and vigour of safflower. Control weeds to reduce risks of harbouring plant pathogens on weeds.
- **Do not over-irrigate.** Moist conditions favour some disease organisms.
- **Turn under residues from infected crops,** if practical, in order to reduce inoculum for rust and Alternaria leaf blight.

Specific Diseases

Sclerotinia head rot
(caused by *Sclerotinia sclerotiorum*)

This is the most serious disease of safflower in western Canada. Sclerotinia head rot is a major disease of safflower in temperate climates (Weiss, 1983). With rains or irrigation maintaining moist soil surfaces around flowering time, Sclerotinia head rot can result in greatly reduced yields (Mündel *et al.,* 1985b). In a study of 20 lines in southern Alberta in 1983, yield losses due to head rot in a field naturally infested with *S. sclerotiorum* ranged from 14 kg/ha (12.5 lb/ac) for Saffire (Mündel *et al.,* 1985b) to 935 kg/ha (834 lb/ac) for the cultivar Gila (Mündel *et al.,* 1985b). Healthy plants averaged 4.4% more oil in the seed than did the corresponding infected lines. AC Sunset and Saffire have comparable field resistance to Sclerotinia head rot. Complete crop losses have occurred in severe infections of susceptible varieties: none of which is registered for use in Canada. Severe outbreaks of the disease may occur under prolonged humid conditions during flowering to seed development stages.

Symptoms

In Western Canada the disease occurs mainly in safflower heads causing head rot. Small mushrooms (called apothecia) emerge (Pic. 9) in moist soil and shed spores which become airborne and infect the heads. Affected heads are rotted and flower bracts have a bleached appearance (Pic. 10). If seed shells form, they are hollow with no embryo or endosperm developed inside. A black, cone-shaped sclerotium is formed in the pith cavity of the stem at the base of the head (Pic. 11). Diseased heads dry up and are easily detached from the stem by strong winds. The pathogen may also attack safflower roots (by means of a white fungal mass called mycelium) causing wilt of the infected plant. Wilt damage to safflower is of minor concern in contrast to the head rot.

Diseases *continued*

Control

- Plant a disease resistant cultivar: Saffire and AC Sunset are resistant to Sclerotinia head rot with generally less than 10% of heads infected under field conditions in severe cases. Other varieties, including S-208 and S-541, are highly susceptible. Even so, it is worth noting that none of the safflower cultivars tested in Canada are immune to Sclerotinia head rot (Mündel *et al.,* 1985b).
- Crop rotation: Allow at least four years between susceptible crops. Canola, dry bean, dry pea, sunflower and lentil are susceptible to *S. sclerotiorum* and they should be avoided in the rotation. Cereals and grasses are immune to this pathogen. Crop rotation alone may not be completely successful due to the persistence of sclerotia in the soil but it is necessary to prevent the build-up of sclerotial inoculum of *S. sclerotiorum* in the soil.
- Use safflower seed free of sclerotia.
- Ensure field sanitation, by controlling other hosts such as broadleaf weeds, volunteer plants of highly susceptible crops such as sunflower, canola and dry beans.

Alternaria blight

(caused by *Alternaria carthami* and *A. alternata*)

The disease occurs most seriously in areas with high rainfall or high humidity, such as in southern Manitoba, especially after frequent showers and heavy dew between the late bud stage and near maturity. Optimum growth temperature for this fungus is 25 to 30°C (77 to 86°F), with maximum growth occurring at pH 6.0 (Weiss, 1983). It can spread rapidly through a crop and, if severe, reduce seed yield and oil content. Infected seeds may be discoloured and, therefore, downgraded or rejected for sale as birdseed. Germination will be reduced in infected seeds. Both Saffire and AC Sunset are susceptible to Alternaria leaf blight.

Alternaria carthami is the most prevalent species found on safflower. Indoor inoculation studies indicated that *A. carthami* was pathogenic at all growth stages; while *A. alternata* also infected healthy plants, but such infections remained dormant until leaf senescence (Mortensen *et al.,* 1983).

Alternaria infected seeds are the primary source of inoculum for the leaf blight during the growing season. Petrie (1974) reported that up to 95% of safflower seeds were infected by *A. carthami* in some fields in Saskatchewan. Production of spores of the Alternaria pathogens are triggered by a combination of temperature, humidity, and wind, with resulting exponential multiplication in a field and beyond for the secondary spread of the disease (Bergman *et al.,* 1979).

Symptoms

The disease appears before flowering on leaves and flower bracts as small brown to dark brown spots which grow to about 1 cm (0.4 inches) in diameter, often with concentric rings (Pic. 12). The spots may join to form large, irregular lesions. Severe infection may cause cracking and browning of the entire leaf. The pathogen attacks safflower heads resulting in brown discolouration at one end of infected seeds (Pic. 13). Infected seeds can cause seedling blight and damping-off. Seeds are shrivelled and empty in severely affected heads. In severe cases, no flower heads are produced.

In years or areas of frequent rains and high humidity, the disease may cause severe damage to leaves, flower bracts, capitula and seeds. Infected buds remain unopened, shrink and dessicate (Weiss, 1983). In addition, the Alternaria pathogens can cause infection of safflower seedlings resulting in seedling blight. A field survey in southern Alberta in 1989 showed that 52% of seedling blight was due to *Alternaria* spp. (Howard *et al.,* 1990).

Control

- Use seed produced in areas of low rainfall. In years or areas with frequent rains, the disease may cause severe damage to leaves, flower bracts, and seeds. Seed source is more important than soil moisture or temperature during germination and emergence in reducing Alternaria seedling blight (Mündel *et al.,* 1997). Visual examinations alone are not sufficient to determine if the seeds are infested with *Alternaria* spp.
- Use low seeding rates. Plant populations that allow good air circulation reduce severity of the disease.

- Adjusting the seeding date to avoid planting safflower when soil temperature is high (15 to 25°C) (59 to 77°F) also helps to reduce the disease (Mündel *et al.,* 1997).
- Include crop rotation to prevent the build up of the inoculum in the field. The Alternaria pathogen can survive in infected safflower seeds (Mündel *et al.,* 1997) and plant debris (Weiss, 1983). Use of clean seeds produced in disease free areas (Ranga Rao, 1989) for planting is crucial as fungicidal seed treatments are often unable to eliminate completely the seedborne inoculum due to the internal seedborne nature of the pathogen (Irwin, 1976).

Rust (caused by *Puccinia carthami*)

Safflower rust caused by *Puccinia carthami* is distributed worldwide (Kolte, 1985) and as such is common in Western Canada. It is rarely a serious problem in the Canadian Prairies because the disease usually occurs late in the season. However, severely rust-contaminated seeds will not germinate well. The disease can occur on most safflower cultivars by seed-borne or air-borne inoculum under favourable conditions. Saffire and AC Sunset are both susceptible to rust.

Symptoms

The pathogen on contaminated safflower seeds may attack cotyledons, leaves and stems of young seedlings, causing yellow discolouration and drooping of the cotyledons. However, the disease is most noticeable from flowering to seed development stages. Numerous tiny (1 to 2 mm [0.04 to 0.08 inches] in length), orange brown pustules are formed on leaves and flower bracts. Later in the season, pustules turn black to form bigger rust patches (Pic. 14). Severely attacked leaves may die prematurely. During the growing season, rust pustules break open to release reddish-brown spores which cause secondary infection from plant to plant.

Control

- Field sanitation: The pathogen may overwinter as black teliospores on infected plant tissue. Remove infected plant debris to reduce the inoculum in the field.
- Crop rotation is important. Continuous cropping of safflower may result in severe damage by rust (Fu, 1993b). While growing safflower continuously can aggravate the incidence of rust, alternating safflower with non-host crops can minimize safflower rust.
- Use of rust resistant cultivars would be useful. However, neither of the two commercial varieties in Canada, Saffire and AC Sunset, is resistant to this disease.

Damping-off of seedlings (caused by *Pythium* spp.)

Damping-off of seedlings is one of the major causes of poor stand establishment in safflower. This disease is most prevalent when the soil is warm and moist following planting. In southern Alberta, Pythium damping-off of safflower is primarily due to *Pythium* spp. 'group G' (Huang *et al.,* 1992). Generally, damping-off is particularly severe in areas where safflower is grown under irrigation (Weiss, 1971). The wide range of host crops for some species of Pythium may be an important factor for the prevalence of this disease on safflower. For example, in southern Alberta, Huang *et al.,* (1992) identified isolate BR583 of *Pythium* spp. 'group G' as a divergent form of *P. ultimum*, which attacks numerous crops including safflower, canola, dry pea, sugar beet, lettuce, cucumber, muskmelon, spinach, marigold, sunflower, carrot and tomato.

Symptoms

Seeds fail to germinate or emerge (Pic. 15) and emerged seedlings (Pic. 16) collapse and die. Gaps in rows or generally thin stands may result. High mortality of seeds or young seedlings is due to rapid invasion of the cotyledons, roots and hypocotyls by one or more of the pathogens. Infected but surviving seedlings may be stunted with one or more lesions on roots and/or hypocotyls.

Control

- Avoid growing safflower in fields which have had damping off in the past. The disease is most severe when the soil is heavily infested with Pythium species.

Diseases *continued*

- Avoid seeding safflower into warm wet soils. In an indoor study, the emergence of safflower seedlings was poor under high soil moisture (near field capacity) and high temperature (25°C) (77°F) (Mündel *et al.,* 1995). It is advisable to plant safflower early, when the soil is still cool. At lower soil moisture, safflower emergence dropped below 80% only when the temperature was increased to 20°C (68°F) or above.
- Avoid deep seeding as this weakens the emerging seedling and encourages infection. Planting safflower on well-drained soils reduces the incidence of this and other root rots (Smith, 1996).
- Seed treatment with Thiram® wettable powder (0.2 to 0.3%) (Thiram® 75% WP) may partially reduce the incidence of damping-off and seedling blight, as well as other soilborne pathogens (Howard *et al.,* 1990). This chemical is registered for control of seed decay and damping-off of safflower in Canada (Anonymous, 1999).

Insects

Insects have not been a serious problem in safflower production, except for occasional thinning of seedling stands by wireworms or cutworms or late season damage by grasshoppers. Although there are several insects that are specific and serious pests of sunflower in Western Canada there are none that are known to be specific for safflower. It may be that safflower has been grown for such a short time and on such a small acreage that potential insect pests have not yet had time to adapt. Some of the insects that occasionally or potentially damage safflower are described and illustrated below.

Insects Causing Stand Reduction

Wireworms are the yellow or amber coloured, firm-bodied larvae of click beetles (Pic. 17). They reduce stands by feeding on the germinating seeds. Because they have a three to five year life cycle effective control can be obtained by the insecticidal seed treatment of a preceding cereal crop.

Cutworms are the soft-bodied larvae of noctuid moths (millers). The three most common pest species in the area where safflower is grown are army, pale western and red-backed cutworms. The army cutworm (*Euxoa auxiliaris*) (Pic. 18), overwinters as mid-size larvae and is most damaging early in the spring, when it feeds on plants above ground during the night but remains hidden in the soil by day. It is unlikely to be a problem unless safflower is planted very early in a field that had weed or volunteer growth the previous fall. Both the pale western (*Agrotis orthogonia*) (Pic. 19) and red-backed cutworm (Euxoa ochrogaster) (Pic. 20) overwinter in the egg stage and are most damaging when the larvae approach maturity in late spring. Female pale western cutworm moths lay their eggs during August, preferably in loose soil that has been disturbed by cultivation or harvesting operations. On the other hand, female moths of the redbacked cutworm prefer to lay where there is some green growth. Safflower seedlings damaged by cutworms rarely recover. Early detection of a cutworm infestation is essential, because once damage becomes evident, it can worsen rapidly.

Seed corn maggots (*Delia platura*) are the larvae of a species of small fly that usually lays its eggs in decaying vegetative matter. They sometimes attack seeds sown in fields with buried plant material, especially if germination is delayed by cool, wet weather.

Insects Causing Damage to Leaves

The beet **webworm** (*Loxostege sticticalis*) and several species of climbing cutworms such as the clover cutworm (*Scotogramma trifolii*) and the bertha armyworm (*Mamestra configurata*) might occasionally cause damage. These species will feed on a wide range of broadleaf crops and weeds. Damage in fields of safflower is most likely to occur when weeds or volunteers of the preferred host - lamb's-quarters in the case of the beet webworm and canola in the case of the bertha armyworm, are defoliated before the larvae reach maturity - they may then switch to the safflower.

The **painted lady butterfly** (*Vanessa cardui*) is a migratory species that occasionally occurs in high numbers on the southern prairies. The preferred host is Canada thistle, but the females will also readily lay eggs on sunflower and borage. The spiny, dark coloured larvae can cause severe defoliation in these crops, but will not eat safflower.

Certain **grasshoppers**, especially the two-striped grasshopper (*Melanoplus bivittatus*) (Pic. 21), can cause significant chewing damage, removing leaves and cutting into green stems. These insects normally cause most of their damage around the margins of fields, during late June and July.

Insects Damaging Buds, Flowers and Developing Seeds

Lygus bugs (Pic. 22) attack a wide range of plants, feeding preferentially on the reproductive tissues. The adults are 4 to 5 mm in length and vary in colour from pale green to reddish brown with a distinct triangle between the base of the wings. The young immatures are about the size of aphids, but can be distinguished from them by the long prominent antennae and distinct dark spot on the top of the abdomen. Feeding on young flower buds can cause distortion or blasting.

It has recently been recognized that lygus feeding on the developing seeds of sunflower causes a condition called kernel brown spot which is of concern for confectionary sunflower (Charlet and Gulya, 2002).

Leafhoppers, mainly *Empoasca* species, sometimes occur in abundance. They suck sap from the underside of the leaves and flower head bracts and can cause stippling and sometimes leaf burn. In some other crops, leafhoppers are important vectors of disease caused by viruses and mycoplasma-like organisms.

Thrips are small, 1 to 2 mm long, elongate, usually dark coloured insects. Mouthparts are used for rasping the outer plant tissue and sucking the juices. They are sometimes present on safflower in large numbers, usually under the bracts of buds or flower heads. Due to the small size of these insects, their presence is most easily recognized by the damage they do to the host plant. Whitish blotches or streaks appear on leaves, flower buds, and petals. Tiny black fecal drops are also signs of their presence. A hand lens is useful for examining plants that appear damaged. In safflower, thrips feed under the bracts of developing buds. Infested buds may remain upright and straight but turn a bronze colour and abort later. Thrips also produce dark margins on the bracts of immature seed heads, but these seed heads do not abort. Heavy thrip migrations can cause considerable silvering and later bronzing to safflower seedlings, but there appears to be no serious seedling damage or plant loss. Often thrips are kept under control on safflower by predators such as anthocorid bugs, predatory thrips, and lady beetles.

Insecticidal treatment is rarely justified for infestations of insects such as lygus bugs, leafhoppers or thrips. Because of its semi-determinate growth habit, safflower can compensate for some loss of flower buds by producing more seeds in the remaining flower heads.

Insects Causing Late-Season Defoliation

Grasshoppers can damage safflower from germination to the post-bloom stage, but are of special concern in late season (Johnson and Mündel, 1987; Mündel and Johnson, 1987). They hatch in late May and early June, begin flying in July, and live until frost. They damage crops by chewing. Some grasshoppers feed on both grass and broadleaf plants, and readily eat the leaves, heads, and flowers of safflower (Pic. 23). In experiments at the Lethbridge Research Centre, individual grasshoppers typically consumed about 1.5 g (wet weight) of leaves in 48 hours. Controlled experiments found that the two-striped grasshopper can consume more than 0.8 g per 48 hours, and under warm field conditions, it can consume even more.

Insects *continued*

This figure can be higher in the field, because of clipping and wastage of the leaves. The clear-winged grasshopper (*Camnula pellucida*) is unusual in that it does not normally feed on broadleaf plants, and it feeds sparingly on safflower. The limited chewing by this species is typically near the tops of stems (Pic. 24), so that significant head-clipping near maturity can result.

Grasshoppers usually avoid safflower in preference for other nearby crops that are still green. If conditions remain warm late in August and early September when cereals are harvested, safflower may be more severely attacked, particularly around the outer margins of fields. Consider chemical control of grasshoppers only if there are 15 or more per square metre (per 10.8 square feet) and crop damage is visible, or if warm conditions cause smaller numbers of grasshoppers to cause severe damage.

In years with warm, dry falls, low numbers of grasshoppers can cause significant damage, so check fields under these conditions. Check in early June to monitor damage to young plants.

Check late in the season to see whether feeding damage by grasshoppers is causing loss of seed, as opposed to the less harmful stripping of leaves.

Only control grasshoppers where they are found feeding on the crop, or where they are concentrated in large numbers. Note that grasshoppers in rangeland and pasture may not be the same species that attack safflower.

Based in part on experiments conducted at the Lethbridge Research Centre, the insecticide Cygon® 480 is registered for control of grasshoppers in safflower.

No other products are currently registered for insect control in safflower.

Other Insect Pests

So far, no stem boring or seed-infesting insects have been reported as being pests of safflower in Canada.

Harvesting and Storage

Harvest Stage

Safflower is physiologically mature about one month after flowering is finished. The plants are ready to harvest when quite dry but not brittle, when the bracts on the heads turn brown and the seeds are solidly white (current varieties) and separate easily from the head. Normally, combining can begin 35 to 45 days after flowering is complete. A killing frost after maturity will help to dry stalks and facilitate harvesting.

Safflower is best harvested at 12 to 13% moisture and then dried by aeration to 9.5%. If aeration drying is not available, harvest safflower as soon as it is dry (9.5% moisture). Moisture charts are available from the Canadian Grain Commission for use with the Model 919 moisture metre. Harvesting at the recommended moisture level will reduce the risk of seed discolouration or sprouting in the head caused by fall rains.

The heads on main stems can often mature two weeks earlier than those on the branches of the plant.

Hand shell a sample (heavy leather gloves or equivalent are mandatory) to check the moisture level. All the heads on a plant should be sampled to get the entire range of moisture content and maturity. Combining a small strip and measuring the moisture content may be the best and most painless way of deciding whether safflower is ready for harvest.

In dry weather, safflower may be left standing in the field for up to a month, as it does not lodge and is relatively resistant to both insect attack and bird damage when mature. Strong winds can cause shatter losses, however.

Swathing vs Straight Combining

Straight combining (Pic. 25) is preferable to swathing. This minimizes shattering losses, bird-seed quality is better, sprouting problems are less likely, and wind cannot roll the fluffy swaths. Safflower, with its great ability to compensate for thin stands by branching, often has a wide range of maturities on one plant. Any attempt to speed the dry-down process results in lower yield and lighter grain as the late branches are cut prematurely and the seeds do not fill properly. Swathing early has generally resulted in yield losses (Table 6). Note: Multiply lb/ac by 1.121 to achieve kg/ha. Safflower has satisfactory shattering resistance. Straight combine the crop where possible. If swathing is the only option, cut safflower directly ahead of the combine.

Desiccants applied too early cause yield losses, especially in crops branching significantly. No desiccants are currently registered on safflower. Any future desiccants for safflower will be a harvest aid rather than a way to speed maturity. If green weeds make straight combining difficult, and since the use of a crop desiccant is not an option, it may be necessary to swath.

Controlling Harvest Losses

Harvest losses can be minimized by combining as soon as the crop is ripe and not too dry, thus avoiding discolouration and sprouting in wet weather, and avoiding shattering losses at the cutter bar.

Combining

Combine at relatively low cylinder speeds: e.g., 500 rpm for a 56 cm (22 inches) cylinder. Concave clearances for 16 mm (5/8 inch) at the front and 13 mm (0.5 inch) at the back are good starting points. In heavy crops, adjust shaker speeds to faster than those used for small grains if possible to prevent plant residue from clogging the machine. Air should be adjusted to reduce the number of empty seeds entering the grain hopper. A reel may not be needed for a reasonably good crop. However, with light crops, the combine reel may help in proper feeding onto the header platform. If a reel is used, watch closely for shattering at the header once the early morning toughness has gone. Reel speed should be about 25% faster than the forward speed of the combine. To minimize shattering at the cutter bar, increase ground speed and make sure the reel is not overly aggressive. Air reels are very effective for eliminating reel shatter loss while providing uniform feeding into the header.

There is a white fuzz in the seed heads of safflower which may clog combine radiators not designed to remove the fuzz from the protective screening. Accumulations of the fuzz can create a fire hazard. Brushes attached to a rotating screen readily remove this fuzz on modern combines.

Drying

If safflower is combined above 9.5% moisture, it must be dried. Farmers with aeration bins or grain dryers have found that harvesting safflower tough (9.6 to 13.5% moisture) or damp (13.6 to 17.0% moisture) (using Canadian Grain Commission moisture terminology) results in easier threshing with less shattering at the cutter bar. When combining in high moisture conditions, make sure that the safflower is dried down quickly because otherwise it develops a musty smell.

Aeration drying can be used to reduce the moisture content to the required 9.5% as long as the air is warm and humidities are low.

Table 6. Effect of swathing dates on yield of irrigated and dryland safflower (Alberta Agriculture field trials).

1988 Irrigated*		1990 Dryland Yield (lb/ac)**				
Swathing Date	Yield*** (lb/ac)	Swathing Date	Warner	Med. Hat	Wrentham	Average
Sept. 9	2145	Sept. 13	1591	1418	2229	1746
Sept. 16	2565	Sept. 21	1388	1529	2145	1687
Sept. 23	2716	Sept. 28	1344	1710	2402	1819
Sept. 30	2937	Oct. 4	1582	1439	2718	1913

*Bow Island.
**Dryland yield measured without adjusting for moisture content.
***Irrigated yield, adjusted to 9.6% moisture.

Harvesting and Storage *continued*

Safflower seed harvested damp needs to be dried with heat in a grain dryer before storage. A grain dryer can also speed up the harvest and preserve the whiteness of the seed coat. Prolonged wet weather at maturity causes dark brown staining of the seed coat if the safflower is left in the field. The discoloured safflower is unsaleable in the bird seed market.

It may be best to run wet, tough grain through the dryer twice to prevent damage to the seed.

Keep grain dryer temperatures below 58°C (135°F). Take care to avoid fires when drying grain.

Storage

Safflower seed is considered dry at 9.5% moisture or below. This moisture level will prevent heating, moulding and deterioration in storage.

Combine Adjustments/Drying and Aeration: Grower Experience

1. Combining safflower with a conventional combine

Combine: M.F. 860 Combine - Brian and Tom Otto, Warner, 1991:

- **Concave:** We have a wide spaced concave with filler bars blanking off the first three rows. It is set according to recommendations: front 0.8 cm (5/16 inch) and rear 0.32 cm (1/8 inch). To combine safflower, we open the front of the concave two notches to 1.11 cm (7/16 inch). We seldom find that we have to adjust the concave from this point.
- **Cylinder speed:** We use the slow speed on the cylinder gear box with the cylinder speed set at 550 rpm. This is our starting point. If we find a lot of damaged safflower (cracked), we slow the cylinder down. We also check for safflower left in the balls behind the combine. If so, we speed our cylinder up. A cylinder speed 500 to 600 rpm is the range for combining safflower.
- **Sieve setting:** We use the settings suggested in the owner's manual for barley for the top two sieves. The top sieve, front and rear will be set at 1.4 cm (9/16 inch). The middle sieve will be set at 0.95 cm (3/8 inch). The bottom sieve front is set at 0.95 cm (3/8 inch) and the rear is set at 1.27 cm (1/2 inch) or a little less. We find that the balls of the safflower tend to plug the bottom rear sieve if it is left open too far. It is recommended that the sieves be checked two to three times a day for plugging by the safflower balls. The balls tend to plug off sections of the sieves at times.
- **Wind:** We leave the wind board set to throw more wind to the front of sieves. This seems to help in cleaning the sample and saving the grain. There is a lot of material passing over the sieves and putting the wind to the front seems to lift it sooner for better cleaning and saving of the safflower. We start with the initial setting of the wind at 3/4 on the indicator. If we find that the machine is throwing over safflower, we adjust the wind downwards. In the past, we have found that by adjusting the wind volume up or down, we can solve most problems of throw-over. In most cases, we find that we are trying to use too much wind.
- **Straw chopper:** We back the cutting knife bar out of the chopper to combine safflower. If you have a Russian thistle problem, this is a must. Also, safflower leaves little trash so we try to leave as much of the plant material intact as possible.
- **Header:** We straight cut our safflower. We use a 9.15 m (30 ft) 9030 style header. The ground speed will be determined by the header. We have found that safflower tends to bunch at the throat of the feeder house. If your ground speed is too fast, this bunching will push safflower plants ahead and allow some plants to slip under the cutting header. Adjust your ground speed to get an even feed at the throat of the feeder house. The fingers should be reaching out as far as possible to feed the material into the throat. We have found that in most situations some plants will be missed.

- **Reel height:** This is also important. If we find that our ground speed is sufficient to feed the safflower plant onto the header without using it, we lift the reel right out of the crop. This happens rarely. Therefore, we have found that putting the reel down into the crop so that the bats hit just below the balls seems to be the best position. However, if the crop is dry and brittle, shelling may be a problem and at this point you have to adjust the reel height to where you get the least amount of shattering. The reel should be set so that the bats are close to the table auger, pulling the plant onto the knife and table. If it is too far out, you will find plants escaping.
- **Ground speed:** Our average ground speed is between 5.3 and 5.8 kph (3.2 to 3.5 mph).
- **Combine conditions:** We try to combine our safflower at a moisture content of 12 to 13%. We find that we lose less to shattering while combining and it is also easier to dry down to the recommended 9.5% moisture content.
- **Drying:** We were using a MC 600 grain dryer. We found that combining our safflower at 16% moisture required 2 to 3 passes through the dryer to get it down to 9%. We were worried about damaging the product if we tried to dry it any faster. The past year (1991) we moved to aeration drying. We have a Keho crossduct, above-floor system with a 5 hp squirrel cage blower installed in a 68 tonnes (at 40 lb/bu, 3,800 bushel) steel bin. We cut the safflower when it is at 12% moisture content. We aeration dried the safflower for five days with daytime temperatures of 20°C (68°F) and humidity of 50 to 60%. We let the blower go day and night only turning it off for one period of rain. Safflower requires less static pressure than other grains and is ideally suited for aeration drying. The product came out of the bin at 9% moisture.

2. Combining safflower with axial flow combines

2.1 I.H. Combines

Brian Otto, Warner, in 2003: using model 2188

- **Header:** I straight combine safflower using a MacDon draper header.
- **Concave:** The 2188 IH operator's manual has initial settings for combining safflower. They recommend using a large wire (wide space) concave for safflower. I have used both large wire and small wire (narrow space) concaves successfully in safflower.
- **Sieves:** The front section of the top sieve is the most important adjustment for threshing safflower properly. It must be adjusted properly to allow as much threshed safflower as possible through without allowing other material through at the same time. Improper sieve adjustment will push clean safflower to the back of the sieve and into the return. You do not want to have a lot of safflower passing through the return as this contributes to excess kernel damage. Sieve settings will vary according to crop conditions.
- **Wind:** Adjusting the wind will help to clean discs and leaves from the sample and also allow the clean material to pass directly to the clean grain tank. The wind adjustment may take some time but is very important in cleaning the sample. The recommended fan speed is between 750 and 850 rpm.
- **Rotor speed:** Rotor speed is very important. Running the rotor too fast leads to over threshing and creates problems in cleaning the sample. The rotor should be in slow speed position and turning at 400 to 500 rpm. Concave clearance should be in the 4 position on the indicator which is significantly wider than for wheat or barley. Check some of the threshed balls (heads) behind the combine to make sure all of the safflower seeds have been removed from the ball. Sometimes it may look like you are doing a good job of combining but on further inspection, some safflower will have remained in the ball. Closing the concave down a little usually solves this problem.
- **Reel height:** I use a pick-up reel, but this is not necessary for safflower. This just happens to be what I have on the header. I run the reel just below the ball height of the plant. If the reel is too high, plants will escape under the header and you will see balls left on the plant behind the combine. If the reel is too far (low) into the plant material, you will experience plants

Combine Adjustments/Drying and Aeration: Grower Experience *continued*

hanging on the reel and to begin a wrapping process. The reel should be set appropriately to the ground speed of the combine. Running the reel too fast will cause excessive shatter loss at the header and running the reel too slow will not allow the header to cut the plants off cleanly.

- **Ground speed:** This will be determined by the thickness of the crop and the ability of the combine to cut the plant off and feed it into the machine. I try to cut the safflower plant just below the balls. This usually leaves 25 to 30 cm (10 to 12 inches) of stubble in an average crop.
- **Crop moisture:** I prefer to start combining safflower at 12 to 13% moisture content and use aeration to dry it in the bin. Combining at this moisture content helps to prevent shatter loss at the header. If you have to pull material from the machine, be sure to use a good pair of leather gloves. Safflower has spikes very much like thorns on the ends of their leaves.
- **Cautions:** There are a lot of fine, white hairs while combining. These hairs will plug a radiator very quickly and I recommend that you blow the radiator out at least daily. These hairs are quite flammable and I recommend that the whole machine be blown off regularly (once a day). Air conditioning filters plug significantly sooner and I recommend that a replacement be kept handy.

Buck Spencer, Nobleford, in 1991:

- Straight combining safflower with the I.H. axial flow is relatively easy. I have used both 1460 and 1660 models. The 1460s were equipped with 810 headers and the 1660s were equipped with 1010 headers. The only difference between them is the larger diameter auger drum of the 1010 header. I was worried that the larger auger drum would shatter the safflower more but there was very little difference.
- There is less shattering when safflower is harvested at 14 to 15% moisture but it must be dried. Safflower will not store at more than 9.5% moisture. We have let the safflower dry standing and lost 1 to 2% by shattering.
- I have the reel turning very slowly, just close enough to stop the stalks from falling off the header. The concaves are then opened about 5 to 7.6 cm (2 to 3 inches), and the rotor speed set at 450 to 500 rpm. Fan speed varies with the weight of the safflower, but tough safflower (14 to 15% moisture) requires the fan speed being set as high as 600 to 700 rpm. I use air foil sieves and set the lower one as for barley. Barley settings for top and bottom sieves work fine if they are both adjustable. No special equipment is needed for the I.H. Axial Flow and it is fast and efficient.

2.2 Gleaner Combine (R6) - Jerry Kubik, Wrentham, in 1991:

- The concave opening is at 1.9 cm (3/4 inch) with a cylinder speed of 550 to 650 rpm. The chaffer opening is approximately 1.9 cm (3/4 inch) with the sieve set narrow at 0.32 cm (1/8 inch). This keeps most of the disks out of the sample. The fan choke should be set at 4 to 5 and checked frequently to ensure that no filled kernels are being blown out. A good wind setting also keeps a lot of fuzz and small branches out of the sample which makes it a lot easier to clean.

3. Combining Safflower with Rotary Combine

Combine: John Deere 9650 STS - Jerry Kubik, Wrentham , in 2003:

- **Header:** Honeybee header. This employs a draper type gathering system (canvases), which do a superior job of both gathering and feeding the crop smoothly.
- **Cylinder speed and setting:** This rotary type combine also allows us to run a quicker cylinder speed (650 rpm.). This seems to do a good job of threshing.

Combine Adjustments/Drying and Aeration: Grower Experience *continued*

- We also run a fairly wide open cylinder spacing (1.6 cm; 5/8 inch)
- **Sieve settings:** fairly wide open on the chaffer sieve (1.9 cm; 3/4 inch), and fairly tight on the bottom sieve (0.32 to 0.64 cm; 1/8 to 1/4 inch).
- **Wind speed:** We also pay very close attention to wind settings and try to run as high wind speed as possible without blowing out full seeds.
- **Sample cleanout:** We try to encourage our growers also to concentrate on cleaning up the sample from (safflower head) disks and fuzz as it makes the cleaning process much quicker and actually contributes to less total dockage! Last year (2003) was an ideal year for safflower and we were able to begin cutting at 11.5% moisture and put aeration on it immediately. This made for an almost ideal harvest as the product was clean, very heavy, of good quality and with very high germination (99%).

Markets in Canada

Safflower is a minor crop in Canada, and as such, not many companies handle it. However, using the following sites, one may be able to make relevant contacts.

The government of Alberta's Alberta Agriculture, Food and Rural Development department, as part of its Ropin ' the Web site, provides links to safflower contractors and other safflower contacts at the following URL: http://www.agric.gov.ab.ca/crops/special/directory/index.html, under 'Minor crops' then 'safflower'.

The government of Saskatchewan's Saskatchewan Agriculture, Food and Rural Revitalization department provides a Special Crop Marketing Company Synopsis at the following URL: http://www.agr.gov.sk.ca/docs/crops/special_crops/marketing/spcryn04.asp. Search for safflower.

The Canadian Grain Commission (CGC) lists licensed grain companies in Canada at the following site. Some of these companies may handle safflower: http://grainscanada.gc.ca/Regulatory/licensees/licensees-e.htm

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Notes

Notes

Conversion Factors

1) Length

To convert inches to cm .... Multiply by 2.54
To convert cm to inches .... Multiply by 0.394
To convert feet to cm .... Multiply by 30.48
To convert cm to feet .... Multiply by 0.0328
To convert feet to meters .... Multiply by 0.305
To convert meters to feet .... Multiply by 3.28
To convert miles to kilometers .... Multiply by 1.6
To convert kilometers to miles .... Multiply by 0.6

2) Area

To convert acres to hectares (ha) .... Multiply by 0.405
To convert ha to acres .... Multiply by 2.47
To convert square miles to sq km .... Multiply by 2.59
(i.e. 1 'section' of 640 acres = 259 ha)
To convert square km to sq miles .... Multiply by 0.386
To convert square feet to sq meters .... Multiply by 0.093
To convert square meters to sq feet .... Multiply by 10.76

3) Weight (mass)

To convert pounds (lb) to kg .... Multiply by 0.454
To convert kg to lb .... Multiply by 2.205
To convert ton (short, 2000 lb) to kg .... Multiply by 907
To convert tonne (long, 2240 lb) to kg .... Multiply by 1000
To convert kg to ton (short, 2000 lb) .... Multiply by 0.0011
To convert kg to tonne (long, 2240 lb) .... Multiply by 0.001

4) Yield

To convert lb/acre to kg/ha .... Multiply by 1.121
To convert kg/ha to lb/ac .... Multiply by 0.892
To convert lb/bu to kg/hl .... Multiply by 1.25
To convert kg/hl to lb/bu .... Multiply by 0.8
(Note: Canadian bu = 2219 cu inches, used in above; U.S. bu = 2150 cu inches)

Yield			Bushels/ac		
lb/ac	kg/ha	Test Weight:	38 lb/bu (47.5 kg/hl)	40 lb/bu (50 kg/hl)	42 lb/bu (52.5 kg/hl)
2400	2690		63.2	60	57.1
2000	2241		52.6	50	47.6
1600	1793		42.1	40	38.1
1200	1345		31.6	30	28.6
800	897		21.1	20	19.0

5) Temperature

To convert °F to °C .... Subtract 32 then multiply by 0.556
(i.e.: 86°F is 30°C)
To convert °C to °F .... Multiply by 1.8 then add 32
(i.e.: 20°C is 68°F)