This bulletin represents the state of safflower production knowledge in Washington State as of February 1999. The information was gathered from a workshop held in Washington State. Workshop speakers included Ed Adams, WSU Plant Pathologist; Jon Newkirk, WSU Economist; Diana Roberts, WSU Agronomist; Clair Stymiest, South Dakota University Agronomist; Doug Walsh, WSU Entomologist; and Ed Warner, farmer, K & L Farms. Several growers and agronomists are producing and testing safflower in Washington to evaluate abilities to produce this crop annually. If you are considering producing safflower, this is a place to start.

**GROWING SAFFLOWER IN WASHINGTON**

Safflower (*Carthamus tinctorius*) is a domesticated broadleaf thistle being evaluated as an alternative crop to cereal grains in eastern Washington (Table 1). Safflower resembles yellow starthistle and is a member of the same plant family as sunflowers.

Safflower breaks weed and disease cycles in cereal crops. The plant grows to a height of 36 inches, producing a large root mass to a depth of 10 feet. It requires a growing season of 110 to 140 days, depending on the variety. To produce a crop, 2,200 growing heat units with a 120-day frost-free growing season is needed, which may be unattainable in some parts of eastern Washington.

Safflower is a spring-planted annual that requires warm, dry conditions when flowering and maturing. Deep, fertile, well-drained soils with ample stored soil moisture are preferred. Producing a yield of 1,200 lbs/acre requires about 15 inches of moisture, either as summer precipitation or available in the soil profile. In the rosette stage, the plant is frost-tolerant, handling temperatures as low as 20°F; however, it is frost sensitive after the initiation of stem elongation.

Safflower has been grown in large test plots in various parts of eastern Washington. At the Wilke Farm near Davenport, where plots are planted no-till, and at a location near Reardan, yields under hot and dry conditions in 1998 were about 600 lbs/acre. The crops were part of a planned rotation that included both spring- and fall-seeded crops.
Rotational benefits and the ability to use another crop to spread marketing and production risks are two reasons why safflower is being evaluated as an alternate crop. Including a broadleaf crop in a rotation with cereal grasses may reduce pesticide requirements for subsequent cereal crops. Other benefits include the opportunity to break insect, disease, and weed life cycles. The dense root structure can improve soil tilth and porosity. When grown in a no-till system, the roots create macropores that act similar to a subsoiler breaking up a plow pan. The roots also add to organic matter, improving soil's water-holding capacity. However, chaff rows from the preceding harvest impeded safflower emergence on the Wilke Farm plots suggesting that crop residues can play an important role when seeding safflower.

Safflower is susceptible to white mold. Because sunflowers, peas, lentils, and canola are also susceptible, it is best not to follow any of these crops with safflower in a rotation.
An oil-seed crop, safflower can produce an oil content up to 45%. Different varieties have different oil characteristics. White-seeded varieties produce oil with higher linoleic acid levels having polyunsaturated characteristics that may be used in salad oils and soft margarine. The birdseed market also prefers white-seeded varieties, which may command premium prices. White-seeded varieties with high oleic acid levels may have more marketing flexibility. The Japanese market prefers oils with high oleic acid levels for cooking and industrial uses. These tend to be striped-seeded varieties.

Some types of safflower oil also have industrial uses. Safflower produces a drying oil that has characteristics intermediate between soybean and linseed oils. The oil is used to produce non-yellowing drying paints, alkyd resins in enamels, caulks, and putties.

Table 1. Safflower at a Glance.

<table>
<thead>
<tr>
<th>Scientific Name:</th>
<th>Carthamus tinctorius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height:</td>
<td>12”–36”; branches 18”–30” long</td>
</tr>
<tr>
<td>Rooting Depth:</td>
<td>up to 10 feet</td>
</tr>
<tr>
<td>Growing Season:</td>
<td>120 frost-free days</td>
</tr>
<tr>
<td>Heat Requirement:</td>
<td>2,200 growing heat units</td>
</tr>
<tr>
<td>Moisture Requirement:</td>
<td>15 inches available moisture for 2,000 lbs/acre yield</td>
</tr>
<tr>
<td>Planting Depth:</td>
<td>1” or less</td>
</tr>
<tr>
<td>Seeding Rate:</td>
<td>20 lbs/acre</td>
</tr>
<tr>
<td>Target Plant Population:</td>
<td>130,000 plants per acre</td>
</tr>
<tr>
<td>Row Spacing:</td>
<td>6”–20”</td>
</tr>
<tr>
<td>Nutrient Requirement:</td>
<td>100 lbs available nitrogen for a yield goal of 2,000 lbs/acre P, K, S, and micronutrients as indicated by soil test</td>
</tr>
<tr>
<td>Potential Diseases:</td>
<td>Alternaria blight leaf spotting disease, Sclerotinia head rot, damping off, rusts, white mold</td>
</tr>
<tr>
<td>Potential Insects:</td>
<td>wireworms, cutworms, lygus bugs</td>
</tr>
<tr>
<td>Markets:</td>
<td>Oilseed and birdseed for good quality, livestock feed for low test weight</td>
</tr>
<tr>
<td>Potential Yield:</td>
<td>In South Dakota, yields range from 1,000 to 1,400 lbs/acre, for an average of 1,200 lbs. A 2,000-lb yield is attainable with 15” of precipitation. In the Pacific Northwest, 1,600 lbs/acre is probably more attainable</td>
</tr>
</tbody>
</table>
WEEDS, INSECTS, AND DISEASES

Washington safflower growers should not expect to see any major crop pest problems right away because many of the known pests have not yet migrated into the area. Currently, farmers are planting into a new field each year, which reduces the possibility of problems unless we bring in contaminated seed. One way to keep pests out of the area is to make sure you get good, clean seed. In a few years, when safflower has been grown in the area for awhile, growers should watch for developing problems.

Weeds. To minimize weeds, use normal, common sense precautions, such as using weed-free seed, seeding relatively weed-free fields, using machinery and vehicles that are free from weeds and weed seeds, and not spreading manure that may contain weed seeds on clean fields. Cultural measures that can help reduce the impact of weeds include tillage, use of competitive crops, or high crop population densities. Small patches of weeds can be hand-weeded. Exceptionally weedy stands or weed patches can be mowed or tilled to keep them from going to seed. If weeds appear to be a potential problem after seeding or before emergence, you may want to harrow.

Volunteer wheat can be a problem in safflower. You can expect a good crop on cereal stubble if you have adequate moisture reserves, but volunteer wheat is a problem to separate from safflower. If you have trouble with wheat volunteering, you may want to plant in fallow fields, or wait until there are some grassy weed herbicides available.

Appropriate herbicides (Paraquat) can also be used in postharvest or follow-up applications the year prior to planting safflower to control weeds. Be cautious when using broadleaf herbicides that may carry

Figure 3. Weeds invading safflower where canopy was thin.
over and harm the safflower. Tri Judiciary can be applied pre-plant and incorporated. It will control a variety of grasses and broadleaf weeds. There are no registered materials for post-emergence control of wild oats.

The availability of herbicides for weed control in safflower depends on the end use of the seed. What is or is not registered depends on whether the end use is for livestock fodder, forage, refined oil, or seed. The important factor in pesticide regulations is the tolerance level, which is set by EPA. The tolerance is the maximum allowable residue on the consumed product. Also involved in pesticide regulations are USDA and the Washington State Department of Agriculture. Products applied to safflower must be registered for use on safflower within the state it is applied to be legal. If the residue level is above the tolerance, then use on the crop is illegal. If there is no stated tolerance, then any residue is illegal since there is no legal tolerance level established.

Insects. Insect pests include wireworms, cutworms, and lygus bugs. Of these, only Lygus spp. are presently a factor in the Pacific Northwest. Wireworms, the larval stage of click beetles, reduce stands by feeding on the germinating seeds. Seed treatment of cereals in the rotation can keep damage by wireworms to a minimum by preventing the buildup of damaging populations. Cutworms feed on seedlings at or below the soil surface, weakening or severing the stem. Cutworms favor loose soil in the fall and a weedy summer fallow. Although not yet a major problem, growers in Asotin County, Washington, have noted damage from lygus bugs. These bugs can destroy seed heads by feeding on them and the developing seeds. There is no economic threshold developed yet to determine treatment levels. Lygus bugs are an occasional pest in south central Washington requiring treatment some years based on populations.

Among the insecticides are biological products, some of which are fungi that kill the insects. These products have a low residual action and some of them require high humidity to be effective.

Among the chemicals, endosulfan (Thiodan) has an established tolerance and a registered label in Washington. A tolerance has been established and a Washington label registered for malathion for use as a foliar spray for seed production and in refined oils. The manufacturer has cancelled the tolerance for Supracide (methidathion).

Diseases. The leaf spotting disease caused by Alternaria does not appear to be present in Washington State. The dryer weather patterns in Washington may help prevent infection by this disease. As a further step in preventing problems with fungal diseases, avoid seeding in cold, wet soils. Thiram can be used as a seed treatment.
SAFFLOWER ECONOMICS

A four-year and a three-year rotation are being replicated on the Wilke Farm near Davenport, as well as by several cooperators around the region. Two safflower treatments were in the rotations in 1998, yields of which were poor. One rotation produced 519 lbs/acre; the other rotation was consumed by wild oats. The full economic costs for the two rotations were $138 and $133 per acre. Only one year of data is available and is not significant. The costs must be considered for the entire rotation system rather than just for the safflower. These costs will not be known for two or three more years depending on the rotation. The project has not drawn any real strong conclusions at this time; however, it is expected that some synergistic effects from one crop benefiting another in the rotation will be seen.

Another cooperator got a yield of 800 lbs/acre and sold for $0.30 a pound, which made the economics look better. Wheat in the same rotation sequences on the Wilke Farm produced double the income of the safflower. A change in the rotation may handle the wild oats problem, which would improve yield. Full costs in South Dakota are $107 to $120 per acre, meaning that a grower needs a price of $0.10 a pound and a yield of 1,200 lbs/acre to break even.

Contracts are essential to ensure a market before planting a crop. A well-established marketing and handling avenue currently is unavailable in Washington; however, oilseed markets are present for crushing plants in North Dakota, Montana, and California. In 1999, McKay Seed offered contracts at $0.115 a pound for the first 500 pounds. After that the open market price prevailed. The other market is the birdseed market. There is a plant in Spokane, Washington, but it is not a big operation and does not have enough capacity to handle all eastern Washington could produce.

GROWER EXPERIENCE—K & L FARMS, WASHINGTON

K & L Farms has two years of experience with no-till safflower using a John Deere 750 drill. They use a four-year rotation with three grasses and a broadleaf. The farm includes 3,000 acres in no-till out of 5,600 acres total. In 1997, the yield was approximately 1,200 lbs/acre on a 40-acre field. In 1998, all the fields had a combined average between 800 and 900 pounds.

Before planting, they conducted a soil test by splitting the first foot into two 6” increments and testing to a depth of 4 feet. The final application rate depends on the soil test results, which reveal the available moisture and soil type.
Rotations are very important both for control of the fungal-type diseases and weed management. A safflower field planted following a crop with poor weed control caused some real nightmares. Part of the problem may have been that K & L was trying to use a herbicide labeled for incorporation, but was not incorporating it. The cleanest fields they have had were those in a spring wheat–spring wheat–safflower rotation. Because of its ability to draw moisture from deeper soil profiles, it might be best to follow safflower with a cool season grass planted early, such as spring wheat.

K & L Farms tries to plant safflower in fields with little or no history of broadleaf weeds and Russian thistle because of the challenges they create. Safflower is a poor competitor in the early growing cycle. It takes up to 3 weeks to emerge and spends 3 to 4 weeks in the rosette stage, so it has 4 to 7 weeks when it is noncompetitive with any broadleaf. This is significant because many wild oats and broadleaf weeds germinate in April and May in our region. Rotating into grass-type crops and not disturbing the ground by using minimal disturbance methods has reduced the broadleaf problem in the safflower crop.

Uniform, clean, high-quality seed with a high germination rate is very important to keep from introducing problems from another part of the world. Seeding rate varies depending on the quality of seed. If fungus diseases are anticipated, K & L Farms treats the seed with Thiram. They aim for a seeding rate of 20 to 20 lbs/acre pure live seed (PLS). The seeding depth is 1"–1 1/2", and they plant into soils that are at least 45°F at seeding depth.

It is also important to separate the seed and fertilizer. Initially, the farm tried banding 13 pounds of nitrogen with the seed; however, that rate proved too high, and they are now using 8 to 10 pounds. Because of the need to separate the seed and the main fertilizer application, they are now fertilizing in late fall or early spring using either a farm-owned Blu-Jet applicator or a rented spoke injector. The Blu-Jet is a disc coulter that slices the ground creating less soil disturbance than a drill. This is followed by fertilizing with either aqua or Solution 32 using a high-pressure (100 to 120 psi) liquid fertilizer injector. The spoke injector is like a bicycle wheel without the rim. The center hub has an opening on the bottom side and as it rolls through the field, fertilizer is injected through the spokes. A 16-20-0-14 starter fertilizer is applied with the seed at varying rates. This is in addition to the aqua or Solution 32 applied pre-plant according to soil test findings.

Using these fertilizer application systems allows application without disturbing the soil at a time when K & L Farms is not pressed for time and labor. Both of these fertilizer application systems have
been used in the fall, but K & L has not used the spoke injector in the spring, only the Blu-Jet. The Blu-Jet has been used under varying soil moisture conditions. When using the Blu-Jet late in the fall, the soil temperatures have cooled to the point where the aqua does not convert. Even when injected in dry conditions, K & L has not seen volatilization of the aqua.

Experience with fertilizer has found better results when applied to the root zone rather than when the crop is planted, due to the rainfall patterns and the way the moisture moves in the soil. In the past, K & L has found fertilizer located above the root zone following the completion of a crop. Fertilizer is applied in the fall and again when the soil warms in the spring, causing the aqua to start converting a little quicker than if it is all applied when seeding.

K & L Farms has tried Treflan pre-plant in the dry granular form unincorporated in the fall, at two different times in the fall, as well as making a spring application. Using Treflan in the fall or in the spring showed little or no benefit; however, other farmers in this area who have used Treflan in the liquid form report having fair success by spraying while it was raining to get the Treflan into the ground. K & L Farms uses the John Deere low-disturbance drill, whereas the other farmers reporting success with Treflan use a Concord drill which creates quite a bit more disturbance.

Harvest the crop when it is ripe—this will be at 9 to 13% moisture since late fall rains and other factors can decrease the quality of the crop. The crop threshes out relatively easily; combine settings will vary with the manufacturer. The usual fall frost will aid the drying process. It is possible to plug a combine. If you do, you need to wear heavy leather gloves, protective clothing, and eye protection.

Storage has not been a problem. The crop must be stored below 9% moisture; aeration is a very good idea if it is available. Because this is an oilseed crop, too much moisture creates heat, which can cause combustion.

K & L Farms has marketed both oilseed and birdseed. The quality was good with bright, uniform, white seed. Quality with no weed seeds is important for birdseed. Contracting the crop in advance, if possible, is advised. Safflower can be grown in a dryland area if all aspects of its production and marketing are considered; otherwise, it can be disastrous.

GROWING SAFFFLOWER IN SOUTH DAKOTA

The following notes from Clair Stymiest’s presentation represent South Dakota farmers’ experiences with the crop. While the climate
is different, South Dakota farmers have a lot of experience producing safflower. Safflower grows in South Dakota in a summer rainfall pattern region receiving between 11”–15” of annual precipitation. The crop is sensitive to rainfall in June, July, and August, and higher humidity is not desirable because Alternaria, which is a major problem for producers in South Dakota, is encouraged by humid conditions. This leaf-spotting disease can dramatically reduce yields if severe.

In South Dakota, safflower is produced at elevations from 3,400 to 1,600 feet. Twenty-two hundred growing heat units are needed to mature the crop, but cool nighttime temperatures do not seem to have a negative impact. If the crop is not mature when the first frost occurs, test weight will be lowered. South Dakota growers tend to plant in mid-April. There is no advantage to planting earlier. A soil temperature of 40°F is needed for germination and emergence. This may be a consideration when planting no-till. Even if you can get into the field and plant, it may be detrimental to the crop. In addition, no-till seeding, if planted with a low disturbance drill, may be slower to germinate and emerge if crop residue on the soil surface keeps soil temperatures down.

Among the advantages of using safflower in a rotation is its ability to adapt to dry weather and the fact that the plant’s root mass actually increases with rooting depth. The crop takes moisture from the subsoil to a depth of 6 feet—nitrogen from even greater depths. Because of this, it may not be necessary to add nitrogen fertilizer.

Quality is important, no matter what the final use of the crop. Standard purity for safflower is 99%. Large seed is called “bold” in the trade. The birdseed market requires well-filled seed with a minimum test weight of 38 lbs/bu. The average for South Dakota producers is 40–42 lbs/bu. High levels of wheat, Russian thistle seeds, or any other type of unclean admixture in the sample can make safflower difficult to clean and hard to market.

The birdseed market includes feed for racing pigeons, parrots, pet birds, gerbils, hamsters, and other small animals such as chinchillas. Seed for this market must be uniformly snowy white and large. It also must be free of “pappus” or the bristles on the end of the seed. Seed carrying the brown stripes, found on some oilseed varieties, or that has molding or staining from diseases or wet harvest weather is unacceptable.

The oilseed market demands seed with more than 34% oil. If the oil content is lower, the crop is discounted. Oil content generally follows test weight; there can be a premium for higher oil content. Factors such as diseases causing premature death of leaves and stems will shorten the seed-filling period and reduce oil content. The Japanese
market prefers oil levels above 40% and generally has purchased safflower from California where oil levels tend to be higher.

In South Dakota, test weight and oil content depend on the weather conditions in late August and early September. If rain, high temperatures, and humidity occur during this period, Alternaria can destroy the leaves and reduce the grain fill of the crop.

Safflower with a low test weight, 28–30 lbs/bu or less, is only marketable as livestock feed at a price of about $0.04 a bushel. The seeds can be fed whole, with no processing.

**Growing Characteristics.** The safflower seed germinates in 1 to 3 weeks, depending on soil type and moisture. Following germination, a slow-growing rosette stage develops, and the taproot forms. This stage lasts 2 to 3 weeks and is then followed by stem elongation and the formation of 18”–30” branches. At the end of each branch is a seed head enclosed by bracts.

**Drills.** The John Deere 750 does an excellent job of planting safflower because of the good depth control it provides. The Concord air drill also works well, despite concerns with depth control on steeper hillsides. Depth control is important; the ideal seeding depth is 1” or less—2 1/2” is not desirable. Planting too deeply will create emergence problems.

Safflower is much more sensitive to soil crusting than you would think considering the size of the seed. Reference materials say you should seed deep enough to put the seed into moisture, but experience in South Dakota reveals crusting can be a problem if it rains.

Good soil-seed contact is essential for germination and stand establishment. Packing of some type is necessary to prevent unwanted
air pockets. Growers should not worry about packing too hard. John Deere solid press wheel drills are used in South Dakota; they do not pack too hard, yet they pack as hard as any. The John Deere air drill, which has a single wheel packer, also performs well.

When using a drill with a disc-type opener, growers have seen some problems with “hair-pinning” of crop residue into the seed furrow in no-till situations with heavy residue, most frequently with chaff rows not spread widely. This can wick moisture away from the seed. If the residue is spread out, this generally is not a problem.

Unlike corn or sunflower, safflower seeds nicely through air systems. The bloom stage lasts 14 to 21 days, depending on stand density, available moisture, and variety. Flowering starts on the central stem and spreads outward. Each head flowers over several days, with the flower developing from the outside towards the center. Developed heads each contain 15 to 30 or more seeds. The seed matures within 30 to 35 days of flowering. It takes about 2 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 grayish-white and rub freely from the least mature seed heads.

South Dakota growers use a seeding rate of 20 lbs/acre and aim for an in-row seed spacing of 3” on 10”-row spacing. The minimum should be two plants per foot in rows spaced at 6” and twice that many in 12” rows. Growers should aim for a population of around 130,000 plants per acre to get good yields. Safflower branches readily and will compensate for skips, but you do not want a skip any longer than 20” down the row. Narrow rows provide the potential for greater disease problems, but fewer weed problems. Problem weeds for South Dakota growers include the yellow and green foxtails. The grasses are generally easier to control than broadleaf weeds. Yield reductions from using 20” rows versus 10” rows have not been seen as long as you can control weeds, but it is a trade-off. Wider rows in wet years have produced better yields due to the reduction in disease pressure, but the wide rows do encourage weed competition.

Although wheat can be a good crop following safflower, it is very important to control the volunteer wheat. It is difficult to separate wheat from safflower. Wheat as a contaminant will lower the safflower quality.

Crop water use peaks in September. The crop is not sensitive to hot weather, is drought tolerant, the extensive root system will compensate in moisture recovery and keep up with the plant’s moisture requirements, and the waxy leaf surface reduces plant moisture loss. The ideal situation is seasonal precipitation to get the crop started, and then rely on soil moisture to finish the crop.
Because safflower is a minor use crop, unless a herbicide is already cleared for use on sunflowers or some other oilseed crop, it’s pretty hard to get it cleared for use on safflower. The best way to ensure good weed control is to plant into a clean field.

At harvest time, safflower combines easily, but green weeds can cause problems. The crop is “fuzzy” and only careful attention will prevent buildup of this highly combustible material on combines resulting in combine fires. There are no chaff rows to speak of when harvesting safflower because the entire crop goes through the combine; however, you have to be careful because the fuzz gets into your radiator. Generally, you should carry a fire extinguisher or water on the combine. You will not plug the combine on safflower by itself, but a big old green kochia weed will plug it.

A typical South Dakota rotation is spring wheat, safflower, millet, sunflowers, and winter wheat. A yield boost occurs when spring wheat follows safflower. This is also true for the Proso millet, which emerges in about 3 days. Barley also will work following safflower and it is not sensitive to Treflan. Winter wheat following safflower is generally not going to work for a couple reasons. Winter wheat is sensitive to Treflan and you would be seeding back into the ground treated with Treflan in the fall. This crop grows through the end of September at which time you will be harvesting. If you do not get a stand in the fall and have to re-seed in the spring, the residue will not catch snow over winter. When you seed in the fall, the drill knocks down an awful lot of stubble, even using no-till. The safflower stubble is fragile and will not leave enough crop residue to stop water erosion.

Safflower is a good crop in which to no-till. The ground is hard and dries out due to lack of ground cover, so you can get into the field and plant spring wheat early enough so it can germinate, grow, and flower before extreme hot weather hits. South Dakota growers typically plant spring wheat in late March. In the Rapid City area, no-tilling into safflower stubble has increased chances of raising spring wheat seven out of ten years, whereas the odds before were three out of ten years.

**Diseases.** Alternaria blight or leaf spotting disease is a major problem for safflower growers in South Dakota, especially under humid conditions. (Note: These conditions are rare in eastern Washington.) Before flowering, the disease will appear on leaves and flower bracts as small brown to dark brown spots which spread to about 1/2” in diameter, often with concentric rings. The spots may join to form large, irregular lesions. Severe infestations may cause cracking and browning of the entire leaf. When this happens, you have lost the crop because it is too late to apply control measures. The pathogen attacks safflower heads and causes a brown discoloration at one
end of infected seeds. Infected seeds can cause seedling blight and damping-off. Crops are lost if it gets inside the seed heads. In severe cases, there is an absence of flower heads, or the seeds are shrunken and empty. Recommended controls include using seed produced in areas of low rainfall and low seeding rates. Plant populations that allow good air circulation reduce the severity of the disease.

Sclerotinia head rot, caused by *Sclerotinia sclerotiorum*, is a serious safflower disease in western Canada where severe infections in susceptible varieties have resulted in crop loss. Outbreaks occur under prolonged humid conditions during the flowering to seed development stages. Small mushrooms emerge in moist soil and shed spores that infect the heads. Affected heads are rotted and flower bracts will have a bleached appearance. If seed shells form, they will be 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. Diseased heads dry and are easily detached from the stem by strong winds. The pathogen may also attack safflower roots via a white fungal mass called mycelium, causing the affected plant to wilt. Recommended control for head rot is to plant resistant varieties. Saffire is resistant to head rot with generally less than 10% of heads infected in severe cases. AC Stirling is moderately resistant, but other varieties, including S-208 and S-541, are highly susceptible. Another control measure is field rotation. Allow at least four years between susceptible crops. Canola, dry peas, dry beans, sunflower, and lentil are susceptible to *Sclerotinia* and should be avoided in the rotation. Cereals and grasses are immune to this pathogen. The final control is seed free of contamination.

A safflower rust, caused by *Puccinia carthami*, is also common in western Canada. It is rarely a serious problem because it usually occurs late in the season. On the other hand, severely rust-contaminated seeds will not germinate well. The varieties Saffire and AC Stirling are both susceptible to rust. Rust on contaminated safflower seeds can attack cotyledons, leaves, and stems of young seedlings. This causes yellow discoloration and drooping of the cotyledons. The disease is most noticeable from flowering to seed development. Numerous tiny orange-brown pustules are formed on leaves and flower bracts. Late in the season, pustules turn black to form larger rust patches. Severely affected 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. Recommended controls include field sanitation and the use of rust resistant varieties. Field sanitation is important because the pathogen can overwinter as black teliospores on infected plant material and removal of infected plant debris will reduce the load of inoculum in the field.
Alternaria cathami, Pythium, or Fusarium may cause damping-off and seedling blight. It is one of the major causes of poor stand establishment in safflower and is most prevalent when the soil is cold and wet following planting. The symptoms include failure of the seed to germinate or failure to emerge. Emerged plants may collapse and die, resulting in gaps in rows or generally thin stands. High mortality of seeds or young seedlings is due to rapid invasion of the cotyledons, rots, 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. Controls include not planting safflower in fields where damping off has been a problem in the past, not seeding safflower into cold, wet soils, and use of Thiram powder (0.2 to 0.3%) as a seed treatment to partially reduce damping-off and seedling blight.

Nutrient Requirements. In South Dakota, growers are using 20 to 25 pounds of P<sub>2</sub>O<sub>5</sub> with the seed in medium and low testing soils to stimulate early growth in the safflower. Safflower is a full-season crop that grows during the warm portion of the summer, so it probably will not respond unless the soil test for phosphorus is low.

Sulfur is another important nutrient for safflower. If soil tests show sulfur at deeper levels, the plant will reach the zone where the sulfur has leached. This means the sulfur will be important if the soil tests do not show sulfates deep in the soil. If they are there, sulfur probably will not be needed.

A 2,000-pound safflower crop has about the same nitrogen requirement as a 40-bushel wheat crop. A total requirement of 90 to 110 pounds of nitro-

<table>
<thead>
<tr>
<th>Yield Goal</th>
<th>Soil Test Phosphorus, ppm</th>
<th>Soil Test Potassium, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bray-1 Olsen fertilizer N required</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil N plus STN</td>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;/acre</td>
</tr>
<tr>
<td></td>
<td>0-5 6-10 11-15 16-20 21+</td>
<td>0-40 41-80 81-120 121-160 161+</td>
</tr>
<tr>
<td>lb/a</td>
<td>lb/ @ 2’</td>
<td>lb/</td>
</tr>
<tr>
<td>800</td>
<td>40</td>
<td>20 14 10 0 0</td>
</tr>
<tr>
<td>1200</td>
<td>60</td>
<td>29 21 13 0 0</td>
</tr>
<tr>
<td>1600</td>
<td>80</td>
<td>39 28 17 10 0</td>
</tr>
<tr>
<td>2000</td>
<td>100</td>
<td>49 35 22 10 0</td>
</tr>
<tr>
<td>2400</td>
<td>120</td>
<td>59 42 26 10 0</td>
</tr>
</tbody>
</table>

Nitrogen recommendation = 0.05YG – STN – PCC – SDA
Bray 1 P recommendation = (0.027 – 0.0014 STP)YG
Olsen P recommendation = (0.027 – 0.0017 STP)YG
Potassium recommendation = (0.048 – 0.0003 STK)YG

Table courtesy of South Dakota State University Cooperative Extension and USDA
units of nitrogen in the soil as either carryover from previous crops or added fertilizer is needed. Safflower is sensitive to salt effects, so do not add nitrogen close to the seed. It is more sensitive than wheat or barley, so do not put more than 10 units of nitrogen in the furrow with the seed. Broadcasting nitrogen is the best application method. In a drier region, apply nitrogen in advance to get it down into the soil before planting. If applying fertilizer when seeding, put most of the required fertilizer in a deep band separated from the seed by 1\(\frac{1}{2}\)"–2". The salt effect is not a problem, and the crop roots will grow down into the fertilizer.

Other micronutrients are generally not a problem unless soil tests show they are totally lacking. Soil tests to depths of 6 feet are recommended, and segmenting soil samples into 6" increments on some fields is suggested. This will show the composition of the soils and concentration of available nutrients in the soil profile. Some farmers in South Dakota have found that nitrate levels have actually been found in the deeper parts of the soil profile in no-till situations following wheat.

The yield goal is determined by available moisture. If there are 15" of total available moisture, a 2,000-pound yield is possible. However, yield expectations of 1,200 to 1,400 lbs/acre are probably more realistic. If 100 pounds of nitrogen were needed for a 2,000-pound crop, the total nitrogen requirement for a 1,200- to 1,400-pound crop would probably be in the neighborhood of 75 to 80 pounds. A moist season can increase the amount of nitrogen available to the crop by increasing the rate of decomposition of crop residues.

Most safflower grown for seed is grown in irrigated dry regions. Seed suppliers always pick up the seed from very dry regions because it is free from diseases. Furrow irrigation is best. In very dry irrigated regions, the potential for seed production is very good if you have moisture to soak up the subsoil and you can pick a time when the soil will be drying after irrigation to minimize disease problems. Safflower will work under irrigation; however, the value of the crop may not warrant the use of expensive irrigation water.

**SAFFFLOWER AS A LIVESTOCK FEED**

Meal from de-hulled seeds is a high quality protein supplement similar to canola meal, but has slightly more protein and energy. Full-fat safflower contains 16 to 18% protein. The meal left after the oil is extracted contains about 24% protein and is used as livestock feed. Most safflower meal contains hulls and is a medium-protein meal containing about 25% crude protein. It has a high fiber content, about 50%.
Hulled safflower meal is comparable to dried brewers’ grains as a feed for ruminants, although the fiber is less digestible. Limited research indicates that safflower meal is relatively high in ruminal “bypass” protein, making it a good alternative protein supplement for lactating dairy cows. Other research indicates that feeding safflower can potentially increase conception rates in beef heifers by as much as 20%.

Safflower has a slightly higher fat content and a slightly lower protein content than cottonseed. Full-fat safflower is the whole, unprocessed seed. It has a high fiber content—about 50% ADF—which limits its use in all but special-situation rations for swine and poultry. On the other hand, it is a good source of fat for lactating dairy cows. Lactating dairy cows receiving more than 2 to 3 kg/day of high linoleic acid safflower seed can develop an oxidized flavor in their milk. When this occurs, feeding higher levels of dietary vitamin E can eliminate the problem.

The easiest way to feed safflower is to just spread it on the ground. After the livestock becomes acquainted with it, they like it and will pick it from the ground. However, in beef cattle, safflower does not work as well as other protein sources in a finishing ration, especially if it is fed free choice. It tends to reduce the consumption of other feeds and actually slows rate of gain for this reason.

The value of safflower meal as a feed is known; the feeding value of whole seeds is not. Producers probably should not rely on the livestock feed market as an outlet for low-quality safflower seed.