

A Crop Profile for Safflower Production in California

March 2016



Safflower Production Facts

- Annual US production of safflower is valued at ~\$52 Million grown on ~170,000 acres.
- There are ~50,000 acres of safflower grown each year in California; the crop is valued at ~\$26 M.
- California produces the highest yielding (~1000-3600 lb/A) and highest quality safflower (~45% oil) in the US.
- Other safflower producing states are Utah, Colorado, Idaho, Montana, North Dakota and South Dakota.
- Safflower acreage fluctuates according to crop rotation needs, relative market value, water availability and other production constraints.
- Safflower provides options when a substitute or rescue crop is needed following crop failure.
- Approximately 60% of the California safflower crop is used in domestic markets.
- Export destinations for the crop include India (~30%) and Japan (~10%).
- Because of its minor status in world crop production, safflower production statistics are difficult to obtain on a consistent basis.
- Safflower is well-suited crop for arid regions and can grow on less moisture than other oilseed crops such as canola, sunflower and soybeans.
- The deep taproot of safflower allows the plant to efficiently mine the soil profile for moisture.
- The crop can also help dry up fields that have been flooded.
- The major value of safflower in California is as a rotational crop and environmental benefits; unlike other crops, it is not grown for direct economic return.
- A primary benefit of safflower is that it gives growers flexibility and options to plant a crop that enables them to adjust to drought conditions, water quality issues (salinity), and changes in local and regional water allocations.
- Soil health benefits of safflower include increased soil organic matter and improved soil structure through bio tillage.
- In wet years, safflower can be a management tool to dry out soils and thus reduce build up of soil borne diseases.
- The strong taproot of safflower provides excellent bio tillage of the soil which can reduce the need for mechanical cultivations. Related environmental benefits include: reduced particulate matter in the air, reduced volatile organic compounds in the air, and finally, to reduce potential for soil compaction.

General Crop Information

Safflower, (*Carthamus tinctorius*) is an annual thistle-like plant in the sunflower family. It is native to Asia, the Middle East and Africa. Initially grown for dyes extracted from flowers, the predominant use is now for oil extracted from the seeds. Cultivated varieties are characterized as being oleic or linoleic according to the type of fatty acids they produce. California produces oleic varieties for human consumption; these are recognized for benefits to cardio vascular health. A by-product of safflower production is the seed meal used as livestock feed.

Safflower is extremely well adapted to arid regions and is considered an easy crop to grow. The upright annual broadleaved plant stands at 2-4 feet upon maturity and has many spine tipped leaves that make contact with the plant unpleasant. The stem and branches are very coarse.

The deep taproot is extremely effective at mining limited moisture and residual nutrients throughout the soil profile. This contributes to many benefits for soil health including building organic matter, improving soil tilth and promoting water percolation throughout the soil. These attributes make it an excellent rotational crop in many states, but especially in California.

California has long been recognized as having an ideal climate for safflower, but focused research by USDA did not begin until the 1930s. Production as a commercial crop flourished in the 1950s when the University and of California and USDA expanded the germplasm base to develop superior varieties for California conditions in the Sacramento and San Joaquin Valleys.

An excellent review of the production, use and history of safflower as a cultivated crop is contained in the book, *Safflower*, written by Joseph Smith in 1996.

Information generated on field practices by the University of California Cooperative Extension Service and two large oilseed companies, Pacific Vegetable Oil Company and Oilseed Products Company supported increased plantings in the Sacramento Valley and San Joaquin Valley. Production peaked in the 1960s at ~400,000 acres, but since this time, production has dropped off significantly.

In California, the loss of safflower acreage has been due to transitioning to higher value crops such as fruits, nuts and vegetables as to land and water costs have risen. Today, there are about 50,000 acres produced each year and safflower is primarily used as a rotational crop to give options to farmers. It has proven to be an excellent in combination with processing tomatoes, cotton, alfalfa, wheat and dry beans particularly in areas under saline and sodic conditions.

The taproot of safflower can penetrate to depths of 8-12 feet, making safflower significantly more tolerant to drought than small grains and other crops. The strong root system helps “open” the soil profile and allow deep water percolation for rotational crops. This “bio-illage” provides an extremely valuable tool to move salts down through the soil profile through subsequent irrigations. Salinity is a major factor limiting soil quality in large portions of the San Joaquin Valley, impacting both crop yield and quality. Conversely, when flooded conditions occur, safflower can be extremely useful to dry out soils.

Germination takes one to two weeks following planting, depending on soil temperatures. Early growth and development into the vegetative stage is very slow, but growth accelerates during stem elongation stage. Flower heads emerge at about 60-90 days and flowering continues for several weeks.

Safflower plants produce several flower heads per plant depending on plant density. Flowers are generally yellow and the crop generally considered to be a self-pollinating, although bees and other pollinating insects are often present foraging for both pollen and nectar. The crop is a virtual insectary for many species of insects which can move into neighboring crops when the safflower fields begin to mature.

Safflower seed is harvested with a combine about 45 days after peak flowering when most of the leaves have become brown with minor greening on the bracts. Seeds must easily separate from the stem for an efficient harvest. A moisture level of 8% moisture is recommended for proper storage. The crop takes from 110 to 150 days from planting to harvest. Harvesting is done with a combine. Most seed is pressed into oil shortly after harvest.

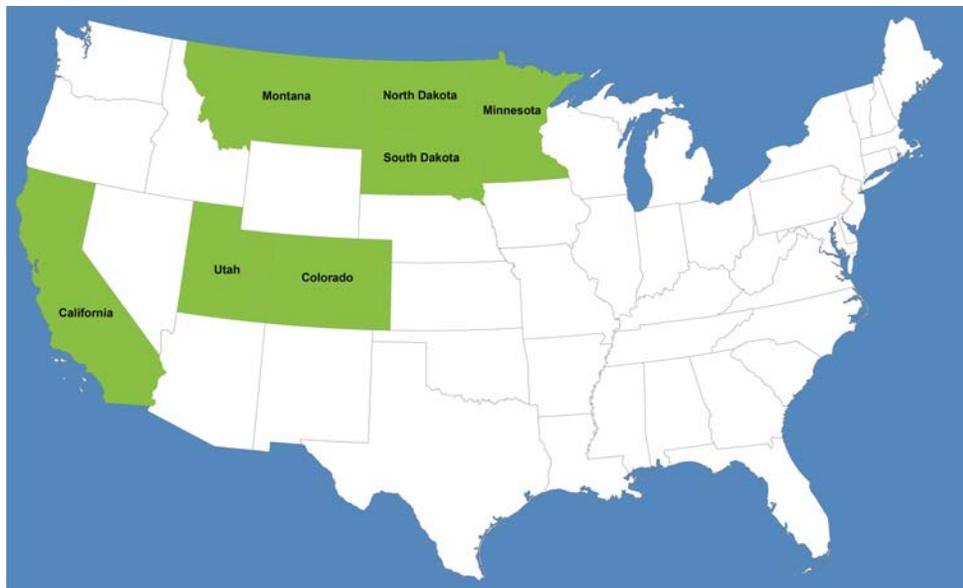


World Production

- Safflower is produced in more than 60 countries.
- India is the world leader in production.
- Other production areas include the United States, Mexico, Ethiopia, Argentina, Australia, China, Canada, Spain, Russia, and Turkey.

US Production

- US production has dropped in number of acres planted since the 1970s.
- Annual US production is generally less than 100 million pounds.
- California typically produces 50 - 60 percent of the U.S. safflower crop in terms of tonnage.
- The remaining domestic production is in Utah, Colorado, Idaho, Montana, North Dakota and South Dakota (Figure 1).
- According to the USDA definition, safflower is a “minor crop”. This means there relatively few acres grown (<300,000 acres annual production) in the US.
- The relatively few acres of safflower results in limited research and registration opportunities as compared to major crops such as major crops such as corn, soybeans, rice, peanuts, wheat and cotton.
- The limited number of pesticide tools registered in safflower and the limited number of acres treated for pests qualify it as a “minor use” crop by USDA and the US Environmental Protection Agency (<300,000 acres).



Major Safflower Production States in the United States

US Safflower Crop Acreage, Production and Value				
Year	Planted Acres	Harvested Acres	Production (1,000 pounds)	Value (1,000 dollars)
2010	175,000	167,000	221,335	38,178
2011	130,700	127,300	169,671	41,416
2012	169,800	160,100	173,937	48,011
2013	176,500	170,700	210,238	58,615
2014	181,500	170,200	208,643	52,146

USDA-NASS 2015

California Production

The primary value of safflower in California is as a rotational crop which provides excellent benefits to soil health. Comparatively speaking, other crops are much more profitable per acre (processing tomatoes, cotton, etc.). These crops, however, would have reduced yields and quality if not for the environmental benefits brought about by having safflower in the crop rotation, especially in stressed areas such as the southern San Joaquin Valley subject to very saline conditions, drought, limited water allocations and soil compaction.

- Safflower can be grown in most parts of California, but production has historically focused in irrigated areas of the San Joaquin Valley and in the Sacramento Valley.
- Safflower is grown for its benefit to soil health and value as a rotational crop, not for the revenue it produces.
- Safflower is grown as a rotational crop with rice, tomato, wheat, corn, sunflower seed, alfalfa, dry beans and cotton.
- The southern third of the San Joaquin Valley comprises the majority of safflower acreage in the state in what is considered the Tulare Lake subregions of Tulare, Kings and Kern County.
- There are approximately 30,000 acres of safflower produced each year in the Tulare Lake subregion, making this the major area of safflower production in California.
- Yields in the Southern San Joaquin Valley typically range from 1000 – 3600 pounds per acre.
- Other less intensive safflower production can be found in the northern San Joaquin Valley counties (Glenn, Tehama, Butte, Yolo, Solano, Sacramento, Colusa, Sutter and Yuba).
- Safflower is only occasionally grown in the Imperial Valley of southern California.
- There are very few commercial varieties of safflower in California, however new lines are continually under evaluation.
- California varieties have been bred to produce the highest quality and highest safflower oil in the United States.
- The predominant variety is CS 90 OL which comprises about 75% of the total safflower acreage.
- An excellent overview of California safflower production is the booklet entitled *Safflower Production in California*. (1999 Pub. 21565) written by University of California research scientist, Dr. Steven Kaffka



Counties of Safflower Production in California

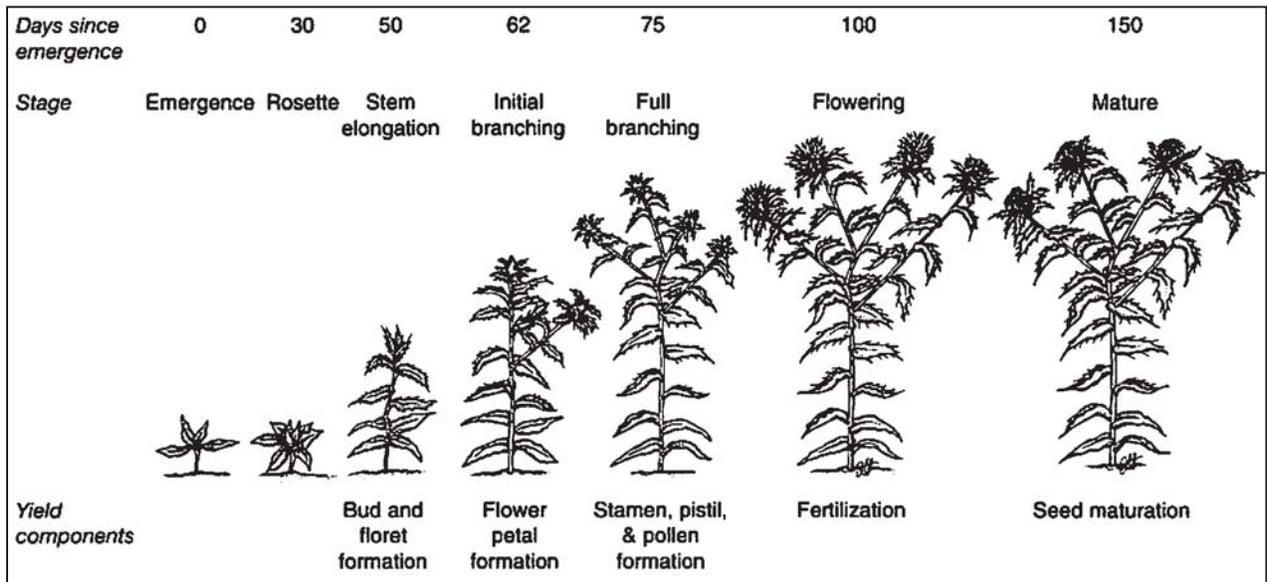
California Safflower Crop Acreage, Production and Value				
Year	Planted Acres	Harvested Acres	Production (1,000 pounds)	Value (1,000 dollars)
2010	56,000	55,500	124,875	21,229
2011	57,000	56,000	106,400	25,004
2012	53,000	52,500	105,000	26,565
2013	50,000	49,500	99,000	26,235
2014	53,000	52,000	105,000	25,620

USDA-NASS 2015

Timeline for Safflower Crop Development in California

Safflower can be planted in California as early as February and planted into late spring. It takes approximately 150 days from emergence through maturity.

A wide range of planting dates provides a great deal of flexibility to growers for options in managing rotational cropping systems. This flexibility is extremely valuable to farmers who must continually adapt to a range of challenges including multi-year droughts, reduced water allocations in local irrigation districts and as water quality provides for agricultural uses continues to decline (salty water). Safflower can also be used as a replacement crop when other crops fail.



Stages of Safflower Development (Kaffka and Kearney 1998 UC ANR Publ. 21565)



Safflower: A Rotational Crop With Soil Health Benefits

A strong, deep taproot is what makes safflower an excellent rotational crop for farmers in the San Joaquin Valley of California.

- As a drought tolerant crop species, safflower requires minimal water to grow; sometimes it can survive solely on residual soil moisture from other crops.
- Bio-tillage by the deep tap root reduces need for mechanical cultivation, thus aids in managing particulate matter as it relates to air quality.
- The taproot can “deep mine” soil moisture.
- The taproot increase pore spaces and pathways to move salts down and out of the root zone of salt sensitive crops.
- Soil organic matter is increased.
- Soil structure and tilth is improved by the physical condition of soil (ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration).

Cultural Practices

<p>Seedbed Preparation and Planting</p>	<p>Seedbed preparation depends on location, previous crop, soil type and water quality.</p> <p>Field selections are usually determined in the late fall or early spring. Seedbed preparation and equipment are similar to pre-irrigated, drilled, small grain crops.</p> <p>Ground is disced 1 – 2 times to condition soil and incorporate pre-plant herbicides.</p> <p>Safflower can be sowed in beds or drilled.</p> <p>Seeds are planted at a depth of 2 – 2.5 inches. Crop is either dry planted and watered up or planted to moisture. Row spacing varies by area.</p> <p>Safflower is typically planted at rates from 10-25 lbs per acre with 5 to 12 plants per foot of row.</p> <p>In areas with heavy clay soils such as the Tulare Lake Basin, fields might not be able to be worked until later in Spring when they have dried out sufficiently.</p> <p>If soil crusting occurs, a rotary hoe can be used to open up the soil to allow plants to emerge.</p> <p>Planting dates in the two major production regions: San Joaquin Valley: February through March Sacramento Valley: Late February to early May</p> <p>Variety: CalWest 99 0L is the predominant variety grown in California (>75%). New varieties are currently under evaluation.</p>
<p>Fertility</p>	<p>Fertilizer applications depend upon residual nitrogen from rotational crops, planting date, soil moisture and yield expectations.</p> <p>Nitrogen is the most important fertilizer element for safflower and is usually deep injected preplant or at planting. If safflower is planted following legumes or a rotational crops such as tomatoes, fertilizer amounts can be reduced substantially.</p> <p>Phosphorous deficiency and potassium deficiency are more common in rotations following rice production in the Sacramento Valley following rice.</p>
<p>Cultivation</p>	<p>Cultivation minimizes soil water loss by eliminating soil cracks and aids in management of weed and disease pests. Usually done only one or two times per season, depending on the location.</p>
<p>Pest Management</p>	<p>As safflower is grown primarily for its soil health benefits and as a rotational crop, pest management is not typically as intensive as compared to other higher value crops grown in the state.</p> <p>Safflower pest management greatly influences highly coordinated area-wide IPM programs focused on Lygus, stinkbug and beet leafhopper management.</p>
<p>Irrigation</p>	<p>Most safflower is grown under irrigated conditions; dryland production (no irrigation) is possible, but rare.</p> <p>Some fields are planted dry and then watered up.</p> <p>Water quality analyses are done several times throughout the season.</p> <p>Fields are pre-irrigated to store soil moisture for the subsequent crop and to push salts down in the soil profile.</p> <p>Irrigation can be furrow or flood.</p> <p>Irrigations can be done in the rosette, stem elongation and bud formation stages. Timing is to manage crop stress and avoid disease problems.</p>
<p>Harvest</p>	<p>The crop needs 110 to 140 days to mature and harvest begins when seed is at 5-8% moisture. Combine harvesting usually starts in the San Joaquin Valley in Late July and ends in Northern California by late August or early September. Plants generally desiccate naturally without the use of harvest aids.</p>

Worker Activities

Land Preparation & Planting	All land preparation and planting is done by machine on tractors.
Fertilizer Application	Soil testing is done annually to assess nutrient status. Fertilizers can applied prior to planting or at planting by injection.
Cultivation	Cultivation is done 1-2 times after planting to control weeds, aerate soil and open up soil for efficient irrigation.
Pest Management	<p>Crop monitoring for insects, weeds and diseases is done 1-2 times per week by field scouts and licensed Pest Control Advisors (PCAs).</p> <p>Sticky traps are also placed throughout fields and production regions to monitor safflower pests and species of concern to areas-wide monitoring programs (e.g., CA Dept. Food and Agriculture Curly Top Virus Program for been leaf hopper)</p> <p>Herbicide applications are made in the fall or early spring prior to planting.</p> <p>Insecticide applications are made to manage pests in safflower and to aid in area-wide IPM programs as safflower is a major host for important insect pests such as Lygus. There are up to four applications of insecticides per year in intensively farmed areas, especially where nearby crops may be affected by migrating pests.</p> <p>Hand weeding is done 1-2 times per season or as needed.</p> <p>Weedy field borders and ditches may be spot treated if needed.</p> <p>All ground pesticide applications are done in enclosed air conditioned cab tractors.</p> <p>Aerial applications of insecticides and herbicides are done with fixed wing airplanes and helicopters.</p> <p>Cultivation is done with a tractor to control weeds.</p>
Irrigation	<p>Minimal water is needed to grow safflower; the tap root is able to mine residual soil moisture from other crops. This moisture is very deep in the soil profile.</p> <p>Water quality is assessed throughout the season.</p> <p>Fields are pre-irrigated prior to planting.</p> <p>Only one irrigation is usually needed.</p>
Harvesting	Combine-harvested seed is collected into trucks in the field and directly transported to the processor.

Pest Management in Safflower

Since safflower is grown primarily as a rotational crop as a part of a drought strategy or as a replacement crop for when other crops fail, pest management has tended to be less intensive than in other higher value crops (e.g. processing tomatoes, pima cotton or nut crops).

Growers have extremely limited pesticide options for insect and weed management in safflower, both in number of total products registered and different modes of action available. Due to the relatively few acres of safflower in the United States, there are few new pesticide registrations. Given the “minor use” classification of safflower, the industry, supported by the California Safflower Growers Association, has actively engaged with the IR-4 Minor Use Registration Program at UC Davis to conduct research trials which support development of tolerances. Since 2013, this collaboration has been very productive, resulting in significant work to expand labels for established chemistries and providing opportunities for new products to advance in the registration process. While very good progress has been made, the industry is eager see an increase in the number of new registrations for safflower.

Care must be taken to manage pests both in the safflower and in the context of other crops grown in the area. This is because safflower can be the only green plant material in an area and mass migration of highly mobile pest species such as Lygus bugs, stink bugs and other species can build up and then quickly move into neighboring crops.

Fields and areas are actively monitored throughout the season for insect pests either by sweep net sampling in crops or on sticky traps located in agricultural and other rural areas. The most susceptible phase of safflower development is during the bud to flowering stage when chewing and piercing sucking insects directly feed on the developing buds causing seed shrinkage or blasting of heads.

Many species of insects are found in safflower fields, but few significantly affect yield and treatments are thus relatively few. Insect damage to the crop can occur at seedling establishment, vegetative development and throughout flowering. Safflower has diverse yield components (number of heads, size of heads per plant, number and size of seed, etc.) along with the ability to developing additional buds if primary buds are damaged. Due to these factors, most problems with early season pests can be outgrown or overcome by the plants.

The use of preplant herbicides and well-timed cultivations have generally allowed growers to effectively manage most weed and disease problems.

All pesticide use in California is closely monitored full use reporting is required by the California Department of Pesticide Regulation (www.cdpr.ca.gov/PUR).

Area-Wide Integrated Pest Management and Ecosystem Approaches to Pesticide Use Reduction

Since Lygus populations build up in safflower and many other plant species during the Spring, management of Lygus within the source crop has been long recognized as requiring an ecosystem-based “landscape IPM” approach to minimize area-wide use of insecticides (Adamczyk and Lorenz, 2009; Goodell and Patterson 2010). This tactic refers to the multiple hosts that pests can build up on and how they move throughout the landscape as hosts (both crop and non-crop) change in suitability throughout the season. Such is the case with safflower which often is the only green plant material for miles in the early part of the year; in many cases, the crop can be a virtual insectary in which insect and mite species thrive before moving into other more lush plant material.

The University of California cites as an example the year of 2008 in Fresno and Kings Counties where safflower acreage increased from a few thousand acres to over 30,000 acres where little or no insect management was conducted, resulting in high levels of Lygus moving into cotton over a six week period. The migration and damage led to significant loss of yield in cotton yield and a nearly 3-fold increase in insecticide use on cotton (Goodell, 2010). In following years, the same amount of safflower was grown in the study area and because Lygus were suppressed in the safflower, the cotton insecticide use for Lygus returned to pre-2008 levels based on pesticide use reports of the California Department of Pesticide Regulation.

Since the time of these studies, California growers have had to increasingly explore additional rotational crops due to the historic drought, which, as of 2015, was in its fourth year. Profitability of cotton has gone down and growers, especially those in the Southern San Joaquin Valley, have transitioned to higher value crops such as processing tomatoes and nut crops to justify the cost of water.

The understanding of the relationship of safflower pest management and its impact on infestations in other crops has been of increasing concern in “area-wide” or “landscape” integrated pest management approaches. Efforts to document the needs of the industry have been initiated through the development of a Pest Management Strategic Plan for Safflower in the Tulare Lake Basin (2015) where industry leaders, regulators, research scientists and pest control experts convened to discuss the issues. In addition, new approaches by IR-4 to more fully describe the “IPM fit” of new products is assisting in a more comprehensive understanding of direct and indirect benefits of pesticides taking into account more factors than efficacy, such as value in overall management of pesticide load in the environment, mode of action, resistance management, impacts on beneficial species, price, compatibility with other techniques and other factors.

The use of landscape approaches to address safflower pest issues will aid in developing sustainable IPM programs that contribute to both agricultural productivity and environmental sustainability in the rotational cropping systems in California.

Early Season Insect Management in Safflower – Key Pests

Planting safflower as early as possible after February 1 generally produces a vigorously growing, high yielding crop which can withstand, outgrow or compensate for any damage from early season insect and mite damage. The use of pesticides is usually not required in early season.

Darkling Ground Beetle

Young plants may be girdled or cut off at or below the soil surface. Darkling ground beetles are generally not a problem unless large populations build up when the plants are in the seedling stage.

- Typical Severity: Species is common, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest which lives below soil surface
- Can only use bait formulations.

Cutworm (*Agrotis* spp.)

Cutworms reduce stands by clipping off seedling stems near or just below the soil level. New shoots may be eaten partway through. No control is necessary unless damage is severe.

- Typical Severity: Species is common, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation; good weed management program is essential
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Wireworms (*Limonius* spp.)

Wireworm larvae occasionally reduce stands by feeding on developing seedlings, roots or shoots. They also bore into stems and other plant structures.

- Typical Severity: Species is common, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Seed Corn Maggot (*Delia platura*)

Seedcorn maggots burrow into safflower seeds and prevent germination. Slow emergence and poor stand establishment are signs of seedcorn maggot activity. Soils with high organic matter, cool soil temperatures and periods of excessive moisture favoring slow seed germination and seedling emergence increase susceptibility to maggot infestations.

- Typical Severity: Species is common, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Green Peach Aphid (*Myzus persicae*)

Aphids can become abundant on primary buds and seed heads, causing discoloration and loss of seed production in individual heads.

- Typical Severity: Species is occasionally found, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Vigorous plants usually compensates for loss due to this pest
- Biological Control: Natural parasites and predators only
- Chemical Control: Not used for this pest

Black Bean Aphids (*Aphis fabae*)

Aphids can become abundant on leaves and terminals of single plants, especially on margins of field. Plants may become stunted, or in extreme, rare cases, may die when infestation get above 50-60 aphid per plant. Usually only very small portions of fields are infested and treatment is rare.

- Typical Severity: Species is common, but treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Onion Thrips (*Thrips tabaci*)

This species of thrips may cause bronzing and silvering of young safflower seedlings. This most often occurs when onion thrips migrate into safflower from newly harvested nearby grain crops.

- Typical Severity: Species is only occasional; treatment is rare. (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Insect Management During Vegetative and Reproductive Stages of Safflower

The most susceptible stage of safflower development is during the bud to flower stage. Lygus and thrips are the most damaging pests and beet leafhoppers carry a virus that can be devastating to many crop plants. Crop and non-crop areas are actively monitored throughout the season either by sweep net sampling in crops or on sticky traps located in agricultural and other rural areas.

Consideration to area-wide IPM is a major concern at this time, since safflower may harbor large numbers of insects, especially Lygus, thrips, stinkbugs and beet leafhoppers that will migrate to other lush vegetation as the safflower dries out. This approach to IPM is also called “landscape” management because it recognizes the importance to all host plant species which contribute to increases in local pest densities. The availability of host material early in the season effectively provides resources upon which insect pests can develop; this in effect as a large “insectary” for some species that will then move in significant numbers to neighboring crops such as tomatoes, cotton, alfalfa and nut crops (almonds and pistachios). Insecticide treatments are made to manage Lygus buildup in safflower and reduce potential insect populations and insecticide use in other crops grown on thousands of neighboring acres.

Lygus Bugs (*Lygus hesperus*)

Lygus bugs are the single most important pest species which drives pesticide use in safflower.



Lygus bugs are a key pest in safflower that can cause bud browning and blasting by direct feeding on the developing seed head prior to bloom. Lygus bugs have the potential to damage not only the safflower crop, but the safflower essentially serves as an insectary for migrating populations to move to nearby crops such as processing tomatoes, cotton and alfalfa. Economic loss in these crops is severe and pesticide use escalates (Goodell reference). The increased use of broad spectrum insecticides such as pyrethroids and organophosphates is disruptive to integrated pest management efforts that encourage the use of beneficial insects that provide natural control mechanisms for other pests such as mites, aphids and worms.

Economic thresholds of 25-30 Lygus per sweep of a standard insect net are generally accepted as the threshold for treatment of safflower to reduce seed loss. In areas where safflower is adjacent or near other host crops such as tomatoes, cotton or alfalfa, thresholds are lower.

Typical Severity in Area-Wide IPM System: Lygus is a key pest which infests 100% of safflower acreage each year. Heavy infestations can damage safflower and have serious ramifications in area-wide IPM programs for cotton and processing tomatoes. Lygus bugs are extremely mobile and will quickly migrate to lush habitat as safflower starts to dry down.

Cultural Control: Weed control may aid in reducing Lygus populations but this impact is minimal. Lygus bugs have a wide host range of over 200 plants including many weeds. Russian thistle, black mustard, London rocket, wild radish, and goosefoot are good Lygus bug hosts. When weedy fields and orchards are located near safflower, the Lygus bug population in these fields may migrate when the weeds begin to dry. Avoid such migrations by removing the weeds before the population of Lygus bugs reaches the winged adult stage. Vegetation in foothills and rangeland should also be carefully monitored as these plant sources harbor Lygus that will move into safflower and other crops. Planting safflower at locally optimal time will promote good growth and development of plants that can tolerate moderate levels of insect pests.

Biological Control: Limited natural parasites and predators; not curative in a timely manner for commercial control. While some biological insecticides are available, these have not been shown to provide commercially acceptable levels of control and they are extremely costly.

Chemical Control: Insecticide availability is critically important for pest management in safflower and in nearby cropping systems. There are generally 3-4 applications of insecticides per year in safflower to manage Lygus and other pests. Key products used are cypermethrin (Mustang), dimethoate, and dibrom (Naled) provide moderate to good levels of control. Timing of application against Lygus is based on the development of the insect populations, and applications are made before populations cycle to prevent movement of adults and broadly overlapping generations. If Lygus are a concern for neighboring crops, insecticides are most effective if applied before nymphs have wings and are able to migrate.

Registered products and limitations for Lygus control include:

- AzaGuard (azadirachtin): Poor efficacy
- Azera (pyrethrin and azadirachtin): Resistance to pyrethrins
- *Bacillus thuringiensis*: Poor efficacy
- Debug Turbo (margosa oil and azadirachtin): Poor efficacy
- Evergreen Crop Protection (pyrethrins and pipernyl butoxide): Resistance to pyrethrins
- Grandevo (*Chromobacterium* extract): Biological options but poor efficacy
- Supracide (methidathion): Being phased out by EPA
- Mustang (zeta-cypermethrin): Resistance; mainly used as tank mix with other active ingredients
- Naled (dibrom): Moderate
- Dimethoate (dimethoate): Resistance; mainly used as tank mix with other active ingredients
- Flubendiamide (Belt): There are concerns this material may be restricted by EPA

Options for Lygus control are very limited due to very few registrations as compared to other crops. In recent years, methidathion (Supracide), an organophosphate, has been removed from the market and Lygus bugs have shown development of resistance to pyrethroids and the remaining organophosphate insecticides.

Growers have been evaluating the efficacy of biopesticides such as Pyganic and Grandevo to help reduce numbers of Lygus in early season. There is concern that Pyganic is broad spectrum and thus does not have a good fit for IPM programs in safflower. These new products have been only marginally effective and efforts are underway to further evaluate the potential of these new insecticides in safflower and to perhaps improve their efficacy and utility in area-wide IPM programs.

The industry is actively working with the IR-4 Minor Use Registration Program and EPA to register new active ingredients, particularly novel chemistries such as sulfoxaflor and novaluron which represent new classes of insecticides. This is a very lengthy process (3-5+ years). In addition, pesticide registrants may be unwilling to allocate resources for minor crops such as safflower due to limited returns on their investment.

Resistance Issues: Populations of Lygus bugs have developed resistance to certain organophosphate, carbamate, and pyrethroid insecticides. Pyrethroid resistance increased significantly in the late 1990s, shortening the residual period for Lygus bug control following an application. Mites are an occasional problem after the use of either organophosphate or pyrethroid insecticides used to control other insect targets.

Beet Leafhopper (*Circulifer tenellus*)

Safflower is one of many plant hosts which harbors beet leafhopper (BLH), a vector of beet curly top virus. This pest is of such economic importance to multiple crops in the state that California Department of Food and Agriculture coordinates control programs in crop and foothill areas throughout the San Joaquin Valley. Pests are detected by field checking and with use of sticky traps. Weekly communications alert growers and other stakeholders regarding recommended treatment timings.

The beet leafhopper is an introduced pest and migratory by nature. Populations develop in selected habitats within the San Joaquin, Imperial, Sacramento and Intra coastal Valleys of California. The Program utilizes intensive surveys to locate and monitor BLH populations throughout the year. As much as 100,000 acres of rangeland and idle agricultural lands are treated annually to control breeding BLH populations on a variety of host plants prior to the migration of adult leafhoppers into susceptible crops. Winter, spring and fall treatment periods coincide with the reproductive biology of BLH.

Chemical Control: cypermethrin (Mustang), dimethoate, and dibrom (Naled) provide good levels of control. Number of Applications for this Pest: Up to three applications per season.

Stink Bug Complex (Conspers stink bug: *Euschistus conspersus* Redshouldered stink bug: *Thyanta pallidovirens* (= *T. accerra*) Say stink bug complex: *Chlorochroa sayi* and *Chlorochroa uhleri* Southern green stink bug: *Nezara viridula*)

In recent years stink bugs have become quite abundant in some safflower fields, but yield losses to these pests are not well understood. Safflower can harbor stink bugs which then migrate to nearby cotton or tomatoes causing severe yield and quality losses. Management of local population densities in safflower assists in area-wide IPM efforts and reduce the pesticide load in the environment.

- Severity: Occasional (Estimate <25% acreage impacted per year but of serious area-wide concern)
- Cultural Control: None
- Biological Control: Natural parasites and predators only
- Chemical Control: cypermethrin (Mustang), dimethoate, and dibrom (Naled) provide moderate to good levels of control.

Cabbage Looper (*Trichoplusia ni*)

Loopers eat ragged holes into leaves, bore through heads and contaminate heads and leaves with their bodies and frass. Young plants can tolerate substantial leaf damage without loss of yield. In some years, cabbages loopers can be quite abundant causing serious defoliation.

- Typical Severity: Occasional (Estimate <25% acreage impacted per year)
- Cultural Control: None
- Biological Control: Important parasites include the egg parasite *Trichogramma pretiosum*, the larval parasites *Hyposoter exiguae*, *Copidosoma truncatellum*, and *Microplitis brassicae*, and the parasitic tachinid fly *Voria ruralis*. A nuclear polyhedrosis virus disease is also important under certain circumstances. If treatment is necessary, use of *Bacillus thuringiensis* insecticide will minimize injury to natural enemies.
- Chemical Control: Pesticides used for other pests usually pick up loopers. Flubendiamide (Belt) and rynaxypyr (Coragen) are rarely used.

Grasshoppers (*Melanoplus spp.*, *Schistocera spp.*)

Grasshoppers occasionally feed on safflower and can cause damage to individual plants, most commonly on field edges during very dry years when food sources are very limited.

- Typical Severity: Occasional (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Field Crickets (*Gryllus spp.*)

Crickets gouge and girdle stems of young plants, and may also feed on leaves. Feeding occurs at night; crickets hide during the day. Injury is significant only in occasional seasons.

- Typical Severity: Occasional (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation and sanitation
- Biological Control: Natural parasites and predators only
- Chemical Control: Not typically used for this pest

Insecticide Use in California Safflower – Key Products

There are very few effective insect control options registered for use in California safflower.

Active Ingredient	Trade Name (other names and formulations)	Formulation	Rate	Application	REI	PHI
Cypermethrin	Mustang 1.5 EW, (<i>Mustang Max EW</i>)	1.5 Lb Ai/Gal	4.3 Oz/A	Ground and Air	12 h	14 d
Dimethoate	Dimethoate 4 EC (<i>Dimethoate 400</i>)	4.0 Lb Ai/Gal	1.0 Pt/A	Ground and Air	48 h	14 d
Methidathion	Supracide 2E	2.0 Lb Ai/Gal	2.0 Pt/A	Ground and Air	3 d	28 d
Naled	Dibrom 8	7.5 Lb Ai/Gal	1.0 – 2.25 Pt/A	Air	48 h	30 d

Rates may be presented as ranges and can vary by formulation. Always read and follow label directions.

For full pesticide use reports, go to www.cdpr.ca.gov/docs/pur/purmain.htm.

For specific queries, use the pesticide information portal at <http://calpip.cdpr.ca.gov/main.cfm>.

Weed Management in Safflower

Due to a very limited number of registered herbicides, selecting a field with a historically low weed population should be an important consideration when deciding if and where to plant safflower. Equally important is to consider the specific weeds that are known to be present and whether or not the labeled herbicide products are effective on those particular weeds.

The most effective approach to manage weeds in safflower is to use weed free seed and rotate crops to reduce the seedbank weed abundance. Efforts should be made to control weeds during the fallow period and before planting to help reduce the impact of weed competition on early crop stand development.

Early weeds in safflower stands compete with young plants for moisture, sunlight and nutrients. The slow growth of seedlings often results in a weedy crop. Thus, in the emergence through early rosette growth stages (~25-40 days), safflower is susceptible to significant yield-limiting competition from other plants.

In later growth stages, safflower can usually outgrow most late spring-emerging weed. Late weed infestations, however, may interfere with mechanical harvesting. Safflower matures faster than most weeds and, as a result, the green plant matter from weeds reduces crop quality.

Most fields are treated with preplant herbicides in the fall or early spring. Incorporation may be mechanically or through irrigation or rainfall, dependent upon the selected product, location and weather.

Good weed control is also achieved with well-timed cultivations before flowering.

Herbicide timings in safflower:

- Fallow ground or preformed beds
- Before planting and mechanically incorporated
- After planting and before crop and weed emergence
- Applied after crop and weed emergence

Trifluralin and ethalfluralin are used as pre-plant incorporated herbicides for grass and broadleaf control. Paraquat or glyphosate will effectively kill grass and broadleaf weeds prior to seeding safflower.

The industry was very pleased to report that, as the result of the efforts of the Western Region IR-4 Program at UC Davis, pendimethalin (Prowl H2O) was registered as a new tool for safflower in 2015.

Key Grassy Weeds

- Rabbitsfoots grass *Polypogon monspeliensis*
- Yellow foxtail *Setaria lutescens*
- Mexican Sprangletop *Leptochloa fusca*

Key Broadleaf Weeds

- Prickly lettuce (*Lactuca serriola*)
- Maretail (*Conyza canadensis*)
- Fleabane (*Conyza bonariensis*)
- Pigweed (*Amaranthus palmeri*)
- Lambsquarters (*Chenopodium album*)
- London rocket (*Sisymbrium irio*)
- Bindweed (*Convolvulus arvensis*)

Dodder (*Cuscuta* species)

Dodder is a parasitic weed most effectively managed through early planting to promote vigorous stands. Workers are trained to identify dodder and it is hand pulled by conscientious hand weeding crews.

Herbicide Use in California Safflower – Key Products

Unfortunately, until new and effective herbicides become widely available, particularly for mid- to late-season applications, weed control in safflower production will continue to be a major challenge.

Active Ingredient	Trade Name (other names and formulations)	Formulation	Rate Acre	Application	REI	PHI
Clethodim	Clethodim 2E (<i>Select, Intensify One, Volunteer</i>)	2.0 lb AI/G	6 – 8 Oz/A	Ground and Air	24 h	70 d
EPTC	Eptam 7	7 lb AI/G	3.5 Pt/A	Ground	12 h	70 d
Ethalfuralin	Sonalan HFP	3.0 lb/Gal	1.5 – 3.5 Pt/A	Ground	24 h	70 d
Glyphosate	Roundup (<i>Rascal, Buccaneer, Glystar</i>)	4.0 lb/ G	1 Qt/ A	Ground and Air	24 h	7 d
Metalochlor	Dual Magnum (<i>Parallel</i>)	7.6 lb/ G	1 Pt/A	Ground and Air	24 h	0 d
Paraquat	Gramoxone (<i>Gramoxone SL, Paraquat</i>)		2.0 – 3.0 Pt/A	Ground and Air	24 h	0 d
Pendimethalin	Prowl H2O	3.8 # AI/Gal	2.0 – 3.0 Pt/A	Ground and Air	24 h	0 d
Trifluralin	Trifluralin 4 (<i>Treflan HFP, Treflan 5, Triflurex HFP, Trust</i>)	4.0 lb AI/Gal	1.5 – 2.5 Pt/A	Ground and Air	12 h	0 d

Rates are presented as ranges and vary by formulation. Always read and follow label directions.

For full pesticide use reports, go to www.cdpr.ca.gov/docs/pur/purmain.htm.

For specific queries, use the pesticide information portal at <http://calpip.cdpr.ca.gov/main.cfm>.

Disease Management in Safflower

The most widespread and serious diseases of safflower are phytophthora root rots, rust and fusarium wilt, all of which result from poor soil drainage and/or humid conditions. Major control tactics include crop rotation, careful irrigation practices, planting disease free seed or use of treated seed. One hundred percent of safflower seed in California is treated with a fungicide to manage safflower rust and fusarium. Resistant varieties help manage fusarium.

Phytophthora root rots(*Phytophthora dreschleri*; *P. cryptogea*)

Phytophthora infected plants wilt, become light colored and die in a very short period of time. This disease is only a problem when irrigating and care should be taken to not irrigate when temperatures exceed 80 degrees.

- Typical Severity: Serious losses can occur due to this disease and 100% acreage subject to infection.
- Cultural Control: Primary means of managing disease. Crops should not be stressed. Plant into fields with good drainage and manage irrigations to be done as rapidly as possible. Beds should not be saturated and top of beds should be kept dry. Do not irrigate when temperature exceed degrees; consider irrigating at night. Resistant varieties offer limited levels of resistance. Crop rotation aids in reducing disease buildup in soil.
- Biological Control: None
- Chemical Control: 100% of the seed is treated with NuSan which provides only partial control.

Rust (*Puccinia carthami*)

Infected seedlings become girdled and die.

- Typical Severity: Occasional (Estimate <5% acreage impacted per year)
- Cultural Control: Resistant varieties offer limited levels of resistance. Crop rotation to avoid seedling infection.
- Biological Control: None
- Chemical Control: Seed treatments are very effective. 100% of seed is treated with NuSan.

Fusarium wilt (*Fusarium oxysporum*)

This is a disease of roots that spreads to branches causing yellowing, wilting, and death of plants.

- Typical Severity: Occasional (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation to non-hosts. Resistant varieties offer limited levels of resistance. Plant when soil temperatures are cool.
- Biological Control: None
- Chemical Control: 100% of seed is treated with NuSan.

Pythium (*Pythium* spp.)

Several species of Pythium can attack safflower seedlings causing damping off of plants.

- Typical Severity: Rare (Estimate <5% acreage impacted per year)
- Cultural Control: Avoid waterlogged conditions. Plant into fields with good drainage and manage irrigations to be done as rapidly as possible. Beds should not be saturated and top of beds should be kept dry.
- Biological Control: None
- Chemical Control: Not used

Bacterial blight (*Pseudomonas syringae*)

This is a rare disease in California. Infected plants develop brownish necrotic spots and pale leaf margins; lesions also occur on stems and petioles. As the disease progresses, flower heads rot.

- Typical Severity: Rare (Estimate 5% acreage impacted per year)
- Cultural Control: Do not plant in areas with high humidity
- Biological Control: None
- Chemical Control: Not used

Botrytis head rot (*Botrytis cineria*)

- Typical Severity: Rare (Estimate <5% acreage impacted per year)
- Cultural Control: Resistant varieties offer good levels of resistance
- Biological Control: None
- Chemical Control: Not used

Sclerotinia stem rot (*Sclerotinia sclerotiorum*)

This is a rare disease in California. Infected plants turn yellow, wilt and die. Sclerotia form at base of seed head or in the stem. Seed heads fall off of plant as disease progresses.

- Typical Severity: Rare (Estimate <5% acreage impacted per year)
- Cultural Control: Avoid planting in areas that have high humidity.
- Biological Control: None
- Chemical Control: Not used

Verticillium wilt (*Verticillium dahlia*)

This is a rare disease in California. Infested plants mature early and die prior to seed formation. Symptoms are interveinal chlorosis of lower leaves.

- Typical Severity: Rare (Estimate <5% acreage impacted per year)
- Cultural Control: Crop rotation with non-hosts such as small grains, corn, rice, sorghum, and sugarbeets.
- Biological Control: None
- Chemical Control: Not used

Alternaria leaf spot (*Alternaria carthami* and *A. alternata*)

This is a rare disease in California. Infected plants develop brown irregularly shaped spots on leaves and floral bracts; entire plants become darkened.

- Typical Severity: Rare (Estimate <5% acreage impacted per year)
- Cultural Control: Partial tolerance is available in some varieties.
- Biological Control: None
- Chemical Control: Not used

Fungicide Use in California Safflower – Key Products

There are no fungicides typically applied in safflower, however 100 percent of the seed is treated with fungicide.

Chemical	Trade Name	Application & Timing	REI	PHI
Benzothiazole	NuSan	Seed Treatment	NA	NA

For full pesticide use reports, go to www.cdpr.ca.gov/docs/pur/purmain.htm.
For specific queries, use the pesticide information portal at <http://calpip.cdpr.ca.gov/main.cfm>.

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California Department of Pesticide Regulation (CDPR) Pesticide Use Reports and Pesticide Information Portal

www.cdpr.ca.gov/docs/pur/purmain.htm

<http://calpip.cdpr.ca.gov/main.cfm>

National Agricultural Statistics Service (NASS) www.nass.usda.gov