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SAFFLOWER

SECTION A

INTRODUCTION

SAFFLOWER AGRONOMY AT A GLANCE | CROP OVERVIEW | END USES

Introduction

Safflower (*Carthamus tinctorius* L.), a member of the Asteraceae family, is a versatile, winter-spring growing, minor oilseed crop in Australia, offering key benefits to diverse summer and winter crop systems as well as components of mixed production systems (Figure 1).

As an oilseed crop, benefits include improved productivity of subsequent crops, lifting farm income, reducing the impact of disease and weeds; and producing edible and industrial quality oil and meal. Safflower integration offers the opportunity to enhance overall environmental, production and economic sustainability.

Safflower is grown largely for the food industry in Australia. Safflower has received focused attention as an industrial oilseed and potentially represents a significant new crop industry for the northern region. Research to establish baseline data to develop agronomic management is crucial for future industry development of safflower and linseed. [1] [2]

Key points

- Safflower is best suited for rotation with cereal crops. Agronomic attributes include roles in integrated disease, weed and pest management programs.
- Limited market development restricts its current contribution to farming systems.
- The development of safflower crop technology for the biodiesel industry presents the potential of a significant addition to crop options in northern farming systems.
- Safflower is heat and drought resistant, adaptable to arid and semi-arid climates as well as irrigation. [3]

Safflower can be used in rotations effectively to break the lifecycle of cereal root diseases such as take-all and crown rot. It has an extensive root system, which can break up hardpans and create channels in the soil profile, facilitating air and water movement. The deep roots, combined with a long growing season, also dry soil at depth, which benefits the management of soils prone to waterlogging and salinity.

MORE INFORMATION

A general summary of the Australian grain growing regions is available at Greijdanus A, Kragt M. (2014). The grains industry: An overview of the Australian broad-acre cropping

1 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

2 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy

3 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

Figure 1: *Safflowers in CSIRO trial.*

Photo: Brad Colliss, Coretext

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Safflower in Australia

Potential role of safflower in Australia's southern farming systems

Compared to traditional winter crops such as wheat or canola, the later sowing window of safflower increases options for the pre-sowing control of problem winter weeds and provides opportunity to generate income from fields where seasonal conditions prevent the establishment of other winter crops.

Safflower can also provide management flexibility to a cropping enterprise. The later sowing and harvest time of safflower suits some growers because peak demands on labour and machinery are spread over a longer period. Safflower fits well into cereal-based cropping systems, with no additional machinery being required.

Safflower may also be sown as an opportunity crop. In such situations, it may be sown outside the optimum window with fewer inputs and still produce economic yields. For example, safflower can be sown in spring to replace failed winter crops. [4]

A.1 Safflower agronomy at a glance

Keys to successful safflower production:

- Safflower requires more water than canola to produce comparable yields; therefore, ensure that moisture is available to at least 1 m soil depth at sowing.
- Keep the market and end use in mind when selecting varieties and consider forward contracts if on-farm storage is not available.
- Always use quality seed and do not sow too deep (1.5–4.0 cm depth recommended).
- Main sowing window is June to August. Early sowing is important to maximise yields in drier situations (June or July).
- Flowering can commence in 85–140 days i.e. at the end of October and during November (depending on genotype, sowing date and environment).
- In wetter situations in southern Australia, safflower can be sown much later (to mid spring) without significantly affecting yield. Increase sowing rate for very late sowing.
- Use moderate sowing rates, especially when sowing early in drier situations (9–18 kg/ha).
- Supply adequate nutrition (fertiliser).

4 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy

- Minimise waterlogging when irrigating safflower, and/or fill the soil profile before sowing.
- Select paddocks carefully because fewer herbicides are available for use in safflower than in the more widely grown crops (some permits are available).
- Manage pests and weeds during establishment and early growth.
- Monitor crops regularly for pests.
- Safflower matures in 110–170 days. Harvest period in northern New South Wales (NSW) is normally from mid-December through to the end of January, varying with location, seasonal conditions and sowing date.
- The rate of dry down of seeds and stems can vary. Harvest delays can occur when drying down to 8% moisture content in the seed (delivery standard) where stems have not dried down sufficiently. Stem dry down can be slowed when periods of rain and high humidity occur and when low crop populations produce plants with thick stems.
- Where food and birdseed markets demand clean bright white seed, timely harvest is imperative.
- Harvest as soon as crops are mature and be careful to avoid seed damage, which reduces quality, and to avoid blocking equipment.
- Harvest during cooler conditions to improve cleanliness of seed and reduce the risk of fire.
- In most seasons, average dryland yields are 1–1.2 t/ha.
- Anecdotally, the highest known commercial yield is reported to be 3.3 t/ha under irrigation in northern NSW.
- Consider on-farm storage of safflower to enable access to more lucrative markets. [5] [6]

A.2 Crop overview

Safflower originated in the Near East and it has been grown for centuries in China, India and North Africa. It is a multi-purpose species with many traditional uses. Preparations made from the florets are thought to benefit the circulatory system, and yellow and red dyes extracted from the florets were once used to colour food and clothing. Immature plants can be grazed or stored as hay or silage, and some forms are used in fresh or dried floral arrangements.

The use of safflower as an oilseed dates to Roman times, and it has been used in India since the 1800s. However, only since the crop was introduced into the United States in the 1930s has it developed into the oilseed crop we know today. Safflower is now grown in >20 countries, with the United States, India and Mexico accounting for ~70% of world production.

Worldwide, safflower is a minor crop compared with other oilseeds. Average production for the 5 years to 2008 was 0.78 million tonnes, or ~0.3% of world soybean production. Safflower has been grown in Australia since the 1950s, initially to extract oil from seeds for use in the paint and resin industries. Production expanded to 42,000 ha by 1968, then declined because of drought and severe outbreaks of Alternaria disease (caused by *Alternaria carthami*). Interest in oilseed production resumed when quotas on the use of vegetable oils for margarine production were abolished in1976. The area sown to safflower in Australia peaked in 1979 at 74,688 ha.

There are two types of safflower, which produce different kinds of oil, one high in monounsaturated fatty acid (oleic acid) and the other high in polyunsaturated fatty acid (linoleic acid). The predominant edible oil market is for the former, which is lower

5 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy

6 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

in saturated fatty acids than olive oil, for example. The latter has uses including in painting in place of linseed oil, particularly with white paints, because it lacks the yellow tint of linseed oil.

In 1987, CSIRO released the two cultivars Sironaria, with resistance to *Alternaria carthami*, and Sirothora, with resistance to *Phytophthora* spp. Nonetheless, the area of production has remained variable. In the 10 years to 2008, the average annual area of production was 25,781 ha, but this has ranged from 3,600 to 45,000 ha. Growers have indicated that this is historically due to many factors including unfavourable seasons, variable prices, limited cultivars, competition from other crops and a lack of information on growing safflower.

Additional cultivars with higher oil content and increased disease resistance have been imported in recent years, mainly from the USA. The main market for these cultivars is oil for human consumption, with the remaining meal suitable for ruminants. White-seeded cultivars can be valuable when sold into birdseed markets; however, prices can be volatile depending on supply and demand.

Worldwide demand for vegetable oil is increasing as consumers seek healthier diets. Inclusion of safflower in rotations can diversify cropping programs and help to spread risk. With appropriate management, safflower can produce satisfactory returns in many cereal-growing regions of Australia, especially in wetter situations.

Safflower is a versatile crop that can add considerable value to cropping systems by playing various strategic roles. [7]

A.2.1 Marketing safflower

Safflower is currently mainly grown as an oilseed crop comprising two main oil types:

Linoleic acid is a polyunsaturated (omega-6) fatty acid. The most widely grown linoleic oil cultivar is Sironaria, released by CSIRO in 1987. Linoleic genotypes contain >75% linoleic acid. Linoleic cultivars are grown for seed and oil.

Oleic acid is a monounsaturated fatty acid. Oleic varieties include S317 and S517 which are grown their oil, for use the food industry for frying and in the manufacture of pharmaceuticals, cosmetics, soap, paint additives, adhesive and sealant compounds, plastics and lubricants.

Current oleic safflower production, comprising principally S317, targets the food industry, supplying manufacturers, wholesalers and food service operators. Export in the form of oil or as seed varies with the costs of crushing and oil extraction. Recent increases in crushing costs from $150/t to $300/t mean that seed imports have replaced oil imports (Bill Slattery, pers comm).

Presently, India is the main market for oleic safflower oil for the food industry, looking to import around 30,000 t seed. Australia currently falls well short to meet this, struggling to supply 4000 t seed.

Safflower is grown under contract on a per hectare basis. Prices paid for oleic safflower in 2014 were $490/t and in 2015 $520/t. Prices are quoted ex-farm, ex-GST. Contracts are written to Australian Oilseed Federation (AOF) Standards. Payments are based on the percentage of oil in the seed and test weight at 8% moisture and 4% impurities. The baseline oil content is 38% with applied 2% discounts and premiums. In 2014, all deliveries exceeded 38% oil.

Seed

Safflower seed is used in birdseed and small animal feed mixes. Visual seed appearance is an important market criterion, preference given to a bright white appearance. Sironaria is the preferred variety. Other varieties like S317 (an oleic oil variety) are not desirable for this market because of inherent varietal characteristics like a creamy coloured seed coat and grey stripe on the seed.

7 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy

Large price variations between seasons are common due to the speculative nature of production. The small market for birdseed and small animal feed mixes is easily over supplied.

Linoleic oil

Linoleic oil is an edible oil, used in products such as salad oils and soft margarines. It is also used in the manufacture of pharmaceuticals, cosmetics and paint in some other countries.

Similarly, overseas in the USA as an example, a by-product after oil extraction is the high fibre meal. The fibre is important in stock with low fibre diets e.g. feedlots and dairy. The meal containing around 24% protein is used as a livestock protein supplement. Meal from de-hulled seed has about 40% protein with reduced fibre content. [8]

A.2.2 Potential industry growth

The unique properties of oleic acid also make it of potential use in biodiesel production. GRDC reports that market analysis indicates global demand for high-purity oleic acid oil could require more than 100,000 ha of the new safflower varieties. As an indication of potential, the size of the Australian cotton industry was estimated to be 270,000 ha in 2015–16 by Cotton Australia.

'Cotton soils' could be classified as 'safflower soils'. Depending on water availability with seasonal conditions, pricing comparisons of crop choice and water costs, and field rotations, some level of substitution may be a potential viable option for some growers.

The Northern Grains region is characterised by a variable climate where agriculture comprises diverse cropping systems. Predominantly comprising soils with high water holding capacity, it is an environment that suits safflower with its heat and drought tolerance. Oleic oil synthesis within the seed is favoured by warmer finishing conditions, promoting high oleic content.

The existing expertise with modern agricultural technology, including GM crop production, and the region's pre-existing oil crushing facilities, combine to offer opportunities for the development of an industrial safflower oil enterprise in farming systems.

Economics will determine industry growth with competition from profitable crop options. [9]

A.2.3 Safflower production in Australia

In Australia, safflower has always been a minor crop and has attracted sporadic attention for research and development. Australian industry began to investigate safflower in the 1940s amid concerns about shortages of drying oil in the paint and resin industries (Smith 1996). Several cultivars were subsequently introduced from overseas, allowing small-scale commercial production to commence in the mid-1950s.

Safflower comprises cultivars that are of two oil types, high in linoleic or oleic fatty acids. Linoleic cultivars were principally marketed as a component of feed mixes for birds and small animals; and oleic cultivars used in manufacturing industries producing paints, resins, pharmaceuticals and cosmetics.

Areas sown to safflower vary widely, ranging between 6100 and 45,000 ha in the decade from 2003 (FAO 2015). Reasons for this include few available cultivars, susceptibility to Alternaria (*Alternaria carthami*) and Phytophthora (*Phytophthora cryptogea*), limited agronomic research, disappointing farmer experiences and

8 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

9 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

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Ground Cover Radio 119: Development may herald new oilseeds industry

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http://www.australianoilseeds.com/__data/assets/pdf_file/0019/6742/Final_Jochinke_paper.pdf

adverse seasons. A history of inconsistent prices and market opportunities because of competition from both alternative oilseed crops and the continuing development of petroleum substitutes have further hampered adoption. [10]

Cultivar Gila was introduced in the early 1960s, and with higher seed and oil yields, the safflower industry expanded to 42,000 ha by 1968. At the time, safflower was mainly grown in Queensland. Production subsequently declined because of drought in 1968 and 1969, followed by several seasons of above-average rainfall, which favoured Alternaria disease. Production continued in Queensland and expanded into other states at varying levels, but in 1975, grower confidence was again lost by a severe outbreak of Alternaria disease in Queensland.

During the 1960s and 1970s, cotton (*Gossypium hirsutum*) and hybrid sunflower (Helianthus annuus) industries developed, creating competition to the safflower industry. The abolition of quotas on the use of vegetable oils for margarine production in 1976 led to increased interest in oilseed production, and in the following seasons record prices were paid for safflower. After the area sown in Australia peaked in 1979 at 74,688 ha, it declined, presumably due to volatile prices and competition from other oilseed crops.

CSIRO developed cvv. Sironaria and Sirothora in response to disease concerns and they were released in 1987. However, this did not revive safflower production in Queensland, with production in the last two decades shifting largely to NSW and Victoria. During this period, the Australian industry has been based largely on Sironaria, which has linoleic oil and is suitable for birdseed markets. [11]

Recent research and development has focused on a new end use for safflower, through a collaboration between CSIRO and GRDC to produce genetically modified safflower with increased quantities of fatty acids with industrial applications, such as biodegradable plastics. [12]

A.3 End uses

The main end uses for Australian safflower seed are oil and birdseed. Safflower seed can contain over 40% oil. Two types of safflower are currently in commercial production.

Some varieties have 70 to 80% polyunsaturated fatty acid (linoleic acid) making it suitable for salad oil and margarine. It is also blended with other vegetable oils to lift polyunsaturated ratios to the level required for edible products. Because this type of oil polymerises readily when heated, it is less suitable for cooking.

Other varieties typically produce oil with 80% monounsaturated oleic acid, which is similar to olive oil. Oils with high levels of oleic acid are stable at high temperatures making them superior for frying. Other minor uses for safflower oil include; livestock rations, industrial lubricants, soaps, cut flowers, pharmaceutical products, infant formulas, cosmetics and biodiesel. Organically produced safflower may command a premium for both monounsaturated or polyunsaturated types.

Safflower seed is also used in pet food products, particularly in birdseed and mixes for small rodents like guinea pigs. Birdseed markets demand large, bright white seeds, without coloured stripes or pappus, that are also free from cracking, sprouting and staining from weather or disease. Some oilseed safflower varieties have striped seed and are not suitable for pet food markets.

Safflower seed for oil production may be either cold pressed, expeller pressed or solvent extracted. The meal remaining after oil extraction is usually high in fibre (30–

10 K Hertel (2016) Tactical agronomy of safflower and linseed: place in the rotation, yield potential, time of sowing, plant growth and marketing. GRDC Update Papers 1 March 2016, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/03/Tactical-agronomy-of-safflower-and-linseed

11 D Jochinke, N Wachsmann, T Potter, R Norton (2008) Growing safflower in Australia: Part 1—History, experiences and current constraints on production. Australian Oilseeds Federation, http://www.australianoilseeds.com/__data/assets/pdf_file/0019/6742/Final_Jochinke_paper.pdf

12 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy

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Development of super high oleic oil in safflower

The molecular basis of high and super-high oleic safflower seed oils

40%) with 20–22% protein and is best suited for ruminant diets, but meal properties do vary with soil extraction method.

Compared to cold or expeller pressing, the meal by-product from solvent extraction is higher in protein, but has a lower oil content (~1%) resulting in a low energy content. On the other hand, cold or expeller oil extraction processes result in a meal with less protein, but a higher oil content in the range of 8 to 11%. Expeller pressed oil has the poorest shelf life.

Hulls can be removed prior to oil extraction increasing protein to 42% and reducing the fibre content to 10%. Such meal is suitable for pigs and poultry, but with no market for hulls at present this process is not economically viable and oil extraction is usually performed on whole seeds. [13]

13 N Wachsmann, T Potter, R Byrne, S Knights (2010) Raising the bar with better safflower agronomy. Agronomic information and safflower case studies. GRDC, http://www.grdc.com.au/BetterSafflowerAgronomy