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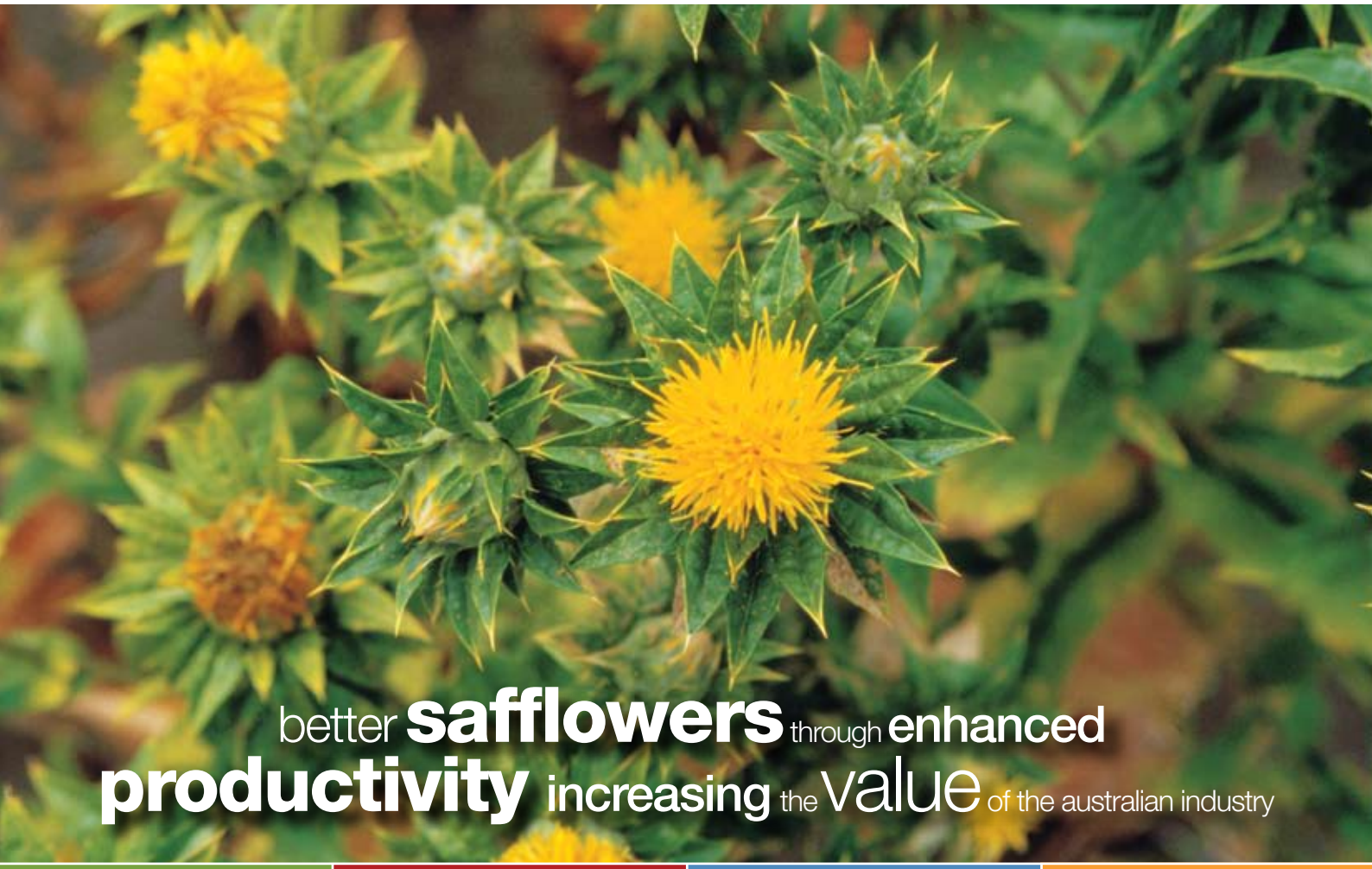
Grains Research and Development Corporation

RAISING THE BAR WITH BETTER SAFFLOWER AGRONOMY

Agronomic information and safflower case studies

AUTUMN 2010



AOF

better OILSEEDS

GRDC

Grains Research & Development Corporation

Photo: Nick Wachsmann

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Acknowledgements
The Better Oilseeds project was funded by the Grains Research and Development Corporation and the Australian Oilseeds Federation.

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Grower involvement
The Advisory Group are grateful for the invaluable contribution of the following growers who allowed the publication of their crop production data for the betterment of the safflower industry; James & Stuart Gall, Breil Jackson, David Jochinke, Ryan Millgate, Graeme Robertson, Brett Shepherd and Greg Weber.

Available
Copies available from: www.australianoilseeds.com or ground-cover-direct@canprint.com.au
or free phone 1800 110 044.

ISBN number: 978-1-921779-08-4

Published: June 2010 – www.agri-mc.com.au

Front cover photograph: Sue Knights. Back cover; Field day at the 7th International Safflower Conference, Wagga Wagga Australia, 2008. Photograph: Sue Knights.

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INTRODUCTION

Safflower (**Carthamus tinctorius** L.) originated in the Near East and 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, whilst 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 back to Roman times and it has been used in India since the 1800s. However, it is only since the crop was introduced into the United States in the 1930s that it has developed into the oilseed crop we know today. Safflower is now grown in over 20 countries with the United States, India and Mexico accounting for around 70% of world production. Worldwide, safflower is a minor crop compared to other oilseeds. Average production for the five-year period to 2008 was 0.78 million tonnes, or about 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 42,000ha by 1968, but then declined due to drought and severe outbreaks of the disease Alternaria. Interest in oilseed production increased again when quotas on the use of vegetable oils for margarine production were abolished in 1976. The area sown to safflower in Australia peaked in 1979 at 74,688ha.

The CSIRO released the cultivars Sironaria with resistance to Alternaria and Sirothora with resistance to Phytophthora in 1987, but area of production has remained variable. In the 10 years to 2008, average annual area of production was 25,781ha, but this has ranged from 3,600 to 45,000ha. 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 predominant market for these cultivars is oil for human consumption, with the remaining meal suitable for ruminants. White seeded cultivars can also be valuable when sold into birdseed markets, but prices in this market can be volatile depending on supply and demand.

Worldwide demand for vegetable oil is increasing as consumers seek healthier diets and including safflower in rotations can diversify cropping programs and help 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. This document describes the plant and collates available agronomic information into a guide for growing safflower in Australia, complemented with grower case studies. The final section contains references and a list of key industry contacts.

Photo: Sue Knights

THE BETTER OILSEEDS PROJECT

The Better Oilseed project was jointly funded by the Grains Research and Development Corporation and the Australian Oilseeds Federation. The project provided much needed support for oilseed growers, aiming to lift the productivity of these crops ensuring critical mass, consistency of production and improved seed quality.

Australian oilseed production peaked in 1999, but at a lower level than what many analysts believed possible. In recent years, poor seasons and/or lower prices have seen the area sown to oilseeds decline from the 1999 peak, with production disappearing from some traditional regions.

This project examined ways to support the Australian oilseed industry. The outcome was for the industry to improve the skill level of advisers and growers so that oilseeds could be produced more reliably in current climatic conditions.

The project commenced in 2006 and for the majority of its history focused on canola, soybeans and sunflower. Safflower was a late addition, being incorporated in 2009.

The specific project aims were:

1. To capture existing knowledge and place relevant information into an easily accessible website.
2. To utilise and share the knowledge of existing successful growers with other growers in their regions.
3. To address common problems and issues through demonstrations and field days. These issues were identified through a review and included production costs, rotation/farming system benefits, weed/pest/disease management and decision support on when to grow an oilseed given a range of seed prices and environmental conditions.
4. Regular forums and field days were used to engage growers and advisers and get them thinking about the possibilities for their farms and clients.
5. The project also identified and highlighted ways that growers could improve seed quality to make the industry more competitive.

Better Safflower case study locations

SUMMARY

Safflower is a versatile minor oilseed crop in Australia which offers a number of benefits to many cropping systems.

This book presents the keys for successful safflower production and describes how safflower can be used as a strategic crop with contrasting roles in crop rotations illustrated with grower case studies.

Safflower can be used in rotations to effectively break the lifecycle of cereal root diseases like take-all and crown rot.

It has an extensive root system which can break up hard-pans 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 benefitting the management of soils prone to water logging and salinity.

Compared to traditional winter crops like 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 as peak demands on labour and machinery are spread over a longer period of time. Safflower fits well into cereal based cropping systems with no additional machinery being required.

The crop 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. Examples include sowing safflower in spring to replace failed winter crops.

Regardless of the reason why safflower is incorporated into a cropping system it is recommended that growers adhere to as many keys to successful safflower production as possible to optimise the crops performance.

Keys to successful safflower production:

1. As safflower requires more water than canola to produce comparable yields, ensure that moisture is available to at least 1m soil depth at sowing
2. Keep the market and end use in mind when selecting varieties and consider forward contracts if on farm storage is not available
3. Always use quality seed and do not sow too deep (1.5 to 4cm depth recommended)
4. Early sowing is important to maximise yields in drier situations (June or July)
5. 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)
6. Use moderate sowing rates, especially when early sowing in drier situations (9 to 18kg/ha)
7. Supply adequate nutrition (fertiliser)
8. Minimise waterlogging when irrigating safflower, and/or fill the soil profile before sowing
9. Select paddocks carefully as fewer herbicides are available for use in safflower than more widely grown crops (some permits are available)
10. Manage pests and weeds during establishment and early growth
11. Monitor crops regularly for pests
12. Harvest as soon as crops are mature and be careful to avoid seed damage reducing quality, and to avoid blocking equipment
13. Harvest during cooler conditions to improve cleanliness of seed and reduce the risk of fire
14. Consider on-farm storage of safflower to enable access to more lucrative markets

BENEFITS OF SAFFLOWER IN AUSTRALIAN CROPPING SYSTEMS

Safflower can be a valuable addition to cropping systems, providing a number of strategic, agronomic and financial benefits as well as cash return, These benfits include:

A break crop

Diseases such as root and crown rot that attack wheat and barley are carried from one cereal crop to the next on stubble, volunteer crop plants and certain grass weeds. These diseases are not hosted by safflower, so with good grass weed control the population of these organisms is significantly reduced in safflower crops resulting in higher cereal yields in the following season. Safflower does not suffer from blackleg and is one of a few crops resistant to both species of root lesion nematodes.

A crop for enterprise diversification

In a cereal based enterprise, safflower can hedge growers against unpredictable weather. Because safflower can be planted later than cereals, it can be substituted for part of the cereal crop when planting rains begin too late for cereals, or where too much rain prevents their establishment. Excessive rain during cereal sowing and harvest can be detrimental to these crops, but may benefit safflower as its growing season is much later. This allows for a more diversified cropping program which has several advantages. For example, the later sowing and harvest of safflower spreads seasonal workloads, may reduce the exposure of crops to frost and the incorporation of another crop species increases the opportunity to rotate herbicide groups. Safflower's late growing season can help mitigate the effect of spring frosts affecting cereals on the whole farm budget, thereby reducing risk.

A drought tolerant crop

Providing the soil profile is moderately wet at sowing, safflower can yield reasonably well with little follow up rain because of its deep taproot. Safflower tolerates heat and drought better than most other crops and can survive for extended periods without rain.

A tool for managing problem weeds

Safflower is often sown later than other winter crops allowing more time for winter weeds to germinate before sowing. Such weeds can then be controlled using knockdown herbicides or cultivation, minimising resistance to selective herbicides. Furthermore, compared to wheat, pre-emergent herbicides such as pendimethalin and trifluralin can be used at higher rates in safflower giving greater control of weeds like annual ryegrass and wild oats.

An entry crop and a soil ameliorant

Safflower's aggressive root system penetrates further into soil than many other crops. The roots create channels in the subsoil improving water and air movement as well as root development in subsequent crops. For this reason some growers use safflower as an entry crop in rotations. Safflower can also be used to dry wet soil profiles, such as after irrigated cotton. This facilitates the natural shrinking and cracking of compacted layers which can be further shattered by deep ripping.

A tool for managing salinity and waterlogging

As safflower is a long season crop with a deep tap-root, it has the ability to use surplus water from deep in the soil profile, lowering watertables with dissolved salts reducing the expansion of saline seeps. Similarly, some growers use safflower to dry soil profiles to reduce waterlogging in subsequent crops.

A pest deterring crop

Due to the prickly nature of safflower later in its growing season, safflower is occasionally grown in situations where other crops may fail due to high kangaroo, bird or feral pig pressure.

It is relatively unpalatable to these animals and growers can achieve an economic return with minimal maintenance of the crop.

PRODUCTION CHALLENGES

Despite the benefits of safflower in a range of farming systems, there are several factors which tend to result in lower yields making safflower a less popular crop. These include:

- Late maturity, which exposes safflower to heat and moisture stress at the end of the season (**Figure 1**). Sowing significantly earlier only brings maturity forward by a small amount and increases the risk of frost damage during stem elongation.
- The upright seed heads are like a cup and easily saturated by rain. Summer rain can therefore cause the staining of seed reducing its value and/or sprouting where ripe seeds germinate in the head.
- In-crop herbicide options are limited, especially for the control of broadleaf weeds.
- The depletion of water from the soil profile by safflower can result in less water being available for the subsequent crop.
- As most cultivars develop spines, care needs to be taken to prevent blockages and header fires during harvest.

Figure 1: Safflower matures 4 to 6 weeks after wheat (photo taken 31 December). In this example both crops were sown on 24 July in the Victorian Wimmera. Photo: Nick Wachsmann

Key for successful safflower production:

No. 1: As safflower requires more water than canola to produce comparable yields, ensure that moisture is available to at least 1m soil depth at sowing.

HOW DOES SAFFLOWER COMPARE TO OTHER CROPS?

The yield of oilseeds is generally lower than cereals due to the higher energy content of the seed. When sown as a winter crop, safflower can produce similar yields to canola but it requires additional water. For example, in an experiment in the Victorian Wimmera, canola used 387mm of water to produce a yield of 3.4t/ha, whilst safflower used 507mm of water to produce 3.7t/ha of seed. In other words, the water use efficiency of safflower is often less than canola.

Where stored soil water and rainfall limit crop water use to less than 300mm, canola, mustard or linseed are likely to be higher yielding winter oilseed options. However, in wetter situations safflower can be competitive with these crops. Safflower generally requires fewer inputs and does not need to be windrowed.

As a spring sown crop, safflower can perform similarly to sunflower and better than linseed. In cooler, high rainfall regions, such as the South East of South Australia traditional winter crops can also be sown in spring. Under these conditions safflower can produce similar yields to canola and mustard and be more reliable.

SAFFLOWER- A VIABLE OILSEED ALTERNATIVE

Farmer case study

MOREE, NSW

Stuart, Jean & James Gall

Enterprises:
Broadacre cropping and cattle.

Location:
Moree, NSW.

Property size:
6,800ha.

Average annual rainfall/moisture availability:
550mm, approximately 113mm falls in-crop in an average season, with the majority of this rainfall occurring in late spring and summer, from stem elongation to flowering growth stages.

Soil type:
The dominant soils are black self-mulching clays.

Soil pH_{Ca}:
Alkaline.

Jean Gall. Photo: Stuart Gall

Take home message

Safflower is a viable alternative oilseed crop which aids machinery efficiency at sowing and harvest due to a later planting window.

Safflower production checks

- **Market using hectare contracts**
- **Avoid paddocks susceptible to waterlogging**
- **Blow down headers every few hours to prevent field fires**

History of property

'Tycannah Station' was purchased by the Gall family in the 1800s and has since expanded in area and management systems from 4,400ha of predominantly sheep to the property it is today. Cropping was introduced in the mid 1990s when 300ha was cropped and this has now expanded to 4,800ha. Sheep were gradually phased out entirely, while cattle numbers remained consistent, and still account for 2000ha of 'Tycannah Station'. This shift was largely due to market influences which saw a decline in wool prices. The grazing area of the property consists of native grasses and 160ha of the property is flood irrigated.

Crop details

The Galls have grown six safflower crops since 1995, ranging in size from 240ha to 350ha. Safflower was also grown in the 1970's, but information about these crops was not well recorded.

The cropping area of the property is equally divided into six block, which support sorghum, cotton, winter cereal (wheat/barley) and chickpeas, with safflower being incorporated into the cereal block when grown.

Why grow safflower?

Safflower is beneficial as a break crop to alleviate cereal disease carryover and increases opportunities to rotate chemical groups to minimise the risk of herbicide and pesticide resistance developing. The later sowing window also improves machinery efficiency at sowing and harvest by spreading workloads throughout the year. There is also opportunity to double crop out of sorghum into safflower, allowing a break crop without missing a season, providing adequate fallow rainfall occurs. An alternative crop such as safflower incorporated in the rotation also spreads market risk as prices fluctuate during the season.

Negative aspects of growing safflower

Safflower is susceptible to waterlogging, which can cause root rot diseases such as Phytophthora, potentially resulting in total loss of the crop, as the Galls experienced in 1995.

Soil tests at 'Tycannah' suggest that safflower utilises more zinc than other crops.

The emergence of safflower can be slower than other crops. In the Gall's experience, it can take up to six weeks for plants to emerge.

Harvesting safflower can be a slow and dangerous process with regards to the risk of starting a field fire, and little stubble remains after harvest, reducing the effectiveness of retained stubble in conserving soil moisture in fallow.

Because safflower is an alternative crop it requires niche marketing which can make the sale of seed problematic. Safflower markets are very sensitive to supply and demand.

Sowing window

The management system the Galls use is to sow safflower as close as possible to the shortest day of the year (21 June).

Paddock preparation

In terms of inputs the Galls use the same paddock preparation methods as for wheat.

Sowing system and establishment.

The Galls use either a disc or tine planter set to sow at 10kg/ha of seed in row spacings of 33, 38 or 102cm.

Varieties

Previously the Galls have grown various varieties of safflower, but mostly Saffola types.

Crop nutrition

The Galls have found safflower to have the same nutritional requirements as wheat, allthough zinc requirements appear higher, probably as a result of the soils characteristics. At sowing, generally MAP or urea is incorporated, depending on soil test results.

Weed control

Grass weeds are controlled using Verdict®, and broadleaf weeds have never been an issue for safflower on 'Tycannah Station'. Problem weeds for safflower on the property are predominantly annual phalaris and wild oats.

Herbicide resistance

Herbicide resistance is not an issue for 'Tycannah Station'.

Insect management

On observing the safflower crops over the years, the Galls have found the presence of large numbers of beneficial insects, such as spiders and ladybird beetles, and as such have never had to spray. This may be attributed to the fact that cotton was never grown in close proximity to the crops.

Disease management

The safflower disease of concern for the Galls is Phytophthora, which is managed simply by avoiding low lying paddocks which may remain wet for too long after rainfall.

Harvest management

Harvest usually occurs mid to late December, and the biggest concern is the risk of fire. To alleviate this hazard, harvest is conducted at night where possible, in cooler conditions and using slower drum speeds. Headers are also blown out every two hours during harvesting, as fires have occurred on the property previously. The Galls usually direct head safflower, and having never windrowed a crop, are unsure if any benefits would arise. A number of different machines have been used to harvest safflower over the years, utilising both conventional and belt header fronts.

Management of safflower residue

The Galls manage safflower stubble in the same manner as cereal stubble, as relatively small amounts are left behind after harvest. Volunteer safflower plants are few in number and controlled easily using regular fallow broadleaf herbicides.

Cost of production

As safflower requires similar nutrition and weed control to wheat, has low insecticide inputs and low disease management requirements, the crop cost is similar to wheat, although harvesting safflower is more expensive due to the slower header speed.

Economic benefit from growing safflower

As an alternative crop, safflower spreads marketing risk and often achieves a higher price than cereals per tonne at sale, however with an often smaller area of crop planted and lower average yields, returns from safflower are often similar to cereals.

Reliability/robustness of safflower

Safflower is a tough crop in most seasons but can be affected by a wet start to summer in northern NSW which can damage seed and reduce oil content.

Crop compared to other crops

Safflower for the Galls is a less management intensive crop than chickpea, but more intensive than wheat. Pests such as pigs and kangaroos do not graze safflower due to its unpalatability and spines. Pressure from such pests in other crops can be significant.

Crop yield

Between 1995 and 2005, safflower yields have ranged from 0.75t/ha to 1.2t/ha, with an average of 0.94t/ha.

THE PLANT

Safflower is an erect, winter/spring growing, annual herb that resembles a thistle. Along with sunflower, it belongs to the daisy plant family (Asteraceae). Despite being related to saffron thistle, safflower will not become a weed. Seeds have no dormancy and plants are easily controlled by cultivation and hormone herbicides. Cross-pollination between safflower and saffron thistle produces only sterile seed.

After emergence, safflower plants slowly develop a rosette of basal leaves (**Figure 2**). As daylength and temperature increase, a fast growing, central, woody stem develops (**Figure 3**) reaching a maximum height around the time of flowering. Depending on variety, management and growing conditions, the maximum height is reached at the start of flowering and may be 30 - 150cm. A strong tap root begins to develop during the rosette stage and can penetrate deeper into the subsoil than many other crops. In one comparison, safflower roots were found to a depth of 2.1m while nearby wheat roots extended to only 1.4m.

Figure 2: Rosette stage of safflower
Photo: Nick Wachsmann

Lateral branches develop once stems are about 20 to 40cm high and these lateral branches may in turn branch to produce secondary and tertiary branches. The central main stem is often referred to as the terminal stem, with the first level of branching known as primary branches. The extent of branching is dependent on variety, sowing rate and growing conditions.

Figure 3: Stem elongation stage of safflower
Photo: Nick Wachsmann

Figure 4: Early flowering stage of safflower
Photo: Nick Wachsmann

Leaves are arranged at both sides of the stem, often at uneven intervals. Leaf dimensions vary greatly between varieties and with distribution on individual plants. Typically leaves are 2.5 to 5cm wide and 10 to 15cm long. The margins of lower leaves range from being almost entire to deeply serrated and terminate with acuminate tips. Upper leaves forming the bracts that surround flowers are usually short, stiff, ovate to obovate and terminate in a spine. Upper leaves frequently also possess spines on the margins and whilst spineless varieties do exist they are not widely grown commercially. While the spines make the crop difficult to walk through, they also act as a deterrent to animals such as pigs and kangaroos.

Buds are borne on the ends of branches (**Figure 4**) and each composite flower head (capitulum) contains 20-180 individual florets. Depending on variety, crop management and growing conditions, each plant can develop 3-50 or more flower heads of 1.25-4cm diameter. Flowering commences with terminal flower heads (central stem), followed sequentially by primary, secondary and sometimes tertiary branch flower heads. Individual florets usually flower for 3-4 days and the whole flowering period can range from less than 10 days to more than 4 weeks. Commercial varieties are largely self-pollinated with less than 10% outcrossing.

Figure 5: Safflower seed
Photo: Nick Wachsmann

The amount of outcrossing is increased by the presence of insect pollinators, but the presence of bees is unlikely to increase yield by more than 5%. Flowers are commonly yellow, orange or red, but white and cream forms also exist. Each flower head commonly contains 15 to 50 seeds, but the number can exceed 100.

The seed

Safflower seeds (**Figure 5**) are contained in a thick hull which in botanical terms is actually a type of fruit known as an achene. However, as with sunflower, most people refer to the whole unit as a seed, so the same will be done here. Depending on variety, hulls may be smooth or ridged, pure white or white with a grey or brown tinge, and/or possess purple, grey or black stripes. Hulls generally lack a pappus and where present, pappus hairs are usually short.

The size of safflower seeds varies between varieties and with growing conditions, but they are shaped like small sunflower seeds. Typically, seeds average 6 to 7mm in length and weigh about 4 grams per 100 seeds, making 25,000 seeds per kilogram. The recognised test weight is 52.5kg/hL, which is similar to oats.

GROWTH AND DEVELOPMENT

Emergence and early growth

Safflower normally emerges 1 to 3 weeks after sowing. It is slower under low temperatures increasing the risk of insect damage and disease. Germination is epigeal, meaning that like canola or lupins, the shoot carrying the seed emerges above the soil where the cotyledons expand and act as the first leaves.

The first true leaves then emerge forming a rosette. During the rosette stage safflower can tolerate frosts to -7°C. Crops should be monitored for establishment pests such as redlegged earth mite during this period.

Growth during the rosette stage is initially slow it occurs in winter with short daylengths and cold temperatures. This stage can last for several weeks and varies with location and sowing date. For the same sowing date the length of the rosette stage is normally longer in southern Australia than northern Australia.

Stem elongation and branching

With increasing temperature and daylength towards the end of winter and spring, plants grow more rapidly and the central stem begins to elongate and branch. Frosts below -4°C at this growth stage can cause stem splitting and death of the growing point. Whilst plants often recover to some extent by producing new shoots from below the damaged areas, yield is likely to be penalised. The number of branches produced is an important determinant of yield as each branch eventually terminates in a flower head. Early sowing allows more time for a large rosette and an extensive branch structure to develop, creating a high yield potential. However, excessive vegetative growth increases crop water use early in the season and can lead to the depletion of soil moisture before maturity, decreasing yield. Delayed sowing (eg August) reduces the period of the rosette and branching growth stages. This results in fewer flower heads per plant lowering yield potential, but can be partially overcome by increasing sowing rates. A development scale for safflower is shown in **Figure 6.**

Flowering to maturity

Flowering generally coincides with wheat harvest in most cereal growing areas. It is more influenced by daylength than by when the crop was sown. The period from the end of flowering to maturity is usually 4 weeks, so that safflower is normally ready to harvest 4 to 6 weeks after wheat.

The need for long days before the crop will flower forces flowering and seed growth into a period of high temperatures and often dry conditions in late spring or early summer. Safflower can tolerate these conditions providing that demand for water can be supplied from soil reserves, but where these reserves are depleted low yields can be expected.

As plants mature they become stiff and woody and therefore are reasonably tolerant of wind and hail. However, too much rain may reduce yield and oil quality by inhibiting pollination, discolouring seed, promoting disease and/or causing ripe seeds to sprout in the heads.

The total period from sowing to harvest maturity varies with variety, location, sowing time and growing conditions but for June or July sowings may be around 26-31 weeks.

SUITABLE PRODUCTION AREAS

In Australia, safflower production commenced in northern New South Wales (NSW) and Queensland, but this has since shifted to include the higher rainfall (>450mm) cereal growing regions of southern NSW, Victoria and South Australia. Safflower can be grown over a wide range of regions providing that severe frosts (< -4°C) are avoided during stem elongation and that harvest can be completed before heavy summer rainfall events that occur after the crop matures. Safflower has a relatively high water requirement and is more reliable where stored soil water and rainfall allow total crop water use to exceed 300mm between sowing and maturity. Traditional production areas include the deep cracking clay soils near Moree, Warren and Griffith in NSW, the Wimmera region of Victoria and the area from Bordertown southwards in South Australia.

Safflower can also be grown successfully as an irrigated crop in most river valleys and irrigation areas, such as the Hay Plain in NSW. Care needs to be taken to prevent waterlogging which causes root rots such as Phytophthora, and some growers prefer to fill the soil profile prior to sowing, producing the crop with no additional irrigation. In some seasons, safflower is grown as an opportunity crop on full profiles of soil water on flood plains or normally dry lake beds after flood water recedes.

SOIL REQUIREMENTS

While safflower can be grown on a range of soil types, it prefers deep neutral to alkaline soils that are well drained, but still have a high water holding capacity, eg deep clay loams. Fertile, deep black or grey, self mulching or cracking clays that allow full development of the root system are ideal. Loams and alluvial soils are also satisfactory, but should be deep and free from hardpans, compacted layers, hostile chemicals or elements so that the root system can reach as deep into the profile as possible to extract water. No-till farming systems with full stubble retention can increase the amount of water stored in soil profiles and therefore the reliability of safflower, providing that weeds can be controlled.

Soils that are prone to extended periods of waterlogging are generally not suitable as they predispose crops to Phytophthora, an often fatal root disease of safflower. Soils that are prone to crusting will reduce plant establishment and unless in high rainfall areas, sandy soils may limit safflower production by having too low a water holding capacity. Paddocks with subsoil constraints like boron that will impair root development should be avoided.

The salinity tolerance of safflower is moderate to high, being similar to barley or cotton. It is more tolerant of sodium, than calcium or magnesium salts and less tolerant as a seedling than at later growth stages where yield is affected by levels above 14dS/$m_{soil\ extract}$. Tolerance to salinity does differ between variety, but little information is available on the cultivars grown in Australia. Due to its deep taproot safflower is often used in a tactical role on problem soils to break up hard pans and improve water and air infiltration into the subsoil through the creation of pores.

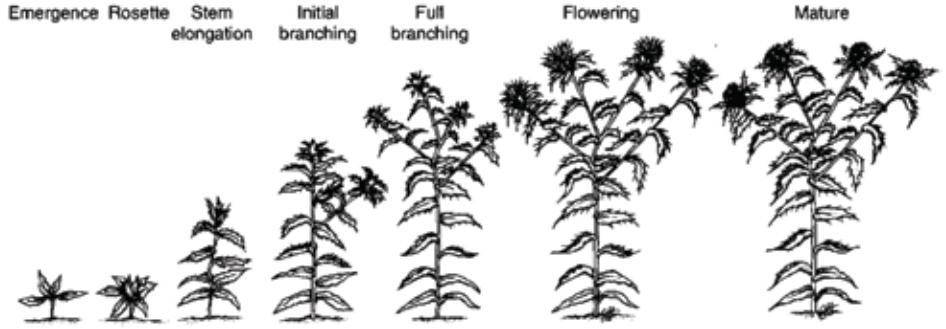

Figure 6: The development of a safflower plant. Source: Kaffka and Kearney (1998).

Safflower - a hard pan breaker

Farmer case study

WALGETT, NSW

Greg Weber

Enterprises:
Barley, wheat, sorghum, faba beans and chickpeas.

Location:
Approximately 50km north of Walgett, New South Wales.

Property size:
2,700ha.

Average annual rainfall/moisture availability:
450mm annually of which, on average, up to 89mm occurs as in-crop rainfall. In the 2009 season, however the crop had close to no in-crop rainfall, simply relying on stored soil moisture.

Soil type:
Vary greatly across the property, but within the safflower crop area, the predominant type is grey self-mulching clay loams.

Soil pH_{Ca}:
7.8 – 8.0

Take home message

Safflower is effective in rejuvenating compacted country, such as that which has been heavily stocked, as it breaks up hard pans, improving soil structure and water infiltration in preparation for cropping.

Greg Weber. Photo: Rebecca Byrne

Safflower production checks

- **Ensure good soil water availability**
- **Consider on farm storage of safflower seed rather than forward selling to ensure the best market price**

History of property

'Fairlands' was purchased into the Weber family by Greg's grandfather in 1927, originally as a grazing property. With time, cropping was introduced to 'Fairlands' and a downturn in wool prices saw sheep leave the farm. Currently cattle occupy 1,000ha of the property, leaving approximately 1,700ha for cropping which made the transition to no-till in the early 1990s. The particular paddock sown to safflower in 2009 was 50km to the north of 'Fairlands' and is share-farmed between Greg and the owners. Greg was initially contracted to sow the area to wheat, however when soil moisture tests revealed insufficient stores for a winter crop and large amounts of winter rain fell, Greg suggested planting safflower to make use of the excess moisture. Prior to 2009 season's safflower crop, the paddock had been heavily stocked and as a result suffered soil structure degradation through compaction.

Crop details

Safflower is generally sown after long fallow under no-till conditions for conservation of soil moisture. In the 2009 season Greg sowed 340ha of safflower which was followed by wheat in the rotation for the purpose of generating ground cover to conserve moisture, as the sowing rate used for safflower is so low as to create an open canopy.

Why grow safflower?

Within a large enterprise such as the Weber's, distance to travel between paddocks within the property is a significant consideration in terms of time and cost. As a natural pest deterrent due to physical traits and unpalatability, safflower is beneficial in this situation as less monitoring is required for pest damage.

The paddock had previously been heavily stocked and as a result contained a hard pan layer. The extensive root system of safflower facilitates the breaking of these hard pans within the profile, which is beneficial in rejuvenating compacted land, such as in the case of Greg's crop in 2009.

Safflower is also strategically used within the enterprise to dewater paddocks with excess moisture in the profile that are unusable for standard crops due to inaccessibility of the paddock at the appropriate sowing time. In this way, safflower allows productive use of paddocks containing good soil moisture which may otherwise be left to fallow, maximising available options and profitability.

Negative aspects of growing safflower

Using moisture probes Greg has found that safflower utilises large amounts of water from the soil profile, which is a factor when considering crop rotation. Also, while market prices can be high for safflower, the crop usually doesn't yield as well as other crops.

Sowing window

The optimal sowing window for Greg's safflower is between 10 and 20 July, to accommodate weather conditions in north-west NSW which are predominantly summer storms and very high summer temperatures. Around Walgett, early spring and summer rainfall while detrimental for other crops at harvest, is beneficial for safflower at the stem elongation growth phase.

Paddock preparation

Greg's pre-sowing management entails one cultivation in fallow, along with three applications of Roundup® and Glean® to maintain a clean fallow.

Sowing system and establishment

Greg uses an air-seeder to sow safflower, and while this method does not produce optimal evenness in emergence, the expense of using a disc or tine planter is not justified. Two germinations may be expected using an air-seeder in Greg's experience. No seed dressing is used on the seed at sowing and a sowing rate of 10kg/ha is sown on 40cm row spacings.

Varieties

Sironaria has been used in the past on Greg's property and is still used, largely due to accessibility of seed of this variety.

Crop nutrition

In Greg's business, the necessity for fertiliser at sowing is determined by the nutritional condition of the soil and paddock history. For this reason, no fertiliser was applied to the safflower in 2009 as nutrient levels were sufficient which not only proved to be a cost saving but with no in-crop rainfall, incorporation of fertiliser would not have been effective or economic.

Weed control

Pre-sowing weed control as fallow management entails applications of Roundup® (1.2-1.5L/ha) and Glean® (20g/ha). Ally® (5g/ha) is used in-crop for problem weeds such as fleabane and milk thistle.

Herbicide resistance

To date Greg has not indentified any herbicide resistance on the property.

Insect management

Insects are generally not an issue for Greg in early crop development, however monitoring continues, especially during flowering and budding when plants are more susceptible to insect damage. While there were no pests in-crop, cutworm can be a concern which is managed using deltamethrin.

Disease management

The most significant disease concerning safflower production is drought! With very little spring and summer rainfall in 2009, the crop relied heavily on stored soil moisture which limited yield potential. Generally disease is not an issue for Greg's safflower crops, considering the dryness of the area and the well draining soil types, so much so that treatment against seed borne disease is not necessary. However ongoing monitoring is conducted should an issue arise, for these reasons, storing the grain on farm is more profitable than selling 'off the header' or using forward contracts for Greg.

Harvest management

Safflower harvest in most years occurs around Christmas in the north of the state, according to time of sowing. Greg uses a Case 8010 to direct head safflower, operating at a slow drum speed of 380RPM and being cautious not to blow the seed out as it can be very light. Greg has not experienced any header fires with Sironaria. Once harvested, the seed is stored on farm until marketed for processing in Queensland.

Management of safflower residue

Safflower stubble is usually broken up and spread across the paddock with harvesting, limiting the need to manage it for following crops.

Cost of production

In 2009 Greg purchased his safflower seed for around $2000/t from South Australia, due to low insect and disease pressure and effective weed control pre-season management costs were low. Greg recieved $600/t for his 2009 crop.

Economic benefit from growing safflower

Greg considers safflower to be of economic benefit through reduced inputs into pest control and monitoring and in breaking up the harvest schedule to allow all crops to be harvested at the optimum time. While market prices for safflower can be attractive, the sensitivity of such a niche market to oversupply and the variability of safflower yields create instability for the market. For these reasons, storing the grain on farm is more profitable than selling off the header or using forward contracts for Greg.

Reliability/robustness of safflower

Safflower is heavily reliant on seasonal conditions, which results in either a wet extreme with damage to heads and grain at harvest or a dry extreme with insufficient water to fill seed fully.

Crop compared to other crops

Safflower is a low maintenance crop in north-west NSW in terms of pest and disease management in comparison with other crops and only requires monitoring every two weeks through to flowering when insects are likely to be present. However, the water requirements of safflower significantly higher than other crops, requiring a full profile at planting.

Crop yield

Greg's best safflower yield has been 1t/ha. In 2009 the crop of Sironaria yielded 0.6t/ha and relied solely on planting soil water. So little rain fell in crop it resulted in the air-seeder tracks still being visible on the soil surface at harvest.

CLIMATIC REQUIREMENTS

Water

Although safflower is often regarded as drought tolerant, it actually has a high water requirement. It survives dry conditions by developing an extensive tap root and scavenging for deep soil water, rather than relying on growing season rainfall. This assumes that deep soil water is present and that adverse soil conditions do not restrict root fill. Safflower's relatively high water requirement is often ascribed to its relatively long growing season and some water must be available to crops during flowering and seed fill. Safflower performs best in regions that receive more than 450mm of rainfall annually, but yields exceeding 1t/ha can be expected on clay soils that are wet to 1m depth at sowing, providing at least 50mm of post-sowing rainfall is received.

The higher water use of safflower was demonstrated in trials in the Victorian Wimmera and near the South Australian border when it was compared to wheat, canola, mustard and linseed. Safflower produced similar yields to canola in two wetter site years, but used an additional ~120mm. Over the four site years that these trials were conducted safflower yields varied 9 fold (0.4 to 3.7t/ha), whilst the yield of canola (1.2 to 3.4t/ha) and wheat (2.1 to 6.0t/ha) only varied 3 fold. Where conditions limited the water use of safflower to less than 290mm, canola, mustard and linseed were more productive winter oilseed options.

Water use data from these and other experiments over a range of sowing times indicate that safflower can produce yields of around 1t/ha where conditions (stored soil water + rainfall) allow total use to be 275mm, but yield reliability increases where more water is available (**Figure 7**). Situations allowing safflower to use 500mm of water have resulted in yields approaching 4t/ha in trials, providing waterlogging is avoided.

Despite a relatively high water requirement, safflower is not tolerant of waterlogging, especially when air temperatures exceed 20°C. Older crops are more susceptible than younger crops. Waterlogging for more than 48 hours can starve roots of oxygen and kill crops, in addition to favouring the development of root diseases such as Phytophthora. Heavy rain and high humidity during the reproductive phase can inhibit pollination, encourage diseases, discolour seed and cause seeds to sprout in the capitula.

Overall, safflower is best adapted to higher rainfall cereal growing regions with a dry climate during late spring and early summer, where water demands can be supplied from stored subsoil reserves. Care should be taken when irrigating crops, especially after flowering to avoid waterlogging.

Temperature

Safflower will emerge at soil temperatures above 4°C, but 15°C is considered optimal. It tolerates frosts to -7°C during the rosette stage, but frosts below -4°C can damage the growing point and split stems during stem elongation and branching. Providing damage is not too extensive the plant can partially compensate by producing new shoots from below the damaged area. Crops sown very early are most susceptible, especially where frosts in late winter follow a period of mild weather favouring the early initiation of stem elongation. Risk can be minimised by sowing later, but many growers tend to over-react and plant far too late, which results in yield losses much greater than those likely to be caused by frost.

Safflower matures during December and January when temperatures are often high in traditional cereal growing regions. It can tolerate these temperatures providing sufficient moisture is available. Experiments on irrigated crops in the Ord River region of Western Australia have demonstrated that mean daily temperatures above 26°C during flowering and seed growth do depress yield and oil content. Other research from the United States has shown that safflower can tolerate up to 46°C, but that yields tend to be highest when daytime temperatures during flowering remain below 32°C.

Wind and hail

Safflower tolerates wind and hail better than cereals. Hail can severely damage young and succulent plants, but as they become stiff and woody towards flowering they develop more resistance. Safflower resists lodging, and whilst ripe plants do not shatter, they are prone to feeding damage from birds.

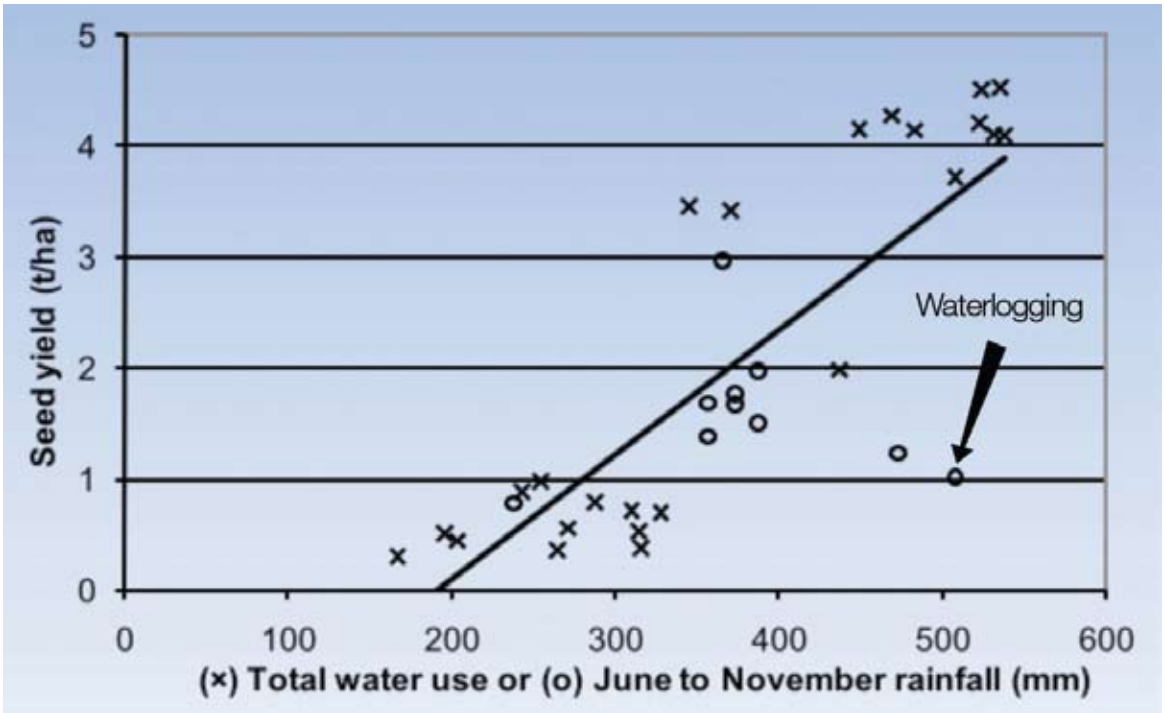

Figure 7. Relationship between safflower yield and total water use (×) for June to November rainfall (o) across a range of experiments in the Victorian Wimmera and the South East of South Australia.

Nick Wachsmann and Trent Potter inspecting safflower plots. Photo Sue Knights.

Safflower - an entry crop

Farmer case study

KANAGULK, VICTORIA

Graeme Robertson

Enterprises:
1214ha cropping, 2,500 cross bred ewes, an Iluka mineral sands mine is located on the property.

Location:
Kanagulk approximately 70km south west of Horsham, Victoria.

Property size:
2,266ha.

Average annual rainfall/moisture availability:
533mm annually of which, on average, 50mm generally falls within the safflower growing season.

Soil type:
The dominant soils are medium to heavy clays.

Soil pH_{Ca}:
4.5-6.5.

Take home message

It is vital to conserve as much soil water as possible before growing safflower.

Safflower production checks

- **Ensure a full profile of soil water**
- **Sow it as early as possible to get the crop up and growing**
- **Hold the moisture in the soil by rolling**
- **Ensure good fertility**

Graeme Robertson. Photo: Sue Knights

History of property

The property has been in the family for four generations. In the last 5 years Graeme has enlarged the property to 2266ha. Historically it was a sheep property with a small amount of cropping; mainly oats and wheat. Graeme utilises auto-steer on his spray tractors, and is in the process of moving to inter-row sowing to cope with the stubble load in his system and reduce the reliance on burning.

Crop details

A typical crop rotation on the property can consist of: safflower or fodder rape/canola/wheat/barley/faba beans/chickpeas/clover based pasture.

Why grow safflower?

Historically the region has been a wet region and mainly utilised for sheep production. Safflower has been used to reduce subsoil moisture and open up the subsoil so the soil can handle the high level of rainfall. The safflower taproot is like a 'biological drill' in the soil, opening and aerating the profile.

Safflower is used as an 'entry' crop into a cropping phase as it prepares the soil much better to sustain a cropping phase. Graeme finds that through the use of a summer crop he is able to create a good seedbed and it gives him the opportunity to level the ground which is very important for the subsequent cereal crops to avoid waterlogging and ponding in the crops.

Negative aspects of growing safflower

Safflower is a high water user. Canola following safflower in recent, drier years, has had a tendency to frost easier due to moisture stress incurred after a safflower crop.

Graeme says that bird damage can be an issue in safflower and it should not be grown in near timbered rather than rimbered areas.

Safflower is also not tolerant to a wide range of herbicides and Graeme cautions growers considering safflower to replace other crops after a flooding event to be careful of residual activity from herbicides used in the first crop.

Sowing window

Graeme sows safflower anywhere from early October to early November and emphasises that a full soil moisture profile should be achieved for successful safflower production.

Paddock preparation

Graeme prepares paddocks going into a cropping cycle with a double knock of glyphosate. The first spray is early winter (1.3-1.5L/ha Roundup®) he then follows up either before or after working the soil in September with another spray application of around 1L/ha Roundup®. His aim is to get onto the paddocks and spray as early as possible to conserve as much moisture for the safflower crop.

A scarifier and finger tyne harrows are then used to work the soil, occasionally off-set harrows are used; trying to avoid bringing up clods. A land-plane is used to level the ground after a safflower crop to avoid ponding of water on the soil surface in following crops.

Periodically Graeme uses a rotary drainer to put shallow drains across his paddocks to reduce water ponding on the soil surface.

Sowing system and establishment.

A Gasson seeder is used and safflower is generally sown at the rate of 18kg/ha at 300mm row spacings with blade points and press wheels. Ideally Graeme would roll the paddocks after sowing which aids in holding the soil moisture. A land plane is used to level the ground after safflower is sown.

Graeme does a germination test on the safflower seed to ensure that the germination rate is 80% or above. He treats the seed with fungicide to reduce damping off problems but does not treat the seed if dry sowing.

Varieties

Sironaria.

Crop nutrition

Graeme routinely applies 60kg/ha MAP. To improve soil structure he applies 1-2.5t/ha gypsum to paddocks after the safflower crop as he finds that gypsum works more effectively, possibly due to the safflower roots opening the soil profile.

Weed control

Problem weeds on the property have included toad rush, onion weed, hogweed and annual ryegrass. Graeme ensures a very clean property by using a double knock herbicide program and summer crops in the cropping rotation. He sees few weeds within his safflower crops and has used appropriate rates of Ally® if needed to control broadleaved weeds.

Herbicide resistance

There is a small amount of herbicide resistant annual ryegrass on the property. This is managed by sowing to pasture, spray topping and cutting the affected area for hay.

Insect management

Rutherglen bugs can be an issue reducing seed weight if not controlled. Graeme monitors the crops regularly and will spray with the appropriate rate of Maldison® if pest thresholds are reached at flowering.

Disease management

Graeme has not encountered any diseases in his safflower crops but acknowledges that standing water in safflower crops can be a concern especially after heavy summer rainfall events. To this effect it is important to have paddocks as level as possible to avoid ponding. He uses the variety Sironaria, bred by CSIRO which is resistant to Alternaria.

Harvest management

Graeme harvests safflower on a visual moisture assessment when the seed is white, not grey and the oil is a brown colour, not grey and the seeds fall freely from the head. He uses his own open front 1680 Axial Flow International harvester and uses settings similar to those for wheat, depending on the seed weight of the safflower being harvested. He says the crop is difficult to feed into the header and acknowledges that a Draper front would be more appropriate. He says losses occurring at the front can be around 5%. To avoid blockages and possible header fires Graeme cleans down the header at least once a day, in heavier crops up to twice a day and he also drags a chain behind the header to reduce static build up.

Management of safflower residue

To reduce the amount of residue left in the paddock, Graeme ensures he takes as much plant material through the harvester as possible.

Cost of production

Graeme considers safflower a cheap crop to grow.

Economic benefit from growing safflower

Graeme has received an average return of around $650 per tonne or more for his safflower going to both domestic and export birdseed markets. Graeme says that this is a volatile market, but some seasons it has been quite lucrative. However he also believes that safflower has a broader economic role in enabling him to better manage and improve his cropping system.

Graeme has sold safflower off the header and usually plans to sell safflower within 6 weeks of harvesting. He can store safflower temporarily in field bins as they are vacant at that time of year which adds to the flexibility of safflower in his cropping system.

Reliability/robustness of safflower

Over the years Graeme has been growing safflower he has only had one failed crop, which he says was sown too late and did not have enough moisture. He says once the crop gets into October it kicks away with the warmth.

Crop compared to other crops

Graeme compares safflower to forage rape in his cropping system as they play similar roles as ‘entry’ crops. He says the forage rape crop probably has the edge on safflower as it does not need as much water and is grazed to further reduce any weed problems. He has not as yet tried grazing safflower but considers that it might not recover as quickly as fodder rape does.

Crop intensity

Each year about 20% of the crop rotation is broadleaf crops, on average 70ha of this is safflower, around 10% of the broadleaf proportion or 5% of the total crop.

Crop yield

Graeme’s average safflower yield has been 1.0t/ha and his best yield 1.6t/ha.

Foreground; Graeme standing on land that has been sprayed with Roundup® in preparation for safflower. Background; a wheat crop sown after a safflower crop. Photo: Sue Knights

VARIETIES

The first commercial oilseed safflower variety in Australia was Gila, introduced from Arizona in the 1950s. In 1970s and 1980s Gila suffered severe losses from the disease Alternaria leading the CSIRO to develop and release the varieties Sironaria and Sirothora in 1987. Sironaria is resistant to Alternaria and moderately resistant to Phytophthora, whilst Sirothora is susceptible to Alternaria but resistant to Phytophthora and recommended for irrigation.

Key for successful safflower production:

No.2: Keep the market and end use in mind when selecting varieties. Consider forward contracts if on farm storage is not available.

A few other varieties were introduced from the United States, including the oleic oil variety-Saffola 517 and the linoleic oil variety-Saffola 555.

Sironaria is still widely grown, but as a dual purpose birdseed and linoleic oil type, its oil content is lower than newer safflower varieties found in other parts of the world. Australia's safflower breeding program ceased in 1987 and with the exception of recent introductions by private companies, little work on variety development has been conducted in Australia.

Some newer introductions are becoming available to growers, but many are only obtainable on a closed-loop selling arrangement. This means that seed is provided by a company and the grower agrees to grow the crop and sell it back to the same company or its agent. At the time of producing this booklet, other new varieties were going through testing and seed multiplication. The characteristics of safflower varieties currently commercially available in Australia are provided in **Table 1**. Oleic and linoleic varieties should be separated by at least 400m to reduce the risk of out crossing which can alter oil quality and reduce the value of seed. Safflower hybrids have been developed overseas, but at present none are commercially available in Australia.

Growers should check with local agronomists and seed companies to determine the most appropriate variety for their situation. Also keep markets in mind, as different varieties are better suited to different markets.

Table 1: Summary of safflower varieties in Australia.

	Variety	Maturity	Morphology	Oil content	Alternaria#	Phytophthora root rot#	Company
Oleic oil types	CW88-OL	-	Tall, yellow/ orange	-	-	-	Adams
	CW99-OL	-	Medium, yellow/yellow	-	-	-	Adams
	S317	Late	Tall, yellow/ orange	42%	MS	-	Devexco
	S517	Medium	Medium, yellow/orange	42%	-	MS	Devexco
Linoleic oil types	CW1221	Medium	Medium, yellow/yellow				Adams
	CW2889	Very early	Short, yellow/ yellow				Adams
	Gila	Early	Medium,	35%	S	S	Public
	Sironaria	Medium	Tall, yellow/ orange	34%	MR	MS	Public
	Sirothora	Early	Short,	33%	MS	MR	Public
	S501	Early	Short, yellow/ orange	42%	-	-	Devexco
	S555	Medium	Medium, yellow/yellow	42%	-	-	Devexco

#MS moderately susceptible, MR moderately resistant, S susceptible.

ESTABLISHMENT

Seedbed preparation

Paddock preparation for safflower is similar to cereals, but with more emphasis on weed control and soil water conservation. Safflower can be sown into cultivated seedbeds or direct drilled into stubble from previous crops. If cultivating, avoid overworking which may damage soil structure reducing establishment, especially where soils are prone to crusting. Safflower can also be grown on raised beds improving drainage, thereby reducing the risk of waterlogging and root diseases.

Ideally the topsoil should be moist enough for seeds to germinate and crop reliability is improved where the profile contains water to a depth of at least 1m at sowing. This can be checked by taking cores or by pushing a steel probe into the soil.
To prevent injury, ensure that plant back periods for safflower are observed for herbicides used in the previous crop, summer or pre-sowing knockdown sprays (eg 7 to 21 days for some 2,4-D products). Several pre-emergent herbicides containing trifluralin, pendimethalin, triallate and EPTC are registered to control a range of grass and broadleaf weeds in safflower. At present, there are no seed applied fungicides registered for use in safflower in Australia, although some products are widely used in the United States.

Seed quality

As for all crops, planting seed should be genetically pure, free from seed borne diseases, have a high germination percentage (>80%) and be free from weed and other crop seeds. Many suppliers can provide a copy of a quality certificate on request, otherwise samples can be sent to an accredited laboratory for testing. The longevity of oilseeds under normal silo conditions is limited, so fresh seed should be used where possible.

Key for successful safflower production:

No.3: Always use quality seed and do not sow too deep.

Planting seed from crops which experience an extended period of warm, wet weather prior to harvest should be avoided. These conditions favour the development of Alternaria which can infect seed and transmit the disease to the next crop. Alternaria can cause newly planted seed to rot in the soil or the damping off of seedlings. The germination percentage of seed can also be markedly reduced by rain on mature crops which causes sprouting in the head.

Sowing time

Safflower development is controlled by a combination of temperature and daylength. Large delays in the time of sowing therefore have a much smaller effect on the timing of flowering. This is because crops progress through the vegetative fill stages much more rapidly, with only a small effect on the period between flowering and maturity (**Figure 8**). The development of safflower is also hastened in seasons that are warm and dry due to higher temperatures in the crop canopy (**Figure 9**).

Key for successful safflower production:

No.4: Early sowing is important to maximise yields in drier situations.

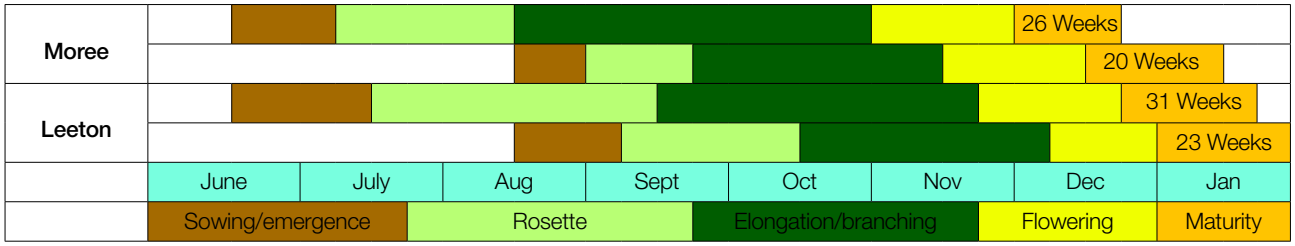

Figure 8: Effect of sowing in mid June and mid August on safflower development at Moree and Leeton in NSW. Source: Adapted from Colton (1988).

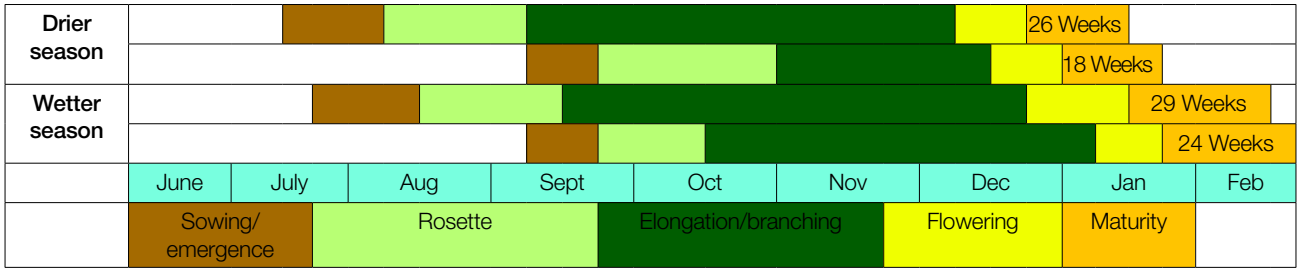

Figure 9: Effect of sowing in mid July and mid September on safflower development in a wetter and drier season at the same location in the Victorian Wimmera.

Sowing too early can result in frost damage during stem elongation, branching and even budding. Risk is greatest in northern areas as the generally warmer climate causes plants to begin stem elongation in winter. Very early sowing followed by good early season growing conditions may cause excessive vegetative growth, increasing crop water use which may be to restrict seed fill if soil water reserves are depleted. Sowing too late reduces yield potential by shortening the duration of vegetative fill and pushing flowering and seed fill into late spring and summer which often coincides with higher temperatures and the decreasing chance of rainfall. Late sown crops may also be at greater risk of seed staining and sprouting in regions prone to significant summer rainfall events.

As a general guide, safflower should be sown in June or early July in central and northern New South Wales and during July in the southern regions of New South Wales, Victoria and South Australia (**Figure 9**). In the southern regions, sowing can be extended to mid August, but consider this only where earlier sowing is not possible or where there are other reasons for growing safflower, such as the pre-sowing control of problem winter weeds. Spring sowing is possible in parts of Victoria and South Australia where in cooler conditions on a full profile of soil water, safflower can be sown between early September and early October and still produce economic yields.

Figure 10: Recommended optimum (☺) and extended (◁ or ▷) sowing window for safflower.

	May				June				July				August				September				October			
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Northern NSW			◁	◁	☺	☺	☺	☺	☺	☺	☺	▷	▷											
Central NSW					◁	◁	☺	☺	☺	☺	☺	▷	▷											
Southern NSW								◁	◁	☺	☺	☺	☺	☺	▷	▷								
Victoria								◁	◁	☺	☺	☺	☺	☺	▷	▷	▷	▷	▷	▷				
South Australia								◁	◁	☺	☺	☺	☺	☺	▷	▷	▷	▷	▷	▷	▷	▷		

The sowing time for safflower is reasonably flexible under favourable conditions in southern regions, or where safflower is included in cropping rotations as a strategic or opportunity crop. However, when grown as a cash crop, to maximise yields it should be sown at the optimum time which is generally earlier in northern regions than southern regions (**Figure 10**).

Safflower yields are related to sowing time and the yield of dryland and irrigated crops is most reliable when crops are sown in late June or early July. Each week of delayed sowing after mid July, generally results in a yield penalty of 5%, although under relatively cool growing conditions with adequate water supply, sowing can be delayed until mid September without substantial yield reduction.

Sowing rates

As for all crops, it is important to establish a consistent stand of safflower at a plant population suited to the expected growing conditions. Safflower compensates for low plant densities by producing additional branches, so the yield of early sown crops in good growing conditions does not vary greatly over a wide range of sowing rates. However, very low sowing rates offer little competition to weeds and can produce very large individual plants with thick, woody stems. These are difficult to harvest and the volume of material passing through machinery may make it hard to obtain a clean sample. Under drier conditions, sowing at too high a rate will create a dense crop canopy early in the season increasing water use. If water in the soil profile is depleted too early in the season, there may be insufficient reserves for flowering and seed fill resulting in reduced yield and quality. Sowing rates should be increased to compensate for the reduced duration of vegetative growth and branching where sowing later is delayed beyond the optimum time.

Target plant populations for safflower over a range of environments are provided in **Table 2**. Sow at the lower end of the range provided when sowing early in June or July or where stored soil water or expected rainfall are less than ideal. Increase sowing rates for late sowing after mid July or where subsoil moisture or seasonal rainfall is more assured. Higher rates should also be used for irrigated crops, or where poor emergence is expected due to issues like seed quality, cold temperatures, depth of sowing to reach moisture or soil surface crusting. In drier environments, such as lakebeds in the far west, lower seeding rates than normal may be justified. Consider 6 to 8 kg/ha in the northern and 10 to 12 kg/ha in the southern regions.

Table 2: Target plant populations (plants/m^2) and sowing rates (kg/ha) assuming 90% germination and 25% establishment losses.

	Favourable conditions	Drier conditions	Irrigated crops
Northern and central New south Wales	20 – 25 plants/m^2	15 plants/m^2	40 – 50 plants/m^2 (25 – 31kg/ha)
	(12 – 15kg/ha)	(9kg/ha)	
Southern New South Wales	30 – 35 plants/m^2	25 plants/m^2	
	(18 – 22kg/ha)	(15kg/ha)	
Victoria and South Australia	30 – 40 plants/m^2	20 – 30 plants/m^2	
	(18 – 24kg/ha)	(12 – 18kg/ha)	

Safflower runs through conventional sowing machinery at about two-thirds the average rate for wheat. A wheat setting of 12kg/ha would therefore sow about 8kg/ha of safflower. Safflower seeds average 25,000 seeds/kg, but this does vary between varieties and with growing conditions. Seed size and germination percentage should therefore be checked before calculating sowing rates and calibrating sowing machinery.

Sowing rates can be calculated using the following formula:

$$\text{Sowing rate (kg/ha)} = \frac{\text{Target plant population/m}^2 \times 10{,}000 \text{ X}10{,}000}{\text{Seeds/kg} \times \text{germination\%} \times (100 - \text{establishment loss})}$$

For example

$$\text{Sowing rate (kg/ha)} = \frac{20/\text{m}^2 \times 10{,}000 \times 10{,}000}{25{,}000 \times 90 \times (100 - 25)}$$

$$= 11.9\text{kg/ha}$$

Sowing depth

Safflower is ideally sown into moist soil with equipment such as press wheels to provide good seed-soil contact. Sowing depth will vary with soil type and conditions, but is normally between 2 and 5cm. Sowing deeper can delay emergence and reduce early vigour (**Figure 11**), leaving crops more susceptible to pests, diseases and competition from weeds. Some growers extend sowing depth to 7cm in order to place seed into moisture, but this should be avoided where possible, especially where soils are prone to crusting.

Figure 11: Seven week old safflower plants sown at 1, 5 and 10cm depth in clay soil.
Photo: Nick Wachsmann

Row spacing

Safflower is normally planted with standard cereal sowing equipment in rows 18 to 36cm apart. Narrower rows allow greater suppression of weeds, whilst wider rows may facilitate better air flow for disease control. Wider rows are also more suited to inter-row sowing, cultivation for weed control or band spraying. Low sowing rates and very wide rows to 50cm may be preferable in very dry situations, but row spacings above 36cm have resulted in lower yields in more favourable growing conditions.

Wider rows can also be used with row crop equipment for planting irrigated safflower crops. Californian experience indicates that planting single rows on hills 75cm apart, twin rows on 1m raised beds or several rows on 1.5 to 2m raised beds can all be satisfactory.

NUTRITION

Safflower has similar nutrient requirements to cereals (**Table 3**), but requires slightly more phosphorus and additional sulphur. Responses to surface applied fertiliser have been variable as the topsoil is often dry later in the season and safflower can extract nutrients from deep in the soil profile. This can be useful to recover nitrates and other nutrients that have leached beyond the reach of most other crops. Fertiliser applications should be drilled at sowing, or topdressed onto damp soil prior to bud formation and allowed to leach to the root zone. Foliar fertilisers are also suitable allowing certain nutrients to be directly absorbed by leaves. Selection of fertiliser type and rate will depend on soil type, paddock history, residual nutrient levels, water availability and expected yield. Ideally soil tests should be conducted in the topsoil and at a depth of 120cm.

Table 3: Nutrient removal by safflower (kg/t seed).

Nutrient	Safflower	Wheat
Nitrogen	25	23
Phosphorus	4.3	3
Sulphur	4	2

Nitrogen

At least 30kg/ha of nitrogen should be applied to most dryland crops and this can be increased to over 100kg/ha for high yielding crops under irrigation. No more than 20kg/ha of nitrogen should be drilled with seed to avoid toxicity, which will reduce crop establishment. Nitrogen fertiliser rates should also consider water availability and be moderated where moisture is limited or where high levels of nitrogen are present deep in the soil profile. Excess nitrogen can boost vegetative seed fill increasing crop water use early in the season, resulting in poor yields where soil reserves are depleted before flowering and seed fill. Economic responses to high rates of nitrogen are most likely in fully irrigated crops, where subsoil water is favourable and/or where soils have low nitrogen fertility. If seasonal conditions are unfavourable, consider sowing with 20kg/ha of nitrogen and topdressing or applying liquid forms later in the season if conditions are favourable.

Phosphorus

An adequate supply of phosphorus is critical to high yields and the long term sustainability of farming systems. Soil tests, test strips, local experience and expected yield are all good guides to phosphorus requirements. Each tonne of safflower seed contains 4.3kg of phosphorus, so a 2.5t/ha crop would remove 2.5 x 4.3 = 11.75kg of phosphorus from the paddock. As a general rule of thumb 12 to 20kg/ha of phosphorus is recommended on deficient soils. Responses to phosphorus are unlikely on soils with Cowell P levels above 40mg/kg, although small amounts can still be applied at sowing to improve early growth and maintain soil levels.

Potassium

Safflower uses moderate amounts of potassium, but most soils in the cereal growing regions of Australia contain adequate levels. The general exception is sandy soils, which are not best suited for safflower production unless in high rainfall regions. Potassium is not very mobile in soils, so where required it is best banded under seed.

Sulphur

Many soils contain adequate sulphur levels for safflower production. Soil sulphur levels should be monitored with soil tests and sulphur can be applied as gypsum or as a component of a blended fertiliser when necessary.

Manganese, Iron and Zinc

On certain soil types, such as the black soils in northern New South Wales or the heavy black or grey clay over limestone soils in South Australia, safflower does respond to manganese, iron and/or zinc. These are best applied as a foliar application around six weeks after sowing if necessary.

IRRIGATION

Key for successful safflower production:

No.8: Minimise waterlogging when irrigating safflower, and/or fill the soil profile before sowing.

Safflower can be grown successfully on well-drained soils under irrigation with yields exceeding 4t/ha possible. Both overhead and flood irrigation can be used, but care needs to be taken to prevent extended periods of waterlogging. The submersion of roots in water for more than 48 hours may kill crops by starving roots of oxygen and creating conditions suitable for root diseases like Phytophthora. The effect of waterlogging on safflower crops appears to be worse during warming temperatures later in the season. Experience suggests that irrigation should stop after flowering allowing water demands during seed fill to be met from soil reserves. Care also needs to be taken with overhead irrigation to minimise the duration of humid conditions in the canopy which favour the development of leaf and head diseases.

Irrigated safflower does best on raised beds with good drainage. For best results, the soil profile should be filled to at least 1.5m depth prior to sowing with small subsequent irrigations between stem elongation and flowering. Fully irrigated crops require somewhere in the vicinity of 500 and 750mm of water and Californian experience suggests that it is best to apply at least sixty percent of this prior to sowing. Sowing dry and watering up is not generally recommended because rain after irrigation on cold soils may reduce crop establishment.

WEED CONTROL

Key for successful safflower production:

No.9: Select paddocks carefully as fewer herbicides are available for use in safflower than more widely grown crops.

The later sowing of safflower enables more time for the control of autumn/winter germinating weeds with knockdown herbicides or cultivation before sowing. Good weed control is essential as safflower is a poor competitor with weeds during the rosette stage, especially when sown in winter. A light harrowing when safflower plants are 7 to 15cm tall can also give satisfactory control of small, later germinating weeds. Results are best when harrowing occurs on a warm, sunny day when safflower plants are supple to reduce crop damage and maximise weed kill.

As a minor crop, fewer herbicides are registered for weed control in safflower. Herbicides such as 2,4-D, MCPA and dicamba which generally kill broadleaf weeds should be avoided. Several pre-emergent herbicides are registered for grass and broadleaf weed control in safflower crops. Some products containing diclofop-methyl and propaquizafop are also registered for the post-emergence control of grass weeds, but registered herbicide options for the 'in-crop' control of broadleaf weeds in safflower are limited to Ally® (metsulfuron) which has only recently been approved for use in all states. A summary of herbicides registered for use in safflower crops is provided in **Table 4. Note that legislation on the use of herbicides does vary between states and label directions should always be followed. Contact your local agronomic adviser for further information.**

Table 4: Summary of herbicides registered for use in safflower at the time of printing.

	Active constituent	Group	Example trade names*
Pre-emergent	Ethyl dipropylthiocarbamate	E	EPTAM®
	Pendimethalin	D	Stomp 330EC®, Rifle®, Fist®, Conquest Charger 330 EC®
	Tri-allate	J	Avadex Xtra®, Avamix Elite®, Approve®
	Trifluralin	D	Treflan 480®, TriflurX®, Trilogy®, Snare®
Post-emergent	Diclofop-methyl	A	Conquest®, Rhino®, Diklofop 375®
	Propaquizafop	A	Correct®, Shogun®
	Metsulfuron methyl	B	Ally® (Varieties Saffola, Sironaria and Sirothora only)

*Note that the trade names provided are examples only and other products containing the same active constituents may be available.

Trent Potter and Don McCaffery checking safflower emergence. Photo Sue Knights.

Safflower - a tool for managing herbicide resistant weeds

Farmer case study

APSLEY, VICTORIA

Ryan Milgate, Manager Llanthro Pastoral Company, owned by Tom Porter

Enterprises:
2,200ha of cropping, 3 sheep enterprises; prime lamb, first cross, and wool comprising 16,000 sheep.

Location:
Just north of Apsley, Victoria.

Property size:
4,000ha.

Average annual rainfall/moisture availability:
550mm.

Soil type:
Heavy loams to heavy clay, the heavier soil types are more suited to safflower production as they retain more moisture.

Soil pH_{Ca}:
5.2-5.8.

Ryan Millgate. Photo: Sue Knights

Take home message

It is vital to conserve as much soil water as possible before growing safflower.

Safflower production checks

- **Retain as much moisture as possible in paddocks designated for safflower by initiating a chemical fallow as early as possible**
- **Try to sow safflower as early as possible to enable the roots to get down as far as possible to help the crop handle some dry spells during the season**

History of property

Up until 15 years ago the property was a straight livestock enterprise running merino wethers. In the mid 1990s cereals were introduced to improve the pastures and manage an onion weed problem. The returns from the cereals were favourable and the cropping enterprise has been built up since then. Ryan joined the business 5 years ago and in that time has grown the cropping enterprise from 900ha to 2,200ha.

Irrigation type and amount if applicable

There is irrigation available on the property, a centre pivot that services 40ha but this is generally used for high value seed production; lucerne, white clover and carrots.

Crop details

The standard rotation used on the farm is canola, wheat, barley then a legume or safflower. The proportion of crop each year is 50% cereal, 25% canola and 25% other, so between 160-200ha is potentially safflower. The best country is continually cropped and pasture is restricted to lower lying, waterlogging prone, heavier soils. Canola usually follows safflower to enable control of grass weeds especially where there may be herbicide resistant ryegrass through the use of 2 broadleaf crops in succession.

Why grow safflower?

Ryan says safflower provides a different species for his crop rotation which has multiple benefits. It is a different broadleaf species for disease breaks. It enables later sowing and harvesting which spreads the workloads. It can be sown later on paddocks which are too wet to access. Safflower dries and breaks the soil profile. He says some cropping paddocks are now performing better after safflower has been grown in them.

Negative aspects of growing safflower

Ryan considers safflower pretty easy to grow, providing you don't block the header during harvest! The biggest consideration is a reliable market for the crop. In the past they have sold to the birdseed market but consider this market too volatile. In 2009 they grew the crop on contract for Devexco Pty Ltd.

Sowing window

The crop is usually sown from August to October and is usually harvested in February to March, a late sowing time of October required desiccation for harvest in April.

Paddock preparation

A short chemical fallow is used with a knockdown using Roundup® in June and the paddock is then left to sit and a second knockdown is used just before sowing in August. There are hard pans present in the soil profile and the use of safflower, with its penetrating taproot together with no-till and controlled traffic are helping to break these.

Sowing system and establishment

Safflower is direct drilled into paddocks using knife points and press wheels on 320mm spacings in a controlled traffic no-till system. It is sown at a rate of 20kg/ha.

Varieties

Sironaria has been grown in the past. In 2009 S555 (Saffola) was grown on contract to Devexco Pty Ltd.

Crop nutrition

Ryan utilises yield mapping and variable rate fertiliser application, particularly with phosphorus. Use of this technology has reduced fertiliser costs by an estimated 15% and he considers that he is growing better crops. Each paddock is soil sampled every 3 years. Phosphorus is replaced in accordance with crop removal via yield maps from the previous crops. Replacement is based on 3kg P/t grain from cereals, 4kg/t for canola and 5kg/t for legumes. Phosphorus levels are quite high across the farm and they aim only for replacement levels.

Weed control

A double knock of Roundup® followed by Spray.Seed® is used prior to sowing and no herbicides are used in-crop. Ryan generally does not see significant in-crop weed issues with safflower and says that provided the knockdowns have been good he achieves a good clean safflower crop.

Herbicide resistance

Ryan believes they have some herbicide resistant ryegrass in the cropping paddocks and safflower is a useful tool in cropping rotations to manage this problem.

Insect management

Redlegged earth mites are treated with Fastac® if present.

Disease management

Very little disease has ever been seen in the safflower crops.

Harvest management

Safflower is harvested with their own John Deere 9660 with a Draper front. It has only required desiccation once due to very late sowing. Ryan drags chains behind the harvester to reduce static.

Management of safflower residue

Residue is chopped and spread by the header and the stubble is grazed by sheep.

Cost of production

For 2009 a total of $229/ha consisting of:

$18/ha seed

$43/ha fertiliser

$34/ha chemical (herbicides and insecticides)

$60/ha harvest

$50/ha sowing

$24/ha spraying

Economic benefit of growing safflower

In 2008 he received $550/t on farm and used his own freight to deliver the crop to Cootamundra NSW.

Reliability/robustness of safflower

Ryan considers safflower an easy and reliable crop to grow provided there is sufficient moisture at sowing.

Crop compared to other crops

Ryan believes the return from safflower is comparable to peas but there is less risk in growing safflower as it is not exposed to frost during its growing season like peas. Where there is excessive moisture in paddocks safflower is the preferred crop as it opens the soil profile and dries the paddock with its more extensive root system. Ryan states that returns from safflower are on a par with field peas. It does not compare to wheat or barley but the benefits in the following year's crop outweigh the lower returns from safflower.

Crop intensity

The designated cropping paddocks are continuously cropped at a level of 10-15% safflower each year. Ryan has seen in the past when there is a dry spring canola following safflower can run low on moisture which translates into a lower yield for canola. In 2009, which experienced a wet winter, canola did really well following safflower probably due to less waterlogging.

Crop yield

Yields achieved for safflower have ranged from 0.5t/ha to 2t/ha but with the use of controlled traffic and no-till, Ryan believes he can consistently achieve 2t/ha.

IMPORTANT DISEASES

A number of diseases can infect safflower, especially in warm and humid conditions. At present there are no fungicides registered for disease control in safflower in Australia, although some success has been achieved with seed and foliar applied products in other countries, including the United States. Control of safflower diseases in Australia relies mainly on using appropriate crop rotations, selecting resistant varieties, using clean seed, controlling volunteer and weed hosts, sound irrigation practices and selecting appropriate soils. Many safflower diseases are hosted on stubble, volunteer plants, other Carthamus species (eg saffron thistle) and some broadleaf crops. The main diseases of safflower in Australia are described on the following pages.

Alternaria blight (Alternaria carthami)

Alternaria leaf blight (**Figure 12**) is the most serious disease of safflower with heavy infection reducing yield by fifty percent or more. Infected seed is also often smaller with reduced oil content.

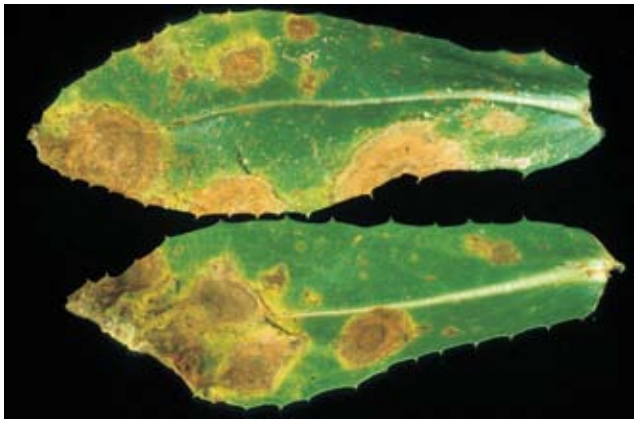

Figure 12: Alternaria blight infection on safflower leaves. Photo: Hans Henning Mündel

It is a fungal disease which attacks leaves, stems, heads and seeds. Transmission may be on infected seed or air-borne spores released from crop residue for up to two years.

- **Symptoms**

Infected seeds may have typical sunken lesions on the seedcoat, but they can also appear healthy. Seed-borne infection results in reduced germination, death of plants prior to emergence and death or malformation of seedlings. Initial symptoms in established plants often appear as large, brown, irregular spots (lesions) on the lower leaves. With warm and humid conditions the disease then spreads up the plant to infect the upper leaves, stems, flower head and eventually the seeds.

- **Conditions favouring development**

Rainfall and high temperatures or humidity during and after flowering are the conditions most favoured by Alternaria blight. It can occur in all safflower growing regions, but it is often more prevalent in northern regions as temperatures as temperatures in late spring are often warmer and the chance of summer rainfall are higher. Losses can be minimised by avoiding poorly drained soils and sound irrigation practices that minimised the incidence of waterlogging.

- **Management**

Control of Alternaria blight is largely preventative via careful crop rotation, stubble management and control of volunteer hosts. Sowing at the correct time is also important to minimise the chance of warm, humid conditions after flowering. Seed from infected crops should not be used as planting seed and resistant cultivars such as Sironaria are available.

Phytophthora root rot
(Phytophthora cryptogea)

Phytophthora (**Figure 13**) is often an unpredictable fungal disease and usually occurs in wet soils, especially when temperatures are high. It is present in all growing areas, but is most prevalent in irrigated crops where yield may be significantly reduced depending on the timing and extent of infection. Losses tend to be most serious as crops approach maturity. Spread is by spores which can be transported by wind, rain splash, surface drainage and waterways.

Figure 13: Patches of dead plants due to Phytophthora
Photo: Bob Colton

- **Symptoms**

This disease can infect seedlings, but more often plants are not affected until flowering. Phytophthora usually becomes evident 4 to 5 days after rain or irrigation. Plants may dry out, appear bleached and collapse in a short time. Lower stems and roots are often discoloured and become rotted. As the plants die, they take on a bleached appearance and the base of the stem and the roots become completely dark. Plants may die individually or in patches that often coincide with low lying or poorly drained areas where surface water has accumulated around the plants.

- **Conditions favouring development**

Phytophthora favours wet, warm soil temperatures above 25°C. Plants in low lying areas of paddocks are most susceptible. The disease will host on a wide range of crops, harbour in the soil and has the ability to survive for long periods in the absence of preferred hosts. Phytophthora can infect the fine roots of many weeds without causing obvious symptoms.

- **Management**

Once infected, plants usually die. Losses can be minimised by avoiding poorly drained soils and sound irrigation practiced that minimise the incidence of waterlogging. The presence of this disease is one of the reasons that many advisers recommend that safflower is not irrigated after flowering. Losses can also be minimised by controlling weeds during fallow to reduce the amount of inoculum present and by growing resistant varieties, especially where crops are irrigated.

Rust (Puccinia carthami)

Safflower rust (**Figure 14**) is often seen on older leaves late in the season, but significant yield losses usually require warm and humid conditions earlier in the growing season. The fungus is borne on seed or soil, and spores from infected plants or crop residues are the main method of spread both within and between crops. Spores can survive on infected stubble from one season to the next and can be spread long distances by wind.

- **Symptoms**

Rust pustules can appear at the base of seedlings, which can collapse and die. In mature plants rust first appears on the upper leaf surface as small yellow pustules, and on the lower leaf surface or stems at ground level as white pustules.

As the disease progresses, the pustules enlarge to form red-dish brown pustules up to 3mm in diameter which may be bordered by a yellow rim. The spores feel like talcum powder when rubbed between the fingers. Severe infection results in premature leaf drop become dormant near the end of the season, pustules may change colour to dark brown or black at which stage, the fungus can dormant.

- **Conditions favouring development**

As with most fungal diseases, safflower rust favours warm humid conditions where cycles of spore development may occur every 10 to 14 days.

- **Management**

The main ways to manage rust in Australia are sound crop rotations, the control of volunteer safflower plants and using clean seed.

Other Diseases

Other less prevalent diseases of safflower include seedling damping off, grey mould, charcoal rot, leaf spot and sclerotinia. Most are favoured by warm humid conditions or waterlogging and can be managed by paddock selection, sound crop rotations and using clean seed. Further advice on managing diseases in safflower can be obtained from plant pathologists or your local agronomic adviser.

Figure 14: Rust pustules on a safflower leaf. Photo: Bob Colton

Key for successful safflower production:

No.10: Manage pest and weeds during establishment and early growth.

Key for successful safflower production:

No.11: Monitor crops regularly for pests.

MAJOR INSECT PESTS

Safflower is most susceptible to damage by insects during establishment and between budding and harvest. A number of insect pests are known to have been recorded on safflower and whilst some are widespread, others are confined to certain regions and climates. Some of the more common insect pests are described here and growers can consult a range of crop insect identification and management guides for other pests or more specific details. A list of insecticides registered for use in safflower at the time of printing is provided in **Table 4. Note that insecticide legislation varies between states. Label directions should always be followed and contact your local agronomic adviser for more specific recommendations. Permits may also be available to use other products (www.apvma.gov.au).**

Table 4: Summary of insecticide active ingredients with one or more products registered for use in safflower in at least one state of Australia at the time of printing.

	Aphids	Cutworms	Heliothis	RLEM/ BOM*	Rutherglen bugs	Thrips	Lucerne flea
Bacillus thuringiensis			✓				
Clorpyrifos		✓		✓			
Deltamethrin		✓	✓		✓**		
Dimethoate				✓			✓
Esfenvalerate			✓				
Maldison					✓		
NPV*			✓				
Trichlorfon		✓			✓		

*NPV – Nuclear polyhedrosis virus, RLEM – Redlegged earth mite, BOM – Blue oat mite

**A general use permit has been obtained by the Australian Oilseed Federation to permit use of products containing 5.5 and 27.5 g/L deltamethin to control Rutherglen bugs in safflower until August 2014.

Aphids (Plum, Green peach and leaf curl)

Aphids are usually yellow, green or brown in colour, oval in shape, up to 3mm long and may have wings (**Figure 15**). They are an intermittent pest of safflower crops, most common during budding and flowering, but may also be present at any growth stage.

- **Damage**

Aphids prefer to eat new shoots and the underside of leaves by sucking sap causing a mottled appearance, distortion and the shrivelling of buds and capitula. High populations can weaken plants reducing yield, especially if crops are under moisture stress.

Figure 15: Green peach aphids. Photo: QPI&F

- **Threshold**

Crops should be monitored regularly, especially during establishment and between budding and flowering. Control is warranted when 20 percent of plants have more than 20 aphids per shoot, bud or capitula. The presence of beneficial predatory insects such as ladybird beetles, lacewings, hover flies and parasitic wasps should also be checked as these can often keep aphid populations in check.

- **Control**

Various biological control options are currently available for use in safflower.

Cutworms (Agrotis spp.)

Cutworm larvae are hairless with dark heads and bodies, often with longitudinal lines and/or dark spots (**Figure 16**). Caterpillars grow up to 50mm long and curl up when touched. The moths are dull brown or black in colour. Although cutworms are not common in early crop growth, crops should be monitored from establishment. Caterpillars reside in the soil during the day so it is best to inspect crops late in the afternoon or at night for this pest when they come to the surface.

Figure 16: Black cutworm (Agrotis ipsilon**) larvae (left) and adult (right). Photo: QPI&F**

- **Damage**

Cutworms feed near ground level, eating leaves and more detrimentally, by chewing through stems so that plants fall over allowing the upper leaves to be consumed at ground level. Plants often die leaving bare patches in crops.

- **Threshold**

When first observed, cutworms may already be at a high population in crops. Treatment is therefore recommended at the first sign of damage and this is most effective late in the afternoon or at night when they move from the soil to plants to feed.

- **Control**

Spraying with chlorpryifos or deltamethrin is the most effective method of control, although biological control agents such as brown earwigs, caterpillar parasites and some spiders may be beneficial.

Native budworm or Heliothis (Helicoverpa spp.)

Newly hatched larvae are light in colour with dark heads. They are yellow, green, pink, reddish-brown or almost black, often with a broad yellowish-white stripe along each side of the body and a dark-edged whitish line down the middle of the back (**Figure 17**). They have 4 pairs of legs at the back of the body, as opposed to the generic 2 pairs. Eggs are laid singly, usually on leaves and bracts surrounding the buds, the upper leaves or the stems below the buds. Fully grown native budworm caterpillars are about 40mm long.

- **Damage**

Heliothis feed on leaves, but most damage is caused when they graze buds and flowers, preventing seed set. Heavy infestations between budding and seed fill can significantly reduce yield.

Figure 17: H. armigera **larvae and moth. Photo: QPI&F**

- **Threshold**

Crops should be inspected regularly for moths, caterpillars and damage to buds or capitula from budding and during flowering. Damage to flower buds from more than 4 to 8 larvae of 5 to 7mm length generally warrants control. However, well grown crops may tolerate higher populations to buds and developing seed heads before treatment is necessary, providing that adequate water is available in the soil profile.

- **Control**

An integrated approach is most successful in controlling heliothis populations in safflower. Control options should consider insecticide resistance management strategies and bio-insecticides like Bacillus thuringiensis and nuclear polyhedrosis virus are available, as well as conventional insecticides. Pupae digging of later summer crops to 10cm depth may reduce the population of 'over-wintering' pupae.

Rutherglen bug (Nysius vinitor)

Adults are 5mm long, grey-brown in colour with clear folded wings, while nymphs are reddish-brown and pear-shaped (**Figure 18**). High populations can substantially reduce the yield and quality of safflower crops. Infestations can be sporadic with the pest moving in and out of crops. Infestations are most common during hot, dry weather, and where there are few other green crops growing. Activity is often greater towards evening.

Figure 18: Rutherglen bugs feeding on a safflower flower. Photo: QPI&F

- **Damage**

Adult bugs feed on the upper stems, buds and developing capitula. Severely damaged buds and flower heads wilt and die or become grossly malformed. Adult bugs may also lay eggs in the developing seed heads and feeding by large numbers of nymphs and adults from flowering onwards can reduce seed yields, especially where crops are deprived of moisture during seed growth. Damage may occur across whole crops or in patches.

- **Threshold**

Due to the transient nature of Rutherglen bugs, check a large number of sites at within a paddock to determine the extent and severity of infestations. The threshold for spraying is generally around 15 adults per plant, but well growing crops may tolerate more, since healthy plants can renew as much as 40 per cent of buds providing adequate water is moisture.

- **Management**

Rutherglen bugs can be controlled with products containing deltamethrin, but there is a continuous risk of re-infestation from crops or weedy areas. Timing is also critical due their transient nature.

Redlegged earth mites (Halotydeus destructor) **and Blue oat mite** (Penthaleus major)

Adults are 1mm long and black to purplish-blue in colour with 8 brightly coloured legs (**Figure 19**). They are an intermittent pest of most concern during establishment. These mites often hide under clods of soil or on the underside of leaves during hot weather.

Figure 19: Redlegged earth mite (right) and blue oat mite (left) Photo: QPI&F

- **Damage**

Redlegged earth mites and blue oat mites have a rasping mouthpiece which damages leaves allowing them to feed on plant fluids. Typically this causes a silver discolouration, often referred to as windowing. Very high populations can also lead to the distortion of leaves and leaf tips or whole seedlings may wither and die. Inspections for these mites are more effective in the cooler conditions of late afternoon or night.

- **Threshold**

Mites are usually present in large numbers, especially in dry seasons. Spraying should occur when significant damage occurs to leaves during early growth. Crops tend to grow away from this pest after stem elongation.

- **Control**

Several insecticides are registered for use in safflower and there are some biological control agents such as ladybird beetles. Some growers choose to spray a residual insecticide to bare soil between sowing and emergence to reduce problems during establishment. Border spraying to reduce the numbers of these pests moving into safflower paddocks is another option.

Other pests

Other pests known to infest safflower crops in Australia include thrips, lucerne flea, black field crickets, grasshoppers, locusts wireworms, false wireworms, jassids and myrids.

Safflower- a pest deterring crop

Farmer case study

NYNGAN, NSW

Breil Jackson

Enterprises:
Broadacre cropping and cattle.

Location:
Nyngan, NSW.

Property size:
6,000ha.

Average annual rainfall/moisture availability:
425mm annually, of which anywhere between 50 and 200mm may fall in crop; the 2007 crop relied heavily on fallow moisture, experiencing only 50mm of in crop rain.

Soil type:
The dominant soils are sandy clay loam – clay loams.

Soil pH_{Ca}:
6.0-6.5.

Breil Jackson. Photo: Breil Jackson

Take home message

Safflower is a beneficial rotational crop for a number of reasons, including soil health restoration and economic gain, providing crops are managed effectively, through careful consideration of available moisture at sowing, target plant population and pre-arranging market contracts.

Safflower production checks

- Secure contracts before sowing, preferably hectare contracts
- Ensure good fallow weed control to reduce in-crop pressure
- Monitor for insect presence at emergence
- Determine sowing rates specific for your property

History of property

Much of 'Bogan River Downs' property was cleared of bimble box and pine in the 1980s, and has been broadacre cropped ever since. A portion of the property is used in cell grazing cattle.

Crop details

When Breil initially purchased part of the farm from his father in 1996, it was smaller in area than present, as Breil has progressively expanded with new land purchases and some leased land. Breil adopted a no-till management system in 1998 and has since progressed to auto guidance and full tram tracking in 2001. The cattle are run on 2,800ha of land separate from the cropping side of the enterprise of 3,200ha.

The current crop rotation is wheat and chickpea alternatively, with safflower finding a fit each season in blocks which benefit most from a safflower crop or have the highest soil moisture. Areas favourable to safflower on the property are those with heavier clay soils, which hold more soil moisture.

Safflower was first introduced to the property in 1984 when, upon returning from agricultural college, Breil persuaded his father to try a different crop in the system to facilitate a better crop rotation. Having such a strong root system and being of the hardy thistle family, safflower was sown that first season and has been grown on 'Bogan River Downs' every season since.

Why grow safflower?

Safflower is a profitable crop within Breil's enterprise through high market prices and its place as a strategic crop within the farming system. Safflower is useful in spreading sowing and harvesting windows, so that all crops may be managed at their optimal time, likewise safflower hedges against damaging cereal harvest rain. Being a broadleaf plant, safflower also acts as a break crop for cereals, in reducing disease carryover. Safflower's deep root system opens up the soil at depth and cracks the soil surface for drying out wet profiles. Safflower is also a low pest maintenance crop, as the physical nature of safflower deters kangaroos, birds, pigs and other potential pests from damaging the crop.

This reduces the risk of plants being grazed off or trampled or invasive weeds being brought into the system with feral animals.

Negative aspects of growing safflower

Safflower, being a niche market crop, experiences price fluctuations on a seasonal and within season basis, creating a need to arrange contracts for sale prior to planting safflower. Comparative poor yield can occur with an absence of spring or early summer rainfall.

Following a crop of safflower, the replenishment of subsoil moisture can take time, as the crop consumes such large amounts of water from the profile as deep as 2m in well structured soils.

Safflower also leaves little trash residue following harvest, which can leave soil exposed in no-till systems, resulting in less water stored. Having a good stubble load before planting safflower can reduce the significance of this.

Sowing window

Over the years that Breil has been growing safflower, sowing times have have ranged between May and mid July but mostly falls between June 1st to June 20th. This is of course seasonally dependent hence the large sowing window.

Paddock preparation

Breil acknowledges that soil moisture is one of the most integral requirements for safflower, and as such water conservation prior to sowing is crucial. For this reason, the presence of stubble during fallow is important within the system and Breil is able to maintain this using no-till.

Weed control is integral to crop production on 'Bogan River Downs', and Breil ensures clean fallows are maintained to minimise in-crop weed problems. Fallow sprays of Group A herbicides such as Correct®, Sertin®, Select® or Verdict® are utilised for black oats and self-sown cereals, which can become problem weeds in-crop.

A knockdown application of Roundup® is also used prior to sowing for wild radish and other hard to kill broadleaves with a spike like Goal®.

Sowing system and establishment

Breil sows at a rate of 4-5kg/ha, using paired skip row configuration of 25cm between each plant in the pair and 50cm between pairs. Many other spacings have been tried, including 75cm, but plants can lodge on wide rows.

The target plant population for safflower has progressively decreased over the years. Experience has shown that for the growing conditions on 'Bogan River Downs' a higher number of plants use up all available water for vegetative seed fill, reducing moisture for seed fill resulting in heads 'full of feathers'. Lighter plant populations also result in more lateral branches which may escape the header, creating a patchy harvest. However, in wetter seasons, the plant population is raised accordingly. Sowing machinery has also been found to influence the plant population of safflower, for example using a disc planter, establishment is more effective allowing a planting rate of 4.5kg/ha, compared with a tine planter that produces lower establishment requiring a higher sowing rate of 5kg/ha.

Depth of sowing can occur down to 4cm, as the epigeal emergence of safflower permits deeper seed placement and success in breaking through crusted soils. An optimal depth of soil moisture at sowing is 120cm

Varieties

Breil began growing Gila in 1984, and progressed to Sirothora and Sironaria at their release around 1987. Sironaria proved the better variety for the growing conditions, considering Phytophthora is of little concern on the property. One of the Saffola varieties (with higher oil content) was also grown periodically, however Breil found that the oily dust produced by the plants during the harvest process increased the risk of header fires, which have never been an issue for other varieties. Therefore Sironaria is grown at present being the most consistent and productive variety for the area.

Crop nutrition

Breil's safflower nutritional requirements are satisfied by applying similar rates and products to those used in wheat production on the property; 70kg/ha of MAP or 80kg/ha of DAP at sowing. Urea is sometime used at sowing, sown separately to the seed at rates up to 60kg/ha.

Weed control

Because Breil implements thorough weed control during fallow, less need is placed on in-crop broadleaf weed management and control efforts can be focused on cleaning up grass weeds such as black oats and ryegrass using Verdict® or Correct®. Broadleaved weeds are controlled with Ally® and while this herbicide has a narrow window of application it is effective.

Herbicide resistance

To date there is no known instances of herbicide resistance occurring on the property, however it is an issue considered in herbicide management.

Insect management

At emergence, cutworms can be of significance for safflower, especially when sowing at such low rates. They are managed using various registered products. In Breil's 25 years of experience in growing safflower these are the only pests of significance to consider in management. Heliothis occur in-crop occasionally however populations have never reached a level at which control has been required. 75ml/ha of Fastac® is usually added to pre-sowing knockdown spray to control cutworm.

Disease management

Safflower does not tolerate waterlogging and Breil manages his crops accordingly to avoid Phytophthora. A fungicide has never been required on safflower. Prior to the release of Sironaria, Alternaria was the most damaging disease.

Harvest management

Safflower is direct headed using an R75 rotary header, operating at a cylinder speed of 450-600RPM, as cylinder speeds too low will cause cylinder choking especially in heavier crops. Sieve settings often need to be adjusted to remove safflower buttons, as in a lower yielding season. Buttons are smaller and have a similar mass to seed, resulting in high admixture with the seed. Similarly, over-threshing is avoided as broken stalks can behave in the same way and are not easily separated from the seed. Header speed of operation is slower than more common crops, however in a thinner plant stand, machinery can move more quickly.

Safflower is very susceptible to weather damage at maturity and a timely harvest is necessary. Seed moisture should be less than 8% at harvest unless there is access to a drier. Header fires. Header fires in Sironaria have not been an issue for Breil.

Management of safflower residue

There is little safflower stubble to deal with following direct heading, as most of the trash is broken up and dispersed by the harvest operation, only hard woody stalks remain.

In terms of managing harvested seed, aerated silos are optimal for on farm storage, with the addition of cold air being circulated through the silo to ensure oil does not turn rancid in the heat. Breil does not target either confectionary or oil markets specifically.

Cost of production

The cost of safflower production on Breil's property is slightly less than wheat.

Economic benefit from growing safflower

Beside the direct monetary benefit of seed sales, safflower can open up hard soils, providing some moisture is present. Safflower, can be grown under high kangaroo pressure therefore requiring less frequent monitoring than other crops. Kangaroos may be pushed to eat safflower during the rosette stage if green pick is limited, however if left unchecked, they will only damage a small percentage of the stand, compared to up to 50% of a cereal crop. Breil has found that pigs will live in safflower but apart from their burrows create little damage. Emus have also been known to pick whole plants from the ground in the very early stages of establishment however this is not a problem once plants are established as safflower is relatively unpalatable in later stages.

Reliability/robustness of safflower

Safflower is a very robust plant across all seasons, providing adequate moisture is available at planting. In Breil's experience, more safflower crops have failed due to insufficient soil moisture at sowing and/or excessive seeding rates than all other causes combined.

Crop compared to other crops

Safflower is an easy crop to grow in comparison to other alternative crops, and has a low intensity of management in contrast with common crops.

Crop yield

Breil's safflower crops average between 0.5 and 1.5t/ha.

HARVESTING

Key for successful safflower production:

No.12: Harvest as soon as crops are mature and be careful to avoid seed damage reducing quality and avoid blocking equipment.

Safflower sown in winter is normally ready for harvest 4 to 6 weeks after wheat and about four weeks after flowering has finished. Harvest usually begins in late December in northern New South Wales and continues into March in the south east of South Australia.

Harvest can commence when most of the bracts surrounding heads are dry and yellow or brown and the stem is dry. Terminal heads are the first to mature and this can be up two weeks before heads on secondary branches. It is therefore important to sample whole plants to get a reliable idea of seed moisture content and maturity. The odd late head that is still green will contain immature seeds and can be ignored. When mature, seeds should be white and can be easily squeezed out of heads using gloved hands. Seed samples can also be extracted by cutting the heads from plants and placing them in a tray and pressing gently down on them using a soft plastic implement such as a dustpan. Seed moisture should be less than 8 percent and most processors will not accept seed above this level as it is prone to overheating and mould formation.

Safflower should be harvested as soon as possible to reduce the risk of yield and quality losses from rain which can stain seed reducing its value. Rain can also cause seed to germinate in the erect cup like flower heads which can hold water for some time. Risk is greater in northern regions, but it could happen anywhere. Safflower does not lodge readily, but seed can be lost in very strong wind. Furthermore, small birds such as sparrows may feed on seed whilst it is still in the head awaiting harvest, while cockatoos can chew plants off at the base, then remove the seed from the flower heads whilst the plant is on the ground **(Figure 20).**

Very hot and dry conditions during harvest will result in very brittle plants, which shatter easily into small pieces making it difficult to maintain clean seed sample. Safflower resists shattering from wind while crops are standing, but they are easily shed at the cutter bar of harvesting machinery if plants are very dry.

These issues can be overcome by harvesting very dry crops during cooler conditions, such as at night.

Safflower will thresh above 8% seed moisture, but harvested seed must be dried quickly in a grain drier to prevent the development of a musty odour. This may also help preserve the preferred whiteness of the seed coat for birdseed markets.

The bristles contained in safflower head are light, fluffy and highly flammable. Harvesting machinery should therefore be cleaned periodically when harvesting safflower to reduce the risk of fire, especially around the engine, radiator, air intakes and exhaust.

Header settings

Key for successful safflower production:

No. 13: Harvest during cooler conditions to improve cleanliness of seed and reduce the risk of fire.

Safflower can be harvested using the same machinery used for cereals. Ground speed is generally 25 percent slower than for cereals. This is mainly to reduce grain losses, but also to reduce the chance of blockages which can be time consuming and uncomfortable to rectify due to the crops spines. Header settings will vary with conditions, crop yield and the type of machinery used.

Reels should be set to gently push the crop over the cutter bar without dislodging seed from the capitula. Drum speeds are generally slower (~500rpm), and concave openings usually wider (~16mm at front, ~13mm at back) than used for cereals. This is to prevent the cracking of seed which will deteriorate oil quality and reduce the value of the crop. Special care should be used when harvesting planting seed, using as low a drum speed as possible.

Wind settings are typically about two-thirds of that required for wheat. Large populations of green weeds can make harvesting difficult and no desiccants are currently registered for use in safflower.

Windrowing or swathing is an alternative, but some losses due to shattering should be expected.

Many growers choose to drag a chain from the travelling harvester to dissipate any static build up and mitigate against possible header fires.

Typical grain losses during harvesting are about 3 to 4%, made up of 2 to 3% at the back of the header and about 1% at the cutter bar.

TRANSPORT AND STORAGE

Key for successful safflower production:

No.14: Consider on-farm storage of safflower to enable access to more lucrative markets.

Safflower is lighter than wheat and more easily lost from the tops of trucks or bulk bins travelling at speed. Loads should be covered securely to minimise losses. Transport costs can also be higher due to the lower bulk density. For example, a truck can carry more tonnes of cereal in a given volume than safflower seed.

Safflower can be sold directly to crushing plants, other markets or stored on farm. Stored seed is vulnerable to common insect pests of stored grain and harvest preparations should include cleaning and disinfesting harvesters, storage facilities and other equipment used to handle seed.

Figure 20: Safflower damaged by cockatoos. Photo: Nick Wachsmann

Safflower - an opportunity crop

Farmer case study

MURRA WARRA, VICTORIA

David Jochinke

Enterprises:
95% cropping, 5% prime lamb.

Location:
Murra Warra is approximately 26km north of Horsham, Victoria.

Property size:
1700ha (owned and leased).

Average annual rainfall/moisture availability:
410mm annually of which, on average, 210mm generally falls within the safflower growing season.

Soil type:
The dominant soils are friable, alkaline, calcareous, self mulching clay loams.

Soil pH_{Ca}:
7.9.

Take home message

Strategic use of the crop is a stronger driver to produce safflower than the gross margin of the crop.

Safflower production checks

- Target early sowing
- Ensure good soil water availability
- Obtain sound, viable seed from a reputable source
- Ensure good weed control in previous crops
- Be prepared to store the crop to enhance marketing options

History of property

In 1950 Albert Victor Jochinke (known as Vic) purchased two 130ha allotments at Murra Warra through a soldier settlement grant. Grandson David currently operates the farm which he has doubled in size since he has been operating it.

Crop details

The farm traditionally had a three phase rotation; medic, fallow followed by wheat. The medic was utilised for grazing by sheep, the fallow for weed control and wheat for cash return. Barley was introduced in the 1960-70s and chickpeas and canola in the 1980s. Over the wetter 1970-80s some sunflower was produced and in the 1980s safflower was introduced, followed by lentils in the 1990s.

The current crop rotation is wheat, lentils, barley, chickpeas usually followed by oaten hay. Canola, safflower and field peas are opportunity cropped. In 2009 David sowed 50ha of safflower.

Why grow safflower?

Generally safflower is grown purely as a cash crop requiring adequate inputs and timely sowing. However it was included in the 2009 season as a strategic crop after missing the window to plant a barley crop in a paddock when it became too wet for timely access. David was also exercising caution in not producing too much feed grain due to the domestic dairy crisis and subsequent drop in feed grain prices. He aimed to spread his production and financial risk by including safflower.

In the past safflower has been used on the property to open up clay soil and dry the profile but recent seasons have not been that wet to necessitate such a practice.

David also keeps an eye on the price of safflower and when the price is attractive he may consider producing safflower. In 2009 he also saw the opportunity to produce fresh planting seed for future safflower growers.

David Jochinke. Photo: Sue Knights

Negative aspects of growing safflower

Safflower generally does not have the gross margin of the other crops in the rotations and requires large amounts of water to achieve high yields.

David also makes the point that you need to be mindful of paddocks with broadleaf weed problems as the lack of in-crop herbicides is a drawback in producing safflower crops.

Sowing window

David aims to sow early in June to July to target the maximum potential yield for safflower crops. If he is not able to sow early due to wet conditions, he aims for maximum oil content with the later sowing. However the decision to sow late safflower may compete with a choice of other summer crops such as sunflower, depending on its market price.

Paddock preparation

Paddocks are usually prepared with a knockdown herbicide up to one week prior to sowing or sprayed in front of the bar generally using a mix of glyphosate and oxyfluorfen to control weeds. David has adopted a no-till system and uses Primary Sale Inverted T points on a 820 Flexi-coil bar with 30cm row spacing and Agmaster press wheels. The press wheels are used to improve seed-soil contact which is critical for no-till systems.

Sowing system and establishment

David sows his safflower seed between 15-20kg/ha and generally uses 18kg/ha to aim for between 20-25 plant/m^2. Seed is placed at approximately 3–5cm depth. The rate must be kept low as excessive plant numbers can lead to water moisture stress later in the season. The seed is cleaned and generally treated with a fungicide to control fungal diseases such as Alternaria, Fusarium, Pythium and Rhizoctonia. In the past an insecticide to control blue oat mite, redlegged earth mite and cutworm has also been applied.

Varieties

In the past S 555 has been grown to target the oilseed market but in 2009 he grew Sironaria mainly because he had seed of that variety in storage.

Crop nutrition

David's safflower nutrition program depends upon the paddock history. In general all paddocks on the property are soil tested before they are sown to a cereal which is around every 2 years. Safflower is treated similar to wheat requiring around 50kg/ha MAP at sowing to target average yields. David says adequate nutrition is essential to set up safflower for its best possible performance.

Weed control

Safflower is tolerant to a very limited number of in-crop broad leaf herbicides. Trifluralin® is applied pre-sowing and metsulfuron methyl with a grass selective are commonly used post emergence. Generally safflower is grown in paddocks with ryegrass and brome grass problems or a strategic delaying of sowing is used to maximise the kill of these weeds before sowing.

Herbicide resistance

David suspects he has two areas of herbicide resistant annual ryegrass on his property which he manages through an appropriate crop rotation including oaten hay and grazing with sheep.

Insect management

Redlegged earth mites are controlled with a combination of using a broad spectrum insecticide at establishment and an insecticide seed dressing. Other insects are controlled on a threshold basis which requires regular crop monitoring. There has been only one case of heliothis and few instances of Rutherglen bug infestations which required control.

Disease management

Safflower seed is treated with a fungicide which prevents most diseases except leaf rust which has been rarely seen.

Harvest management

Safflower is harvested anywhere between Christmas and March, depending on the time of sowing. David uses his Case 2388 with a 30ft 1020 fixed front. A rotary header is preferred to a Walker type as safflower stems tend to get caught in the Walkers which is difficult to remove and causes seed loss.

He ensures that crops are harvested as soon as they are ready to reduce any weather damage to the seed although the plant is very resistant to lodging and shattering. Harvesting only begins once the moisture is well below 12% and often during harvest it will drop to 8-9% which is ideal to be stored successfully. Safflower is harvested gentler than other crops to reduce the number of buttons in the sample and prevent the cracking of seed and to avoid blockages. A wheat setting is used with a slower fan and rotor speed but a slightly wider concave setting. It is recommended that the engine bay and especially the exhaust manifold are blown down at least two to three times a day to stop potential hazardous caking. David also uses an air compressor each morning to blow the pappus out of the radiator and as a precautionary measure he also uses two chains to earth the header in an attempt to prevent a buildup of static electricity.

Management of safflower residue

During harvest David tries to take as much of the safflower plant as possible through the harvester which is chopped and spread to avoid having to slash the stubble. Before the introduction of the no-till system to the farm safflower stalks were an issue damaging machinery tyres as they wore near the lugs. This is still one of the main reasons to reduce the trash as much as possible.

Cost of production

Table 5 gives a typical safflower gross margin for a 50ha paddock on David's property assuming safflower is worth $600/t and reasonable growing conditions.

Economic benefit from growing safflower

David considers safflower a good opportunity crop when the price is attractive however the birdseed market is extremely volatile. He has never forward contracted a safflower crop as he considers the yields of the crop too variable. He very seldom sells at harvest and uses some of his 1300t on-farm storage to store safflower for up to a few years. In the longer term he will convert more storage to be sealed and aerated. David has sold to a number of birdseed markets.

Reliability/robustness of safflower

The reliability of safflower in the Wimmera region is very much rainfall dependent. However David considers safflower as a robust crop in the years he has grown it as he has never had a crop totally fail.

Crop compared to other crops

Safflower is a very thirsty crop compared to other crops in his rotation. Some limitations of safflower are the lack of availability of in-crop herbicides and it has slow early vigour which is like canola, however it does compensate with rapid growth in spring. David considers available water and the net margin for safflower as the biggest determinants of the crop's viability.

Crop yield

David's safflower crops have yielded in the range of 0.2 to 2.7t/ha with the best yield achieved when crops were sown early into a fallow and at the end of June.

Table 5: A typical safflower gross margin for a 50ha paddock on David's property assuming safflower is worth $600/t and reasonable growing conditions

										$/ha	$/tonne	Paddock
INCOME	Sironaria				0.9	t/ha	@	$600	per tonne	$540	$600	$27,000
EXPENDITURE												
Machine	Implement	Activity	Ha	Input			@					
John Deere	Goldacres	Knockdown	50		60	ha/hr	@	$300	per hour	$5.00	$5.56	$250.00
			50	Water softener	0.4	L/ha	@	$0.87	per litre	$0.34	$0.39	$17.48
			50	Glyphosate	1	L/ha	@	$5.50	per litre	$5.50	$6.11	$275.00
			50	Oxyfluorfen	0.075	L/ha	@	$32.40	per litre	$2.43	$2.70	$121.50
			50	Wetter	0.05	L/ha	@	$6.90	per litre	$0.35	$0.38	$17.25
John Deere	Goldacres	Pre-sowing	50		60	ha/hr	@	$300	per hour	$5.00	$5.56	$250.00
			50	Trifluralin (480g/L)	1.4	L/ha	@	$6.80	per litre	$9.52	$10.58	$476.00
Versatile	Flexicoil	Sowing	50		10	ha/hr	@	$350	per hour	$35.00	$38.89	$1750.00
		Seed	50		18	kg/hr	@	$720	per tonne	$12.96	$14.40	$648.00
		Seed dressing	50		1.5	kg/t	@	$8	per kg	$0.22	$0.24	$10.80
		Seed dressing	50		1.5	kg/t	@	$20	per kg	$0.54	$0.60	$27.00
		Fertilliser	50		50	kg/ha	@	$550	per tonne	$27.50	$30.56	$1375.00
John Deere	Goldacres	Post-emerge	50		60	ha/hr	@	$300	per hour	$5.00	$5.56	$250.00
			50	Metsulfuron	5	g/ha	@	$0.10	per gram	$0.02	$0.02	$0.98
			50	Grass herbicide	0.075	L/ha	@	$80	per litre	$6.00	$6.67	$300.00
			50	Spray oil	0.5	L/ha	@	$5	per litre	$2.50	$2.78	$125.00
Case		Harvesting	50		10	ha/hr	@	$350	per hour	$35.00	$38.89	$1750.00
		Storage	50		6	month	@	$1.50	per month	$8.10	$9.00	$405.00
		Insurance	50		1.2	%	@			$6.48	$7.20	$324.00
Total Variable Costs										**$167.46**	**$186.07**	**$8,373.01**
Net Margin										**$372.54**	**$413.93**	**$18,626.99**

END USES

The main end uses for Australian safflower seed are oil and birdseed. Safflower seed can contain over 40% oil and like sunflower oil, it contains no linolenic fatty acid resulting in greater stability and a longer shelf life.

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, 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. These 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 – 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 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 this process is not economically viable and oil extraction is usually performed on whole seeds.

A new end use may be developed for safflower in the next 10 years through a collaboration between CSIRO and GRDC to genetically modify safflower to produce increased quantities of fatty acids with industrial applications, such as biodegradable plastics.

MARKETING

Most safflower grown in Australia is sold to two domestic traders (Devexco Pty Ltd and Adams Australia) and then crushed through subcontractors. Alternatively safflower for oil may be stockpiled for shipment and oil extraction overseas. There are various Australian traders of safflower for birdseed. Care needs to be taken to segregate birdseed, oleic and linoleic oilseed types.

The main markets for Australian monounsaturated safflower include Japan and USA which also import smaller amounts of polyunsaturated product. Europe and India are the main consumers of Australian grown polyunsaturated products.

Australian safflower for birdseed is sold domestically and to Europe and Taiwan.

Organic Australian safflower oil is marketed into the USA (mainly monounsaturated), Europe (mainly polyunsaturated), Japan (mainly monounsaturated) and a small amount within Australia (mainly monounsaturated).

DELIVERY STANDARDS

The standard oil content is 38 per cent, with a 2 per cent price premium or reduction for each percentage point above or below this level.

Seed can be rejected if it contains over 4 per cent of impurities and there is a one-for-one penalty above 4 per cent if the seed is accepted. Impurities consist of weed seeds, pieces of stem and seed and other very small material which will pass through a screen with holes of 2mm diameter.

Crops can be rejected if over 7 per cent of the seed is broken and there is a price penalty of 0.5 per cent for each percentage point of broken seed above this level. Broken seed normally results from mechanical damage, and consists of hulls, kernels and seed pieces.

Up to 3 per cent of seed may be damaged without penalty, and seed will only be rejected if over 40 per cent is damaged. There is a half-for-one penalty above the 3 per cent level. Seed is regarded as ‘damaged’ if it is affected by heat, frost, sprouting or other weather damage.

The current receival standards for polyunsaturated and monounsaturated safflower are shown in **Tables 6** and **7**.

Table 6: Delivery standard for polyunsaturated (linoleic) safflower, as at August 1, 2009.

Commodity: SAFFLOWER - Polyunsaturated		**Standard Reference No: CSO 10**
Parameter	**Specification**	**Comment/Price Adjustment**
Physical & Chemical Parameters		
General		Safflower tended for delivery shall be free from any uncharacteristic odours, live stored product insect infestation and any nominated commercially unacceptable contaminant
Oil	38% base level	2% premium or deduction for each 1% above or below 38%
Linoleic Acid	75% minimum	Rejectable under this limit
Moisture	8% maximum	Immediate processing - if accepted over the maximum, 2% deduction for each 1% over maximum For storage - if accepted over the maximum, 1.5% deduction for each 1% over maximum plus a drying charge
Test Weight	n/a	
Protein	n/a	
Seed Retention	n/a	
Germination	n/a	
Defective Safflower (Maximum % wt/wt based on cleaned half litre sample retained above 2.0mm round hole sieve)		
Broken or Split	7% maximum	0.5% deduction for each 1% over the maximum
Total Defective, including:	10% maximum	0.5% deduction for each 1% over the maximum
Damaged	3% maximum	0.5% deduction for each 1% over the maximum, rejectable over 10%
Sprouted	5% maximum	0.5% deduction for each 1% over the maximum
Contaminants (Maximum per half litre unless otherwise stated, rejectable over unless deductions are stated as applying)		
Impurities	4% maximum	
Snails/Stones	Nil above screen	Nil tolerance per 2.5 litre sample for any snails/stones remaining above a 3.0 mm round hole screen. If one snail/stone is found above the screen in the ½ litre sample, then a further four ½ litre samples should be taken. If a snail/stone is found in any one of the subsequent samples, the load is to be rejected.
	1 stone/snail per ½ litre below screen	Tolerance of 1 stone/snail per ½ litre sample, passing through a 3.0 mm round hole screen
Field Insects	10 large per ½ litre	Includes Rutherglen bugs, ladybirds, grasshoppers and wood bugs
	100 small per ½ litre	Includes all species of aphid and all species of mites
Ryegrass Ergot	0.5cm maximum	Maximum of all pieces aligned end on end
Objectionable Material	nil	Harmful substances include live or dead stored grain product insects, live or dead pea weevil, glass, metal, specified weed seeds in excess of the limit prescribed in any of the State Stockfeed Regulations lists of permitted weed seeds, the presence of pre or post-harvest chemicals not registered for use, used in excess of permitted levels or with residues in excess of their permitted levels, smut, material imparting an odour to the grain, sand, earth, sticks and pickled grain. Includes Degraded seed such as smutty seed, hot seed, musty seed, sour seed, mouldy seed.
Seed Contaminants (maximum tolerance per half litre to apply to individual seeds, rejectable over)		
Type A	nil	Alligator Weed, Cape Tulips, Castor Oil Plant, Coriander, Creeping Knapweed, Darling Pea, Dodder, Giant Sensitive Plant, Opium Poppy, Parthenium Weed, Ragweed, Rattlepod, Saffron Thistle, Star Burr, Stinkwort, St. Johns Wort
Type B	1	Burrs (Xanthium spp.) – all except where otherwise stated, Wild Mignonette
Type C	2	Crow Garlic, Skeleton Weed, Thornapple
Type D	3	Common Heliotrope, Darnel, Hexham Scent, Jute, Mexican Poppy, Mintweed, Nightshade
Type E	65	Sesbania Pea

Table 7: Delivery standards for monounsaturated (oleic) safflower, as at August 1, 2009.

Commodity: SAFFLOWER – Monounsaturated		Standard Reference No: CSO 11
Parameter	**Specification**	**Comment/Price Adjustment**
Physical & Chemical Parameters		
General		Safflower tended for delivery shall be free from any uncharacteristic odours, live stored product insect infestation and any nominated commercially unacceptable contaminant
Oil	38% base level	2% premium or deduction for each 1% above or below 38%
Oleic	75%	Rejectable under this limit
Moisture	8% maximum	Immediate processing - if accepted over the maximum, 2% deduction for each 1% over maximum For storage - if accepted over the maximum, 1.5% deduction for each 1% over maximum plus a drying charge
Test Weight	n/a	
Protein	n/a	
Seed Retention	n/a	
Germination	n/a	
Defective Safflower (Maximum % wt/wt based on cleaned half litre sample retained above 2.0mm round hole sieve)		
Broken or Split	7% maximum	0.5% deduction for each 1% over the maximum
Total Defective, including:	10% maximum	0.5% deduction for each 1% over the maximum
Damaged	3% maximum	0.5% deduction for each 1% over the maximum, rejectable over 10%
Sprouted	5% maximum	0.5% deduction for each 1% over the maximum
Contaminants (Maximum per half litre unless otherwise stated, rejectable over unless deductions are stated as applying)		
Impurities	4% maximum	1% deduction for each 1% of impurities up to 4%, 2% deduction for each 1% of impurities over 4%
Snails/Stones	Nil above screen	Nil tolerance per 2.5 litre sample for any snails/stones remaining above a 3.0 mm round hole screen. If one snail/stone is found above the screen in the ½ litre sample, then a further four ½ litre samples should be taken. If a snail/stone is found in any one of the subsequent samples, the load is to be rejected.
	1 stone/snail per ½ litre below screen	Tolerance of 1 stone/snail per ½ litre sample, passing through a 3.0 mm round hole screen
Field Insects	10 large per ½ litre	Includes Rutherglen bugs, ladybirds, grasshoppers and wood bugs
	100 small per ½ litre	Includes all species of aphid and all species of mites
Ryegrass Ergot	0.5cm maximum	Maximum of all pieces aligned end on end
Objectionable Material	nil	Harmful substances include live or dead stored grain product insects, live or dead pea weevil, glass, metal, specified weed seeds in excess of the limit prescribed in any of the State Stockfeed Regulations lists of permitted weed seeds, the presence of pre or post-harvest chemicals not registered for use, used in excess of permitted levels or with residues in excess of their permitted levels, smut, material imparting an odour to the grain, sand, earth, sticks and pickled grain. Includes Degraded seed such as smutty seed, hot seed, musty seed, sour seed, mouldy seed.
Seed Contaminants (maximum tolerance per half litre to apply to individual seeds, rejectable over)		
Type A	nil	Alligator Weed, Cape Tulips, Castor Oil Plant, Coriander, Creeping Knapweed, Darling Pea, Dodder, Giant Sensitive Plant, Opium Poppy, Parthenium Weed, Ragweed, Rattlepod, Saffron Thistle, Star Burr, Stinkwort, St. Johns Wort
Type B	1	Burrs (Xanthium spp.) – all except where otherwise stated, Wild Mignonette
Type C	2	Crow Garlic, Skeleton Weed, Thornapple
Type D	3	Common Heliotrope, Darnel, Hexham Scent, Jute, Mexican Poppy, Mintweed, Nightshade
Type E	65	Sesbania Pea

Safflower - a soil conditioner

Farmer case study

KYBYBOLITE, SA

Brett Shepherd

Brett Shepherd. Photo: Sue Knights

Enterprises:
Organic cropping, stud sheep; Poll Dorset and White Suffolk, organic beef.

Location:
'Mullinger Park', Kybybolite, Limestone Coast, SA.

Property size:
506-688ha.

Average annual rainfall/moisture availability:
533mm, 50-100mm falls during the safflower growing season.

Soil type:
Red gum loam and black cracking clay, the loam soils are not as resilient to cropping as the clay.

Soil pH_{Ca}:
5.0 -6.0.

Take home message

Safflower is an excellent soil conditioner in cropping rotations and its benefit in cropping systems must be considered in terms of the yield gain and performance of the subsequent crop.

Safflower production checks

- **Ensure you sow as early as possible, September to October**

History of property

The property has been in the Shepherd family for over 80-90 years and has been organic for 22-23 years. Brett's father converted the property to organic production following the wool crash and a family medical situation when he saw a market opportunity to produce healthier food. The family market their own produce.

Irrigation

Brett has 25ha of irrigation available on the property which is applied using a gun irrigator. This is used to finish off high value crops including lentils, chickpeas and linseed.

Crop details

The crops grown on the property are oats, linseed, chickpeas, safflower and lucerne; 50% of the property is cropped. The usual rotation is pasture, linseed, lentils, oats, safflower, chickpeas, linseed or pasture. If weeds are a problem in the system they cut a hay crop to manage these. All the crops are grown organically and Brett plans to continue with this farming system in the future. To maintain organic status 7% of the property is sown to native trees.

Why grow safflower?

Safflower is grown at 'Mullinger Park' as a key part of the cropping rotation. Not only is it used for weed management, as the spring sowing enables additional paddock cultivations, but it has a significant role as a soil conditioner. The tap root of safflower opens the soil profile and helps to dry paddocks and the extra working of paddocks controls Rhizoctonia. Brett has not seen this disease in oats due to this management practice.

Negative aspects of growing safflower

Brett says that safflower is not a valuable crop in its own right but plays a significant part in his cropping rotation.

Sowing window

Safflower is normally sown early October, but actual dates are often dictated by paddock accessibility and rainfall. Sometime sowing can occur as early as late August but in 2009 it was sown very late in October.

Paddock preparation

The year before cropping paddocks lime and dolomite are applied to improve the soil pH. An off-set disc is used to mulch cereal stubble and a prickle chain is then used to crack the stubble and knock it down further. Paddocks are widelined or scarified over winter to control weeds and may be finger tined over summer. In spring the paddocks are scarified and prickle chained then sown.

Sowing system and establishment

Safflower is usually sown at 18kg/ha using a combine and then the paddock is rolled. Brett usually does not have a problem with germination, however in 2009 the conditions were unusually hot in early November when the crop was germinating and he suffered a patchy germination.

Varieties

Brett has grown Sironaria in the past but found that it did not yield and had difficulties marketing it. Now he grows S 317, a high oleic variety on contract to Devexco Pty Ltd.

Crop nutrition

Cropping soils are tested every 2-3 years for nutrient status. An organic mineral fertiliser is applied to cropping paddocks at the rate of 100kg/ha but not with safflower. This is a Western Mineral Natural Product from WA and contains 4% phosphorus, 2% potassium in a pellet form. Foliar fertilisers are applied to crops including a mix of fish oil, sea minerals and kelp.

Weed control

Several mechanical approaches are used to manage weeds on the property; off-set discs, wide line, scarifier. To use these it is important to be able to access the paddocks during winter.

Herbicide resistance

As the property is certified organic this is not an issue.

Insect management

Previously, Brett ensured that the plants are kept healthy to minimise insect damage, to do this he uses between 1-2 foliar fertiliser applications. He has considered using pyrethrum to control heliothis and previously has used Bt sprays to do this.

Disease management

Diseases are minimised in crops through careful choice of rotation and avoiding wet paddocks. Brett says that ensuring good air movement around the plants also helps to reduce disease.

Harvest management

Brett uses a Case Rotary Header with finger trays to feed the crop in. He uses the same harvesting speed as oats.
To reduce static build up he drags a chain, and he works into the wind to avoid the build up of fluff on the header as well as blowing the header down regularly.

Management of safflower residue

Little residue is left after safflower crops are harvested. Stalks may be off-set disced into the ground or grazed by sheep to tidy up buttons and any weeds. Brett finds that 90% of the stubble has broken down by mid winter.

Reliability/robustness of safflower

Brett usually finds that safflower is quite a reliable crop if the germination is good.

Crop compared to other crops

In Brett's cropping system chickpeas would substitute for safflower. Chickpeas are a more valuable crop and he found that they coped better than safflower with the heat during germination in 2009.

Crop yield

Brett has achieved crop yields for safflower ranging from 1.0 to 2.5 t/ha.

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ACKNOWLEDGEMENTS

Additional Photographs:

- Bob Colton
- Agriculture and Agri-Food Canada via Hans-Henning Mündel.
- Queensland Department of Primary Industries and Fisheries.

The base document to produce this publication was Safflower growing. AgFact P5.2.2. The author, Bob Colton, is acknowledged.

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