Seed Oils for Industry and Energy

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ABSTRACT
Australia is seriously dependent on fossil fuels. Mineral oil, mostly in the form of petroleum, diesel and fertilizers, is currently essential for agriculture and in those and other forms, for most aspects of community life and economic systems. Mineral oil is non renewable and depleting. However, there are various alternative sources of energy available, some renewable some not eg. wind, solar, nuclear, coal, gas and plants. It is unlikely that there is one single renewable source that can replace all that is derived from mineral oils. It will need to be a combination of alternative resources that could eventually replace fossil fuels. Plant based oilseeds are a renewable, sustainable source of oil for biofuels; for heat or energy and also for industrial uses such as for lubricants, to produce erucamides (often used as a slip agent in plastics), in the manufacture of nylons and polymers, in printing inks and for many other uses. Oilseed crops could also be a source of high protein meal for livestock feed, in biodegradable bioplastics, adhesives, cosmetics, lawn care and fertilizer products. Trials conducted at a range of sites in the wheat belt of WA have shown that some of the species are well adapted to WA and can often produce higher yields than canola particularly in the drier areas of Western Australia.

The diversity of crops that may be profitably grown in southern Australia would have additional benefits in rotations, as disease breaks and in the reduced use of chemicals.

Key words: oilseeds, erucic acid, bioenergy, mineral oils.

INTRODUCTION
Over the past few years, in projects funded by RIRDC and GRDC, with the support of Elders and the Grain Pool and conducted by CLIMA and DAWA, a number of alternative oilseeds have been evaluated for their suitability to Western Australian growing conditions. The oilseeds have a range of qualities and characteristics that make them suitable for different markets not generally accessed by canola. Various species in the *Brassicaceae* produce oils that are particularly suited for many industrial applications. Several of them have seed oils that contain a high proportion of erucic acid. These include *Brassica juncea* (Indian and Oriental Mustards), *Brassica carinata* (Ethiopian mustard), *Brassica rapa ssp campestris* (Turnip Rape) and C*rambe abyssinica* (Crambe or Abyssinian mustard). The seed of *Camelina sativa* (false flax, Gold of Pleasure) contains oil that is low in erucic acid but has characteristics that make it suitable for other industrial applications eg in the cosmetic industry, and where *Linum usitatissimum* (linseed) has been traditionally used in polishes, varnishes and paints. Markets for specialty oils exist globally, but are generally underexploited.

The Australian oilseed industry is currently dependent on canola (*Brassica napus*) despite the diversity of environments and the threats from diseases and pests. A single oilseed is unlikely to be the best fit for all environments and disease exposures. Canola is poorly adapted to very dry areas, those with incipient waterlogging, sandy or saline conditions. There are alternative oilseed crops that could be grown profitably in these areas. There is also a need for oilseed crops that produce higher seed yields, have higher oil content in the seed and lower production costs than canola. Increasing the options of profitable crops would have benefits in rotations, as disease breaks and reduced use of chemicals. However, any new oilseed crops would need to have a market for the oil and meal, have high value oil and/or produce equivalent or better yields in a given environment.

MATERIALS AND METHODS

More than 400 lines of different oilseed species were obtained from the Vavilov Institute in St. Petersburg, the Australian Temperate Field Crops Collection at Horsham, Victoria, USDA and from plant collecting missions to Nepal and Ethiopia. The lines were grown in a common environment at the UWA Research Station in Perth WA for a preliminary assessment of their potential. The seed was usually sown in May each year and harvested when plants were mature, between October and December. The oil content and qualities were assessed to determine the variation between the lines of each of the species.

Since 2000, small plot trials of selected lines of the different oilseeds have been conducted on farms in various locations around Western Australia. The locations have included Miling (2000, 2001), Mingenew (2002), Meckering (1999, 2003, 2004), Wagin (2000, 2001), New Norcia (2003) and Albany (2004). Plots were seeded using a cone seeder at varying seed rates depending on the species. Plots were generally sown dry, early in May. The plots comprised 8 rows 20cm apart but varied in length from 10 m to 40 m. in different trials. Varieties of canola were used as controls in the trials. *Brassica carinata* (Ethiopian mustard) was included for the first time in 2001. Plots were harvested at maturity using a conventional plot harvester. Seed for each species was collected, cleaned by sieving and weighed to determine yield. The seed of *Crambe abyssinica* retains its fruit coat intact during and after harvesting, i.e. seed is unhulled. The comparative seed yields obtained these trials are given in Table 1.

In 2004 larger areas of *Brassica juncea* were put in by DAWA for a biodiesel demonstration trial. These included 40 hectares at Wongan Hills and 30 hectares at Newdegate.

The oil content of the seed was measured using chemical extraction methods (soxhlets) or by NMR technology. The fatty acid profiles were determined using gas chromatography on a Shimadzu G17A; helium being used for the carrier gas and hydrogen for the detector gas. The mean oil contents, typical oil qualities and protein content of the seed are shown in Table 2.

RESULTS

The results shown in Table 1 represent the comparative yields of alternative oilseeds species grown in regional trials conducted by CLIMA/Elders and DAWA (2000 to 2004). The cleaned seed yield is quoted in tonnes/ha. The maximum seed yield for each trial is highlighted. In 2001, 95% of the canola was lost due to shattering at the Wagin site whilst the other species suffered losses of up to 25% due to high winds and the rains that delayed harvesting. The seed yield of the 2 bulk areas seeded in 2004 were 50 tonnes for Wongan Hills (1.25 tonnes/ha) and 15 tonnes at Newdegate (0.5 tonnes/ha). However, canola grown at Newdegate yielded only 0.2 tonnes /ha.

Table 1. Alternative oilseed yields for the trials 2000 - 2003

Year	Location	*B. napus*	*B. carinata*	*B. juncea*	*B. rapa*	Camelina	Crambe
2000	Miling	1.88	2.50	**2.75**		1.94	2.54*
2000	Wagin	0.75	1.65	**1.90**		1.13	1.30*
2001	Miling	**2.40**	1.90	1.90		1.00	1.90*
2001	Wagin	Shattered	1.27	**2.53**	0.78	1.23	1.11*
2001	Muresk	0.83	0.87	**1.11**		0.82	0.82*
2001	Merredin	1.54	1.21	1.34		**1.91**	1.83*
2002	Wongan Hills	0.78	0.54	**0.79**	0.48	0.18	0.75*
2002	Mingenew	0.80	0.71	0.55	**0.86**	0.59	0.42*
2003	New Norcia	2.13	**2.19**	2.02	0.35	0.42	1.63*
2004	Albany	**1.80**	1.15	1.58			1.70*
2004	Avondale		0.73	**0.74**			0.96*
2004	Meckering	1.04	1.22	**1.23**	0.71	0.20	0.98*
2004	Merredin	**0.56**	0.16	0.39			0.27*
2004	Mullewa	0.14	0.16	**0.39**			0.27*
5 yr	Mean	1.22	1.16	**1.37**	0.64	0.96	1.17*

*seed with hull

Considerable variation in the fatty acid composition was detected between the lines of some of the species, in particular for *Brassica juncea*. Table 2 gives a fairly typical fatty acid profile for each of the species. The most important fatty acid for each species is highlighted. Tables 3 shows the maximum and minimum values for each of the fatty acids detected in the seed oil of 25 lines of *Brassica juncea.*

Table 2. A typical oil content, fatty acid profile and protein content for each of the alternative oilseed species grown

	B. napus	***B. carinata***	***B. juncea***	***B. rapa***	**Camelina**	**Crambe**
% Oil content	42	40	42	42	38	52**
Palmitic acid	5	3	4	2	5	2
Stearic acid	2	1	2	1	3	1
Oleic acid	**59**	9	31	16	17	15
Linoleic acid	21	15	25	13	16	8
Alpha Linolenic acid	10	11	11	7	**36**	7
Eicosenoic acid					15	2
Erucic acid	0.4	**47**	13	**54**	3	**60**
% Protein content	21	22	22	22	28	9

** seed without hull

Table 3. Variations in fatty acid composition found within *Brassica juncea* (25 lines)

	Palmitic	**Stearic**	**Oleic**	**Linoleic**	**A Linolenic**	**Arachidic**	**Erucic**
Minimum	2.0	1.0	9.7	11.7	9.1	1.1	0.4
Maximum	5.3	3.0	61.1	32.7	14.3	14.1	52.6

DISCUSSION

Australia is dependent on fossil fuels. Mineral oil, mostly in the form of petroleum, diesel and fertilizers, is currently essential for agriculture and in those and other forms, for most aspects of community life and economic systems. Mineral oil is non renewable and depleting. Oilseeds are renewable sources of oil that have the potential to reduce dependency on fossil fuels. However, to fulfill that potential, oilseeds are needed that produce high seed yields, have high oil content in the seed and have lower production costs than canola or produce oils that have high value for industry eg those oils that contain a high proportion of erucic acid. The yield trials of alternative oilseed species have shown that in different environments or in different seasons, several of the alternative oilseeds can yield better than canola (see Table 1). *Brassica juncea* in particular, frequently out yielded canola. Its oil content is close to that of canola and as it does not shatter as easily as canola, it does not require swathing. *Brassica juncea* is more drought tolerant than canola and will grow and potentially yield well in areas where canola is not usually productive. Its input costs are less than canola. In assessments comparing energy input to potential energy yield (RIRDC 2004), in most seasons, *Brassica juncea* could be grown profitably as a crop for energy (biofuels) production. However, its profitability is conditional on the market value of the meal. Oilseed crops could be a source of high protein meal for stock feed, in biodegradable bioplastics, adhesives, cosmetics, lawn care and fertilizer products. The potential uses for the meal are many however, the industries would have to be developed.

Crambe abyssinica seed without the fruit coat has an oil content of between 55 and 60%. The seed oil of *Crambe abyssinica* is high in erucic acid (between 54.6 and 63.4%), Current world demand for oils rich in erucic acid is increasing. These oils are used as industrial lubricants, heat transfer fluids, surfactants, coatings and slip agents. A very early maturing *Brassica campestris* line had unusually high erucic acid content (55%) for that species and may have potential as an alternative source of erucic acid.

Brassica carinata is grown as much for its value as a leaf vegetable as it is for its seed oil in Ethiopia. It flowers much later than the other Brassica species. However it is highly resistant to black leg and can be grown in areas were this disease is present. The oil has a relatively high content of erucic acid (37 to 52%) and its value may be as an industrial oil as a source or erucic acid or for biodiesel.

Camelina sativa oil has high content of the long chain Omega 3 fatty acid alpha linolenic acid (20 – 40%). However its high content of natural antioxidants help to stabilize the oil. Camelina oil is currently being marketed in Europe as a food, as an emollient base in cosmetics and as a health food supplement. In some environments it has been shown to yield well and maybe it has potential as a biofuel. The residual meal is suitable for human consumption and could have a market in the health food industry.

CONCLUSIONS

The oilseeds that would be grown for energy must consistently produce a nett profit of energy. Crops that are high yielding, have seed with high oil content but have reduced inputs are needed. The residual meal would also need to have a marketable use. Amongst the alternative oilseeds there are species with the potential to be grown for fuel. Other species would have greater value in specialised industrial applications.

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