Development of *Brassica juncea* as a biodiesel feedstock in low rainfall areas of Australia

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Abstract
In Australia, interest in biodiesel production has varied over the past few years. One of the main options that biodiesel companies have targeted is *Brassica juncea* in the low rainfall zone so that crops are not competing with canola. Several small scale breeding programs aim to develop cultivars that will produce feedstock for biodiesel production. However, the quality likely to be produced is highly variable with some programs producing lines with high erucic acid and/or glucosinolates. SARDI is undertaking a breeding program to develop mustard for biodiesel production but aims for low erucic acid and glucosinolates to reduce the risk of contamination of canola types. One line, SARDI515M, has been grown commercially for the past two years with 5,000 hectares sown in 2009 and about 13,000 hectares in 2010. This cultivar will not compete with canola because oleic acid content is below 50%. Grain yields are higher than canola in low rainfall conditions. Further improvements in grain yield have been shown in early generation breeders lines, while triazine tolerant lines are also being developed due to endemic *Brassica* weeds in many low rainfall areas.

Key words: Biodiesel, *Brassica juncea*, Australia, canola, breeding, oilseeds

Research into *B. juncea* in Australia has occurred over the past 25 years with the aim of developing an oil crop with equivalent oil quality to canola (Burton et al., 2003). *B. juncea* has many characteristics that should make it a viable crop in lower rainfall areas of Australia. These include good early vigour, early flowering, good blackleg tolerance, shatter tolerance and higher grain yields than canola when site yields are 1.2 t/ha or less. Both canola and *B. juncea* have ready acceptance by farmers in lower rainfall areas as both crops have been shown to fit into cropping rotations and act as disease break crops in cereal production (Potter et al., 1997; Angus et al., 1999). Interest in *B. juncea* in Australia centres around three uses: as a food crop equivalent to canola, as a condiment crop and also as a feedstock for biodiesel. The first canola quality *B. juncea* cultivars were commercialised in 2008 and have low erucic acid, low glucosinolates and oleic acid levels of greater than 60%. This paper outlines the development of *B. juncea* varieties for biodiesel feedstock production.

SARDI initiated a breeding program for *B. juncea* to develop this crop as a feedstock for biodiesel production. Initial breeding material was sourced from the Victorian Department of Primary Industries and a selection program began in 2003. Selection criteria have been earliness to flower, high grain yield, low glucosinolates and high oil content. Lines with lower levels of oleic acid have been used to prevent impact on the development of canola quality *B. juncea* which will be marketed as juncea canola. A crossing program began in 2006 to enable a greater diversity of germplasm to be evaluated. While initial breeding was with non-herbicide tolerant germplasm, triazine tolerance has also been used to allow better control of broad leaf weeds. As much of the initial breeding over the past 25 years has been to develop canola quality characteristics, it is thought that more rapid improvement in grain yield is possible for *B. juncea* than for early maturing canola.

A biodiesel producer (Smorgon Fuels) contracted a biodiesel variety from SARDI in August 2008 and seed was multiplied under irrigation over summer. High oil content was achieved with low erucic acid and low glucosinolates (Table 1). Oleic acid content was lower than that achieved by canola while both linoleic and linolenic acid content were above the level achieved by canola. About 10 tonnes of seed was crushed and made into biodiesel and the quality of the biodiesel was acceptable to industry.

Table 1. Grain quality of seed of SARDI515M, grown under irrigation in 2008/09

Quality	SARDI515M
Oil content	46.7%
Protein content	23.4%
Glucosinolates	11 µmoles/g
	% of fatty acids
Oleic acid C18:1	47.3%
Linoleic acid C18:2	29.8%
Linolenic acid C18:3	14.4%
Erucic acid C22:1	<0.1%

In 2009, approximately 5,000 hectares was grown in lower rainfall areas in South Australia, Victoria and New South Wales. Conditions were characterised by an early break to the season in April in most areas. Sowing began in April and good establishment occurred in most areas except where the soil surface dried out quickly. Some crops did not receive any rain for the next 6 weeks and so the majority of these crops did not emerge till later in June. Crops grew very well during winter but spring conditions were very dry until rain in October. Grain yields ranged from 0.12 – 1.02 t/ha, often producing more than canola crops grown in the same district. Oil content ranged from 36-47%, with the majority of crops producing less than 40% oil, indicating the dry season.

In 2010, approximately 13,000 hectares was sown for biodiesel production. Some crop area was lost due to locust damage but many crops grew very well. The season began well and generally continued with above average rainfall for the whole year. Extreme late rain during November to January resulted in delayed harvest with some crops receiving up to 450 mm of rain after harvest maturity. Some of these crops were not harvested until late January (10 weeks after maturity). There was little evidence of shattering, however, these crops did suffer from sprouting damage. Grain yields of up to 1.7 t/ha were produced commercially but best yields were from those crops harvested early.

The aim in 2011 is to further increase the area of *B. juncea* sown for biodiesel feedstock.

The main aim of the breeding program has been to further increase grain yields of conventional breeding lines. A series of crosses have been made and selections have been taken in the field. We have aimed to select earlier flowering lines, up to 10 days earlier flowering than the current early maturing canola cultivars. Additionally, only lines that have low erucic acid and low glucosinolates are promoted to ensure limited contamination issues if the biodiesel material became co-mingled with canola.

Table 2. Grain yield (t/ha) and oil content (%) of *B. juncea* tested at 9 sites in 2010

	South Australia					Victoria	New South Wales			Mean
B. juncea	Spa	Keith	Too	Min	Lam	Ultima	Coo	Tra	Cond	
Grain yield	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha	t/ha
Oasis CL	1.33	1.82	1.13	2.08	0.75	1.15	1.51	1.51	1.62	1.43
SaharaCL	1.08	1.59	1.05	1.96	0.66	1.17	1.19	1.20	1.05	1.22
SARDI515M	1.30	2.41	1.17	2.37	0.97	1.36	1.68	1.65	1.40	1.59
Site mean	1.51	2.65	1.50	2.43	1.11	1.15	1.95	1.66	2.11	
CV%	9.1	7.1	5.8	8.8	4.7	5.1	7.1	8.9	11.3	
Oil content	%	%	%	%	%	%				%
Oasis CL	47.4	41.3	47.3	47.4	45.9	50.9				46.7
SaharaCL	41.4	38.7	44.7	44.4	40.5	48				42.9
SARDI515M	46.4	43.4	46.9	48.7	45.9	52.5				47.3

Table 3. Grain yield (t/ha) and oil content (%) of breeders lines tested at 4 sites in 2010

Entry	Condobolin	Minnipa	Walpeup	Lameroo	Mean
	Grain yield t/ha				
SARDI515M	1.47	1.25	0.85	0.95	1.13
SARDI725M	1.8	1.36	0.59	1.00	1.19
SARDI727M-BO804M	2.03	1.27	0.46	1.01	1.19
SARDI727M-BO807M	2.2	1.24	0.58	1.04	1.27
SARDI745M-BO802M	2.23	1.26	0.73	1.14	1.34
SARDI906M	1.91	1.16	0.92	1.00	1.25
SARDI918M	2	1.35	0.46	1.03	1.21
SARDI935M	1.68	1.13	1.05	0.99	1.21
SARDI938M	1.7	1.29	1.11	1.02	1.28
lsd (p<0.05)	0.67	0.29	0.24	0.13	
CV%	16.6	8.8	11.4	7.5	
	Oil content (at 6% moisture)				
SARDI515M	44.2	47.6	40.4		44.1
SARDI725M	43.6	47.9	38.6		43.4
SARDI727M-BO804M	43.5	48	36.9		42.8
SARDI727M-BO807M	43.1	47.4	37.6		42.7
SARDI745M-BO802M	44	46.1	37.8		42.6
SARDI906M	41.1	46.8	38.4		42.1
SARDI918M	43.8	48.3	37.2		43.1
SARDI935M	43	48.7	39.1		43.6
SARDI938M	44.1	47.6	41		44.2

To be able to compete with canola in lower rainfall areas, we need to produce higher grain yields and oil content as the biodiesel manufacturers can not pay the same price per tonne as is paid for canola. Higher grain yields than the commercial juncea canola cultivars were produced over 9 trials in 2010 (Table 2), although with the mild season the *B. juncea* produced lower grain yields than canola at most sites (data not shown). Several breeders lines have been shown to produce higher grain yields than the control SARDI515M but only one of these lines had equivalent oil content (Table 3), so there is potential for increased yields in future cultivars.

A further aim has been to develop herbicide tolerant lines as *Brassica* weeds are endemic in much of the low rainfall environments where *B. juncea* is to be grown. *B. juncea* lines have been crossed to triazine tolerant canola to incorporate the triazine tolerance into the *B. juncea* cytoplasm. Up to five backcrosses have now been made and lines are to be grown in the field over the next several generations to select elite lines for further wide scale evaluation. It is hoped that a triazine tolerant *B. juncea* line will be in at least small scale commercial production by 2014.

Based on current rotations, if *B. juncea* could be grown on 10% of the total cereal growing area in the low rainfall winter cereal zones, the production area for Australia would be over 600,000 ha per year (Norton et al., 2005). In South Australia, we have estimated that up to 165,000 ha could be grown at maximum uptake of *B. juncea*. With the further development of improved *B. juncea* it is likely that this crop will increase in area up to this estimation and provide farmers with another crop that can fit into rotations with good economic returns and also provide a disease break for the following cereal crop.

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