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Crop Updates 2007 - Lupins, Pulses and Oilseeds

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Best wishes to all with research and extension for season 2007.

Wayne Parker
LUPIN, PULSE AND OILSEEDS BOOKLET EDITOR

Monthly rainfall data from experimental sites in 2006

Table 1. Rainfall in mm from rainfall stations throughout Western Australia

Site	J	F	M	A	M	J	J	A	S	O	N	D	Total	M - O
Badgingarra	49	22	0	15	20	28	58	95	62	18	18	6	391	280
Bonnie Rock	86	14	57	60	7	15	19	13	42	9	43	15	379	104
Chapman	17	39	4	10	10	6	39	62	16	3	1	8	214	136
E. Beverley	147	25	1	29	9	24	43	77	33	4	14	23	430	191
Eradu	30	25	1	9	7	8	36	40	18	3	2	12	190	112
Floreat Park	41	14	6	31	18	21	73	99	51	14	26	6	400	276
Holt Rock	66	11	53	42	20	12	26	26	33	6	18	4	318	123
Kalannie	106	54	8	35	19	11	16	17	30	2	11	10	318	93
Lake King	82	28	46	44	10	16	28	30	38	7	11	2	342	129
Lancelin E.	74	23	1	16	21	29	82	114	79	19	12	12	483	345
Meckering N.	141	37	1	14	20	15	32	31	45	12	11	30	388	154
Medina	57	3	11	31	48	28	115	158	29	23	23	4	532	403
Merredin	96	20	28	35	51	8	33	26	59	17	14	6	393	194
Mingenew	78	14	0	18	10	17	36	43	29	4	6	32	287	139
Moora	174	32	0	12	19	13	22	39	49	14	10	13	398	157
Morawa	92	39	1	23	6	7	20	18	25	5	7	11	254	80
Mullewa	31	12	2	17	2	2	19	18	20	0	1	12	137	62
Muresk	30	19	1	20	16	12	29	53	46	4	8	9	246	159
Newdegate	151	12	31	28	4	16	32	66	28	16	29	11	425	163
Northam L.	131	37	1	18	9	16	28	63	57	5	11	10	387	179
Salmon Gums	96	16	25	44	21	14	25	17	11	12	16	5	302	100
South Perth	40	12	6	28	22	29	70	105	51	26	27	5	421	303
Wickepin	117	14	10	33	13	16	29	43	9	8	16	3	309	117
Wickepin E.	175	10	23	37	12	12	46	64	15	8	21	14	439	159
Wongan Hills	93	44	0	12	7	16	24	41	44	19	18	9	326	150
Yilgarn S.	123	15	70	42	33	13	27	27	43	11	13	28	445	153

2006 Regional round up

SOUTH EAST AGRICULTURAL REGION

Mark Seymour[1] and **Jacinta Falconer**[2], [1]Department of Agriculture and Food, Western Australia; [2]Cooperative Bulk Handling Group

2006 was panning out to be another excellent year in the Esperance port zone with good opening rains allowing growers to sow their crops in a timely fashion. However a hot, dry and windy spring put paid to many hopes of above average yields.

Field pea yields ranged from 0.6 to 1.5 t/ha, with the port zone producing 30,000 tonnes of grain for export from an area sown of 40,000 ha. The average yield of 0.75 t/ha is well below the average for the port zone which is normally around 1.2 t/ha.

Windy conditions at harvest saw many field pea swaths moving around, ending up on fence lines and in general looking messy although the losses may have not always been that high. This was particularly the case for trailing field pea varieties like Parafield, which are susceptible to being blown around; and even more so if the crop had a low seed to biomass ratio (most crops in 2006). Things to consider to improve this situation would be to: only swath high yielding crops so there is more weight in the swath; only swath semi-leafless lines which lock in better; and use a flatter roller as it was evident that many canola rollers are not flat enough to form a good enough swath.

Few farmers chose to grow faba bean in 2006, with about 3,500 ha sown primarily in the Scaddan area. Foliar diseases were again not an issue, with dry conditions being the main determinant of yield. Yields were around 1.2 t/ha.

19,400 ha of narrow-leafed lupin were grown in the Esperance port zone. Most of the grain was held back on farm so it is difficult to give an accurate measure of total production. Generally it is thought yields averaged 1.0 t/ha, again lower than most years.

Canola faired better than most crops yielding on average 1.25 t/ha which is close to the 5 year average of 1.34 t/ha. This is most likely due to the majority of canola being grown on the coastal sandplain areas, which did not suffer from transient waterlogging in 2006.

CENTRAL AGRICULTURAL REGION

Ian Pritchard, Department of Agriculture and Food, Western Australia

The 2006 season was one of the driest if not the driest on record for the CAR. Growing season rainfall for many centres was Decile 1 subsequently the yield potential for the season was also low, average yields for many would be a good result. Some growers did achieve yields close to their long term average which may indicate the value of current varieties and agronomic practices such as stubble retention, minimal cultivation and herbicide use or they might have been the lucky few with the amount and timing of rainfall. The 2006 season showed that not only is the amount of rainfall important but also the timing of the rainfall. A fairly common comment from growers at the end of season was "if only I had just one decent rainfall event in August/September the season would have been completely turned around" typifies the 2006 season.

The 2006 year was particularly hard for canola with the very light late opening and follow up rains, canola crops struggled to establish generally having to be sown shallow and being so small seeded. Subsequently the majority of canola crops were very patchy with a low plant density, yields ranged from 0.7-1.0 t/ha.

Relative to other crops in 2006 lupins performed very well with generally average yields being reported where crops were well established and clean. However weed control or lack of it was an issue in many crops due to the low activity of the soil applied herbicides at sowing with the lack of rainfall. Growers continue to be happy with the performance of Mandelup.

Of the pulse crops field peas continue to be the only crop of any significance and area. The summer autumn conditions experienced in 2005/06 delayed the development of blackspot spores such that it was generally recommended that field peas should only be sown in the last week of June or early July. The very late start followed by one of the driest seasons on record was a combination which field peas are quite well adapted. It meant that blackspot did not really get going until very late in the growing season which was also good news for the field pea crops. Throughout the region Kaspa continued to live up to the majority of growers expectations for yield and ease of harvest, some Kaspa crops in the medium rainfall zones averaging over 1.5 t/ha. Kaspa's standing ability at harvest, sugar pod trait and yield have not just been steps in the right direction but significant leaps forward for growers.

The Avondale and Merredin research stations continue to play important roles in the evaluation of pulse and canola crops for the WA wheatbelt, allowing trials and demonstrations that would otherwise not be possible on farmer properties to be carried out.

GREAT SOUTHERN AND LAKES REGION

Rodger Beermier, Department of Agriculture and Food, Western Australia

Another contrasting and challenging year started with heavy rain falls in January throughout the region. Higher than average falls also occurred in February, March and April in the Eastern part of the Great Southern (GS). However, when it came time to sow, May and June dried up with poor falls across the whole region which extended sowing into July. With average to below average conditions in July and August, we were all hoping for a wet spring which did not eventuate. Again, poor falls in September and October did not give the crops the moisture they needed to finish well.

Table 1. Rainfall across the Great Southern 2006

Rainfall/Town	Boyup Brook	Katanning	Borden	Lk Grace	Hyden
May – Oct.	341	213	160	115	133
Total Rainfall	R530	330	284	530	358

The field pea variety Kaspa continued to be planted despite the late sowing opportunities. As Kaspa flowers later than Dundale or Parafield growers were relying on a good finish to the season to assist with pod fill. Yields were not great due to the poor finish ranging from 0.6 to 1.2 t/ha across the region with 0.8 t/ha being average. Most growers were satisfied with the performance of Kaspa despite the season and late sowing.

As Parafield is still the main conventional variety being grown, it yielded similar to Kaspa from Hyden to Borden. Averages were 0.7 t/ha. The area sown to Helena continues to decline due to increased area sown with Kaspa volume and Parafield.

Flights of Heliothis moths were a concern in the eastern GS much earlier than usual. The warmer weather in August/September when eggs were laid saw Native Budworm grubs in mid-September. Pea weevil were also active this season with reports of them in areas they had not been in previously.

Faba bean yields were not exciting. Yields ranged from 0.2-0.5 t/ha in the Pingrup region up to 0.9 t/ha in the Hyden area. Areas of faba bean will continue to decline as a result of recent poor seasons. However seeking frost tolerance and early sowing sees a number of specialised growers pursuing greater areas of faba bean.

Lupin yields, similar to faba bean yields, ranged from 0.3-0.6 t/ha across most of the region. However, up to 1.0 t/ha was achieved around Hyden. Growers continue to rely on lupin crops for their ability to be grown on acidic, sandy soils and as a high quality sheep feed. Yield reliability is a major limiting factor though.

Canola was grown across most of the region even though the start of the season was not favourable. Yields ranged from 0.6-0.9 t/ha all with good oil. However, it was noticed that there were considerable numbers of red seeds in the samples.

Trial work for 2006 included faba bean germplasm, field pea time of sowing, Pea Seed Borne Mosaic Virus demonstrations and inoculum work in conjunction with Murdoch University. Kabuli chickpea and faba bean variety trials were also a part of the program. The results and conclusions from these trials are written in this booklet.

NORTHERN AGRICULTURAL REGION

Wayne Parker and **Martin Harries**, Department of Agriculture and Food, Western Australia

2006 was a testing year for all crops in the Northern Agricultural Region. This year highlighted the fact that dry seeding can be spectacularly bad. As a result there has been a shift in attitude to dry sowing many crops, most importantly lupins. Many growers are now opting for a set end date to sowing rather than a start date. This gives more opportunity for wet sowing of lupins but if the season breaks late much of the lupin program is still dry sown. Much ground truthing and crop modelling was included in the 2006 trial program and is reported in an attempt to better understand how to manage the seasonal risk of wet versus dry sowing.

In July and August most lupin crops looked as though they would struggle to yield. This raised concerns that growers would find it difficult to source lupin seed for 2007. Mandelup was made available to trade between growers and fortunately in some areas there was a reasonably soft finish. This allowed lupins to yield well enough to be profitably harvested at current prices and 30,000 tonnes were delivered to CBH throughout the northern zone. This represents approximately 10 per cent of the 5 year average. Total wheat deliveries in the northern port zone were also about 10 per cent of the 5 year average.

Kaspa field pea continues to make the headlines with improved standing ability. In the absence of blackspot disease pressure field pea crops continue to yield well where moisture is less limited. Shorter season varieties with good standing ability are still in the pipeline. Release of these varieties, better suited to the northern region, is still a couple of years off. Keep an eye out for the line WAPEA2113 which is an exceptionally early flowering pea, selected from a Kaspa crop in 2003.

The dry 2006 has kept the desi chickpea industry on hold twelve months. Most on farm bulkups planned for Genesis 836 were unsuccessful or did not get sown. Two varieties of interest to the region, Genesis 090 and Genesis 510, were to be bulked in 2006 but only minimal returns from seed were made. Genesis 510 began the season with nearly 35 tons in stock, to finish with approximately 45 tons unclean.

The two new Kabuli varieties released last season, Nafice and Almaz, were in high demand from growers in Victoria and New South Wales. They were favoured over the local varieties for their seed size and colour and their high levels of resistance to ascochyta. Kabuli chickpea are best suited to higher rainfall conditions. As such commercial production was put on hold in the northern region in 2006. A small amount of Genesis 090 was sown in a block in Moora, yielding 600 kg/ha before seed cleaning. At this stage it is still under evaluation here in the West and has yet to be released for growers.

Neither Faba Bean nor Lentil were of any consequence for the northern growers this season. All crops were sow too late into marginal moisture and did not receive follow up rain to support an economic yield.

Andromeda seed sold out quickly prior to the 2006 season highlighting that growers were keen to try a new heavy soil legume. Most of this seed was kept in storage as it became obvious that it was not a good year for bulk-up. Testing continued on the anthracnose tolerance of other albus lupin lines. However, very little was determined this season as the anthracnose trials in the region were abandoned through drought and lack of disease.

There were limited sowing opportunities for canola and dry sown crops struggled throughout the year. Patchy germination was compounded by poor growing conditions. 6,000 tonnes were delivered in the northern region.

Feeling remains positive about the future of pulses for the region. The desi chickpea varieties show immense promise, provided farm equity levels don't disqualify the attempt. 2007 can be the year to lay foundations for a new chickpea industry.

LUPINS

Development of anthracnose resistant and early flowering albus lupins (*Lupinus albus* L.) in Western Australia

Kedar Adhikari and **Geoff Thomas**, Department of Agriculture and Food, Western Australia

BACKGROUND

Andromeda is currently the only variety with substantially improved resistance to anthracnose over Kiev Mutant. It is recommended in medium rainfall areas where the risk of anthracnose is moderate to low. There is a need to develop varieties suitable for high anthracnose risk areas (high rainfall sites) in northern agricultural region. There is also a need to develop varieties for low rainfall areas (east of Morawa, Mullewa and Perenjori areas), where Andromeda may not be suitable because of its later flowering time compared to Kiev Mutant. There is a potential to expand albus in to suitable soils in Great Southern as there is low risk of anthracnose in this area because of the absence of blue lupins. However Andromeda represents no advance in yield compared to Kiev Mutant. We need to develop varieties substantially better than Andromeda in disease resistance and yield potential.

KEY MESSAGES

- WALAB2008 has improved level of resistance over Andromeda and it is being bulked up for release.
- The early generation lines have higher level of resistance to anthracnose, but they are in late flowering background.

AIMS

To develop new albus lupin cultivars with levels of anthracnose resistance sufficient to enable reliable production to recommence in WA.

METHOD

More than 70 lines in Stage 2 were tested for yield and agronomic characters at Woorree, York and Mt Barker. Due to shortage of seed, not all lines were tested in all sites. All these lines along with segregating populations and F5 derived F6 families were tested for anthracnose reaction in irrigated conditions at Medina disease nursery. Flowering time was studied in F2 populations derived from early and late flowering parents (Table 1).

RESULTS

Advanced lines

The Woorree site failed due to drought and yields were poor in York and Mt Barker sites. Results in previous years indicated that WALAB2008 had the best anthracnose resistance among the first cohort of crossbred lines, but it was also the latest in maturity. It yielded almost as much as Kiev Mutant in the high rainfall site at Deepdale and suffered the least yield loss at Woorree in high rainfall area under disease pressure. The limited data in 2006 indicate similar results. Because of its longer flowering time, it will not be suitable for low rainfall areas, but it can be grown in medium rainfall areas with the advantage of a better level of protection for anthracnose than Andromeda. Release is anticipated in 2007/08. Its seed was multiplied at the Avondale Research Station in 2006, but owing to the severe drought the yields were very low and produced only about 900 kg seed. Summer seed multiplication under irrigation at Manjimup is expected to produce about one tonne by April 2007.

Besides WALAB2008, there are at least three advanced lines at Stage 2 that are similar to Andromeda in anthracnose resistance. Lines, such as 97B050-4-1, 97B101-3 and 97B120-5-2 seem promising, but due to drought their yield performance in 2006 was inconclusive. The former line (97B050-4-1) is earlier and has slightly better resistance to anthracnose than Andromeda. It flowered only a couple of days later than Kiev Mutant, but matured at the same time with Kiev Mutant at Woorree.

Early generation lines

Anthracnose resistance, early flowering and low alkaloid content are essential traits in albus breeding for Western Australia. A minimum benchmark for anthracnose resistance is set at the Andromeda level. In 2006 trials at Medina, nearly 200 F3 to F6 families (Figure 1) and more than 40 advanced lines (Figure 2) were resistant to anthracnose. Early generation lines have better resistance to anthracnose than the advanced lines indicating further improvements can be made in the disease resistance. Although there are many lines with Kalya level of resistance, they are medium to late in flowering. There was low frequency of early flowering in all crosses and mostly late flowering lines were resistant to anthracnose and the early flowering lines were susceptible indicating a linkage between the disease resistance and lateness. However, not all late lines were resistant. Studies on 189 F8 derived recombinant inbred lines showed only four early flowering lines and none of them were resistance to anthracnose. Examinations of more than 150 F3 families also indicated the similar results. Since the anthracnose resistance is a recessive trait and there was very low frequency of early flowering progenies, the combination of both characters in a single line would be almost a rare event if the population size is small.

Two large populations of F3 families derived from early flowering and anthracnose resistant lines were evaluated for anthracnose resistance at Medina. There were three classes in the population: resistant, intermediate and susceptible. The frequency of the susceptible class was bigger than the combined frequency of resistant and intermediate types suggesting the involvement of recessive genes for anthracnose resistance. Screening of nearly 200 inbred lines also indicated similar results.

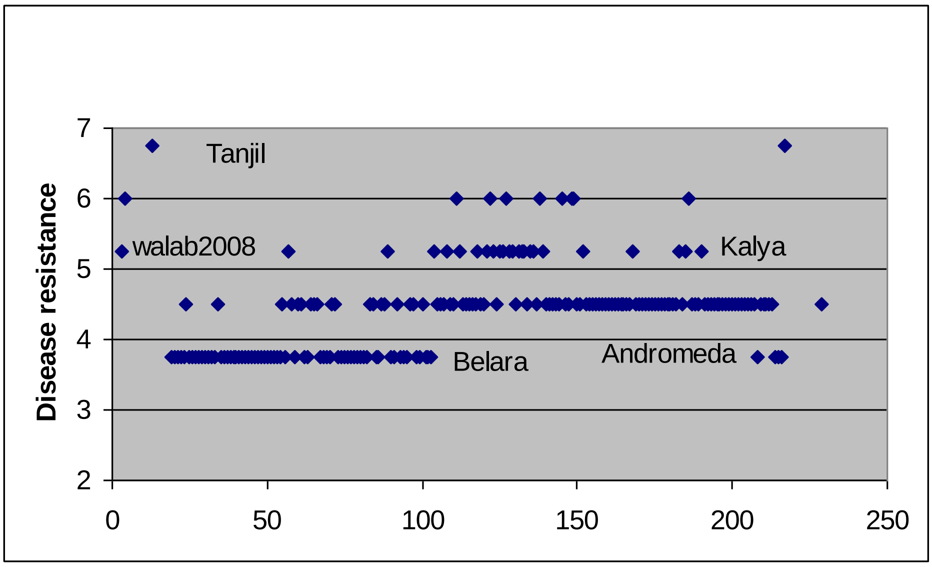

Figure 1. Anthracnose resistance in *Lupinus albus* early generation lines when tested at Medina disease nursery in 2006. Resistance score is 1-9 where 1 is extremely susceptible and 9 is immune. Horizontal axis represents the number of lines/varieties tested.

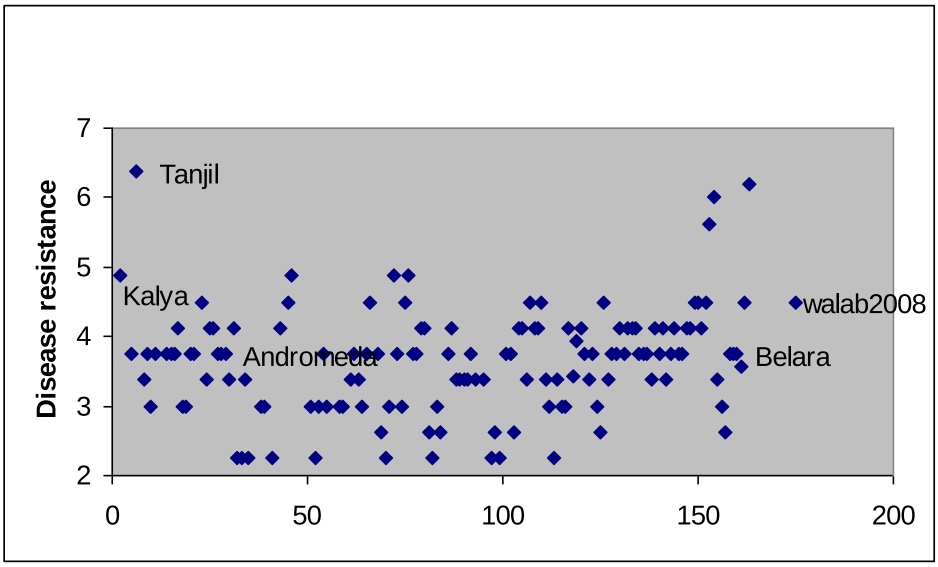

Figure 2. Anthracnose resistance in Lupinus albus advanced lines when tested at Medina disease nursery in 2006. Resistance score is 1-9 where 1 is extremely susceptible and 9 is immune. Horizontal axis represents the number of lines/varieties tested.

In view of having difficulty in finding high frequency of early flowering progenies, a different source of early flowering parent was used in crossing. In 2006, two F2 populations from crosses between early flowering (Start) and late flowering (also anthracnose resistant) parents were examined (Table 1). Start flowers 4-5 days earlier than Kiev Mutant. There was segregation for distinctly 3 classes. More plants flowered as early as the earliest parent, Start, showing a dominance of the early flowering trait. The segregating classes fit to a 9:6:1 ratio indicating a complete dominance at both gene pairs. However when both dominant genes were present the phenotype was early flowering. If only one was present, the phenotype was medium early flowering. In contrast, another population derived from Kiev Mutant/P27174 (early/late) gave only four early flowering plants from a population of 189 suggesting flowering is a quantitative character. This is unusual as flowering time in Kiev Mutant is controlled by a single recessive gene (brevis). Although Kiev Mutant flowers early, it still needs a mild vernalisation to induce flowering, whereas Start is supposedly thermoneutral. The results indicated an influence of vernalisation requirement of a parent on the expression of early flowering in progenies and the need of a thermoneutral parent in crossing to combine disease resistance and early flowering. The combination of both early flowering and disease resistance is yet to be studied in the above F2 derived F3 families.

Table 1. Segregation of flowering time in F2 populations from two crosses of Lupinus albus

Crosses	Pedigree	Number of plants				χ^2 9:6:1*
		Early	Medium	Late	Total	
05B017	Start/98B001-5-6-1	115	90	18	223	2.54
05B019	Start/P27174	31	18	6	55	2.24
	Total	146	108	24	278	3.35

* Value for significance at P = 0.05, 2 df is 5.99.

It seems that high frequency of early flowering progenies can be achieved when the source of early flowering is thermoneutral. Identification of early flowering and thermoneutral parent with large seed and pauper gene (low alkaloid content) is essential in the breeding program. There are supposedly thermoneutral lines, such as Start (Russia), P25944 (USA) and P24745 (Wat, a Polish cultivar) in the breeding program. Start has another sweet gene and cannot be used in the breeding program (crossing lines with two different sweet genes results in high alkaloid in the progenies.), but the other two lines seem to have the same pauper gene as in Kiev Mutant and could be included in crossing program. Now we have identified lines, such as 98B001-5-6-1, 02B002-9, 04B022-42 and 04B025-23 with a high level of anthracnose resistance in the domesticated background. Crossing an early flowering parent with the above characters to anthracnose resistant parents should give the

combination of early flowering and the disease resistance progenies. Crossing the desired early flowering parent with anthracnose resistant Ethiopian lines have potential to produce resistance as observed in *L. angustifolius* cv. Tanjil. The Ethiopian lines are as resistant as Tanjil, but the resistance in progenies has been lower than Tanjil until now.

CONCLUSION

WALAB2008 has improved level of resistance over Andromeda. Its suitability in high rainfall areas needs to further examination. The level of resistance to anthracnose is higher in early generation lines showing a promise to develop better anthracnose resistant cultivars in 3-5 years. The combination of early flowering and anthracnose resistance seems to be possible when the source of early flowering is thermoneutral.

KEY WORDS

L. albus, early flowering, anthracnose resistance, grain yield, inheritance

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New lupins adapted to the south coast

Peter White, Bevan Buirchell and **Mike Baker**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- There are several lupin genotypes with resistance to black pod syndrome (BPS), a common disorder on the south coast of Western Australia.
- WALAN2224 produced more than 30% higher yield than Mandelup in situations where BPS was severe and may be suitable for release as a new variety for the south coast.
- We don't yet fully understand BPS in lupins; there maybe more than one cause.

INTRODUCTION

Lupins have a reputation of yielding below their potential in the southern agricultural regions of Western Australia. Observations by Seymour (1994) indicate that yield potential can exceed 4.0 t/ha, but harvested yields are often less than 2.0 t/ha. Common explanations involve excess vegetative growth causing poor pod set and low harvest index.

During 2005 there were several reports that pods on some lupin plants had turned brown or black prematurely and that seeds in these pods were poorly developed. This characteristic, termed black pod syndrome (BPS) here, may be one cause of the low and variable yields produced by lupins on the south coast. Mark Sweetingham and Greg Shea observed that there was considerable genetic variation to BPS in crop variety testing (CVT) trials at Esperance and Mt Barker during 2005. The varieties Mandelup and Belara seemed more susceptible to BPS, while Quilinock and related genotypes seemed less susceptible.

Gladstones (2003; unpublished report), observed symptoms similar to BPS in lupins trials on the south coast in 2001 and 2002 but he attributed the cause to Bean Yellow Mosaic Virus (BYMV). He noted that the varieties Mandelup (then called WALAN2141) and Belara were very susceptible to BYMV but Quilinock was not. Virus screening trials, however, have not shown Quilinock to me more resistant to BYMV than Belara (Roger Jones personal communication).

Two trials were conducted in the Esperance region in 2006 to further investigate BPS in lupins.

AIMS

- Determine if there are advanced breeding lines, with potential for release as varieties that have higher tolerance to BPS than Mandelup.
- Determine if BPS is caused by excessive vegetative growth leading to poor pod set in susceptible lines.

METHOD

The trial was designed to force plants to set different numbers of pods on the main stem versus lateral branches. This was achieved by varying seeding rate and with the application of paclobutrazol, a hormone that increases pod retention in plants.

The trial was conducted at two locations near Gibson, north of Esperance. Site 1 was on the Esperance Downs Research Station (EDRS) and site 2 was located on the farm of Mr Nils Blumman. The trial was a complete factorial of two seeding rates (aiming for 30 and 60 plants/m^2), two levels of hormone spray (nil and 1000 mL/ha Payback ® (250 g paclobutrazol/L) applied half at big bud stage and the remaining half two weeks later) and five genotypes (Quilinock, WALAN2224, WALAN2235, Mandelup, Tallerack). The experiment had a split-plot design. Seeding rate x hormone spray constituted the main-plot. The trial was sown incorrectly at the Blumann site so it was analysed as an unbalanced design using Genstat version 9.1.0.145.

Wheat was sown in 2005 at the EDRS site while at the Blumann it had several years of pasture prior to establishing the trial. Soil at EDRS was a grey shallow sandy duplex. The sand extended to about 40 cm and sat on top of coarse gravel in a pale, clayey matrix (pH 5.0 at 5 cm; pH 4.5 to 5.0 at 20 cm; pH 6.0 at 57 cm (pH taken as a soil water paste)). Soil at the Blumann site was a deep sandy gravel. (pH 5.0 at 4 cm; pH 6.5 at 40 cm and pH 5.5 at 60 cm (pH taken as a soil water paste)).

Both sites received glyphosate for pre sowing weed control. Plots were sown on the 12th (EDRS) and 15th (Blumann) of May 2006. They were sown on 2 m centres and consisted of six rows spaced 24 cm apart and 20 m long. Both sites received 112 kg/ha Summit lupin fertiliser (this is 75% Summit pasture and 25% $MnSO_4$) at sowing and Gesaprim (simazine) granules (550 g/ha) immediately post sowing. Aramo (tepraloxydim) was applied on 17 June at 300 mL/ha for post emergent weed control at both sites. Dimethoate (800 mL/ha) was applied to the EDRS site for aphid control on 30 August and Fastac (alpha-cypermethrin) was applied to both sites to control native budworm (heliocoverpa) on 16 October.

Whole plots were machine harvested on 30 November.

RESULTS

Large patches of the trial at the EDRS site were waterlogged for several weeks during the plants' early vegetative stage. Many plants died in these patches and others were slow to recover. Most data presented here is from the trial at the Blumann site.

At five weeks after sowing plant density was high and the numbers of plants established for each density treatment was the same across genotypes (Table 1). At podding many plants showed symptoms of blackening (described below) and some plants had died. Two to five times more plants of Tallerack and Mandelup were blackened compared with Quilinock, WALAN2224 or WALAN2235 (Table 1). Fewer plants of Tallerack and Mandelup also survived to maturity than for Quillinock, WALAN2224 or WALAN2235.

Hormone spray did not affect plant density or the number of black plants so data in Table 1 is averaged across hormone treatments.

Symptoms of blackening were variable and began to appear about 12 weeks after sowing. We did not attempt to distinguish between the different symptoms. In some cases whole plants were black and appeared dead (Figure 1a); other plants only had some black pods while the rest of the plant remained green (Figure 1b); some other plants had one or two black branches (including pods) while the rest of the plant remained green (Figure 1c). All were classified as blackened.

Table 1. Total number of plants emerged at 5 weeks after sowing, number of plants blackened at podding and total number of plants present at maturity at the Blumann site

Genotype	Plant density at 5 weeks after sowing		Number of blackened plants at podding		Plant density at maturity	
	Low PD	High PD	Low PD	High PD	Low PD	High PD
Mandelup	35.7	73.4	14.5	16.3	31.8	47.7
Quilinock	41.5	79.5	5.9	6.3	37.0	72.0
Tallerack	37.4	74.9	17.1	30.4	29.1	36.9
WALAN2224	39.1	80.7	6.2	4.6	41.8	68.8
WALAN2235	36.3	77.2	6.2	7.9	38.7	59.6
lsd (5%)	*9.28*		*3.60*		*7.60*	
CV%	*15.44*		*21.3*		*15.96*	

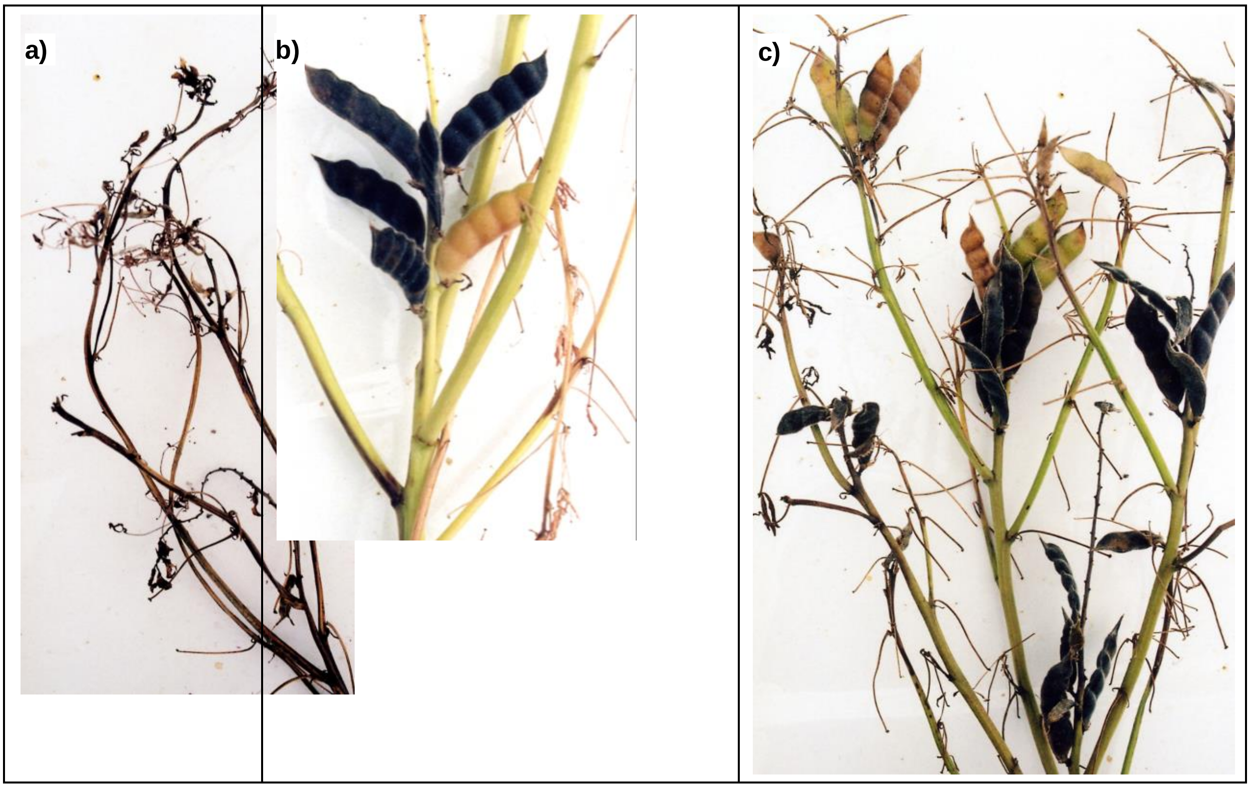

Figure 1. Symptoms of blackening 22 weeks after sowing: a) some plants were completely black; b) some pods on the main stem only turned black; and c) whole branches including pods of other plants turned black.

WALAN2224 grown at the low plant density and without hormone application produced the highest ($P < 0.05$) grain yield of all genotypes when measured using quadrats (Table 2). Mandelup produced about 40% less grain than WALAN2224 and Tallerack produced the lowest yield of all genotypes which was about 70% less than WALAN2224. Applying hormone tended to increase ($P < 0.05$) yields while growing plants at high density tended to decreased ($P = 0.05$) yields. There was no interaction between genotype plant density or hormone spray.

Tallerack produced a lower ($P < 0.001$) harvest index than other genotypes (Table 2). Applying hormone increased harvest index for all genotypes. Plant density had no effect on the harvest index.

Table 2. Grain yield (t/ha) and harvest index using hand-cut quadrats at the Blumann site

Genotype	Quadrat grain yield				Harvest index			
	Nil hormone		Plus hormone		Nil hormone		Plus hormone	
	Low PD	High PD	Low PD	High PD	Low PD	High PD	Low PD	High PD
Mandelup	2.11	2.28	2.62	2.19	0.25	0.27	0.31	0.27
Quilinock	2.63	2.04	3.41	2.94	0.27	0.23	0.29	0.26
Tallerack	1.14	0.99	1.62	1.33	0.18	0.19	0.22	0.22
WALAN2224	3.64	2.49	3.20	2.96	0.29	0.28	0.31	0.29
WALAN2235	2.87	2.55	3.01	2.95	0.28	0.28	0.31	0.29
lsd (5%)	*0.80*				*0.042*			
CV%	*21.98*				*10.82*			

WALAN 2224 produced the highest ($P < 0.01$) grain yield of all genotypes at both the EDRS and Blumann sites when the whole plot was harvested (Table 3). Tallerack, on average, produced the lowest yields and Mandelup the second lowest at both sites. When hormone was applied plants produced higher yields at high density compared to low density. All genotypes responded similarly.

Table 3. Grain yield (t/ha) at the EDRS and Blumann sites after harvesting the whole plot

Genotype	EDRS				Blumann			
	Nil hormone		Plus hormone		Nil hormone		Plus hormone	
	Low PD	High PD	Low PD	High PD	Low PD	High PD	Low PD	High PD
Mandelup	1.21	1.38	1.42	1.51	1.27	1.61	1.32	1.68
Quilinock	1.44	1.21	1.65	1.76	2.10	1.93	1.86	2.17
Tallerack	0.92	0.92	0.88	1.18	0.88	1.08	0.94	1.02
WALAN2224	1.49	1.44	1.79	1.92	2.13	2.07	2.04	2.33
WALAN2235	1.37	1.08	1.46	1.52	2.04	2.03	2.08	2.05
lsd (5%)	*0.42*				*0.33*			
CV%	*21.73*				*12.99*			

Tallerack and Mandelup had higher ($P < 0.01$) numbers of pods than Quilinock, WALAN2224 or WALAN2235 (data not presented). Plants with symptoms of blackening tended to have more pods on their main stem and fewer pods on the secondary branches compared with plants not showing symptoms of blackening (data not presented). Applying hormone tended to decrease the number of pods on the main stem but increase the number on the secondary branches.

DISCUSSION

WALAN2224, WALAN2235, and Quilinock have a higher level of resistance to BPS than Mandelup and are likely to be superior genotypes for environments where BPS is prevalent. The high yields and low level of blackening seen for these genotypes in this trial is consistent with results from CVT trials from 2004 to 2006 (Figure 2). WALAN2224 was consistently high yielding over these three years and has been equal to or better than Mandelup. This was especially apparent in the high yielding year, 2005, when WALAN2224 out performed all named varieties. WALAN2224 has a lower level of anthracnose than Mandelup (it is equivalent to Belara), but the south coast region is not a high risk area for anthracnose. It also has poor tolerance of the herbicide metribuzin (equivalent to Tanjil). Most other characteristics are sufficient to allow it to meet the standards for release.

Black Pod Syndrome does not appear to be caused by excessive vegetative growth and subsequent poor pod set because Tallerack and Mandelup showed higher levels of BPS but also higher numbers of pods. Similarly, BPS does not seem to be caused by the lateral pods forming a large sink and drawing assimilates away from pods on the main stem because plants with higher levels of BPS had fewer pods on lateral branches. Furthermore, hormone application changed the yield, harvest index and pod numbers but had no affect on the severity of BPS. Finally, symptoms of plant blackening first appeared about 12 weeks after sowing, which was before plants were developing pods on lateral branches. Clearly, however, there was some relationship between pod number and BPS. We don't know whether the differences in pod number are a cause or a consequence of BPS.

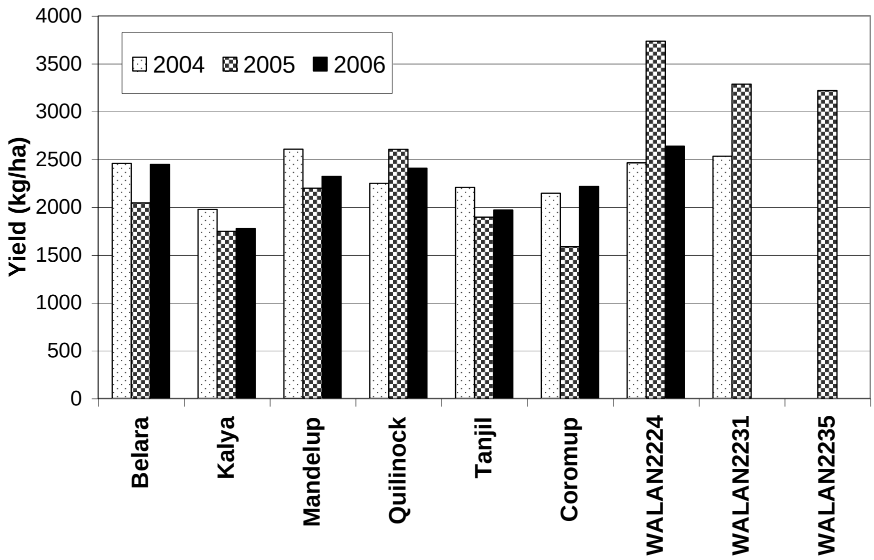

Figure 2. Yield of lupin varieties and breeding lines in CVT at Esperance Downs Research Station from 2004-06.

It is likely that there is more than one cause of BPS which may interact. Genotypes such as WALAN2224 may have some tolerance to one of the causes but not the other. The range of symptoms seen in plants was diverse so it is difficult to favour either a pathogen or physiological (e.g. nutrient deficiency) cause for the disorder. Some of the symptoms in plants were very similar to those caused by BYMV, but, separate screening trials, conducted during the year in South Perth did show a difference between these genotypes in their susceptibility to BYMV.

The different effect that plant density had on grain yields when measured by hand-cutting quadrats or machine harvesting whole plots is likely to be caused by edge effects. The quadrat yields only sampled the inner four rows of the plot, leaving the two outer rows behind. These two outer rows are included in the whole-plot yields and are likely to bias results because they had less competition for water, nutrients and light. Mr Nils Blumann, the owner of the farm on which the trial was conducted said that yields of his lupin crops are reduced when there are more than 30 plants per square metre.

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Lupin species and row spacing interactions by environment

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BACKGROUND

The aims of these trials were; to asses the effects on environment, row spacing and their interactions on lupin plant growth and yield of three lupin species.

Recently *L. angustifolius* has been proven to yield well in wide rows of 50 cm throughout much of the Western Australian lupin growing area. The use of wide rows may improve harvestability (increased plant height), delay the onset of terminal drought and allow alternative weed management options to be utilised. There is also interest in assessing the suitability of other lupin species, *L. luteus*/yellow and *L. albus* to wide row cropping to determine if the same advantages observed in angustifolius translate to these species.

METHOD

A series of trials were undertaken across a range of environments throughout the wheatbelt. Eight trials were sown at five sites; Mullewa, Mingenew, Merredin, Mount Barker and Boyup Brook. Two trials at Mullewa and one at Mingenew were abandoned due to drought. Sites in this analysis include two from Merredin one on a light soil and one on a loam, Mingenew sandplain, Boyup Brook forest gravel and a Mount Barker loamy gravel. The Merredin Light site was seeded on 24 May, Merredin Heavy 25 May, Mingenew 26 May, Boyup Brook 31 May and Mount Barker 3 July. At each site treatments included three lupin species, narrow leaf, yellow and albus combined factorially with 4 row spacings 25, 50, 75, 100 cm. The 12 treatments were arranged in four randomised complete blocks. Plots varied in width from 3.0 to 4.0 meters wide depending on row spacing and were 18 meters long. Plant density, height, width, biomass, pod height, yield, grain yield components and grain quality were measured.

RESULTS AND DISCUSSION

Establishment

Average establishment was 35 plants per square meter. This was lower than the target of 40-45 plants per square meter. Across sites plant population ranged from 32 to 39 plants per square meter, Mount Barker with the highest of 39 and Merredin Light soil site lowest with 32. The narrow leaf lupins established better than albus and yellows, by 5 and 7 plants/m^2 respectively (Table 2).

Vegetative biomass

Albus produced less biomass than the other species (Table 1). Averaged over sites row spacing was inversely proportional to crop weight, all spacings significantly different. Biomass production at Mount Barker was five times lower than at Mingenew site. This equated to growth rates of 0.26 and 1.8 grams per day respectively clearly indicating reduced winter growth in the cooler climate. Species biomass production response to row spacing averaged across the sites did not differ significantly. Species produced different amounts of biomass relative to each other at different sites. At Mount Barker all species produced statistically the same biomass. At Mingenew and Merredin Heavy soil all species produced significantly different biomass narrow leaf the most and albus least. It was apparent from this early sampling that the species varied in their environmental adaptation, as expected. Biomass production in each row spacing differed between sites. At all sites except Mingenew the 25 cm rows produced the most biomass, significantly more than all wider spacings. At Mingenew the 50 cm spacing produced more biomass than the other spacings. Mount Barker was the least responsive site with all spacings except the 25 cm being statistically the same. Boyup Brook, Merredin Heavy and Mingenew were very responsive to row spacing, all spacings with significantly different biomass than each other. Clearly the impact on crop growth caused by sowing the plants in different rows was influenced heavily by environment. There was no three way interaction.

Flowering biomass

All species produced different biomass, albus lowest and narrow leaf highest (Table 1). Averaged across sites each row spacing contained significantly different biomass, inversely proportional to row spacing. All trials produced different biomass except the two at Merredin. Of the locations Boyup Brook produced the most biomass and Mingenew least. Species responded differently across the sites. Narrow leaf lupin produced significantly more biomass than the other species at Boyup Brook, Mount Barker and Merredin Heavy. At Merredin Light and Mingenew narrow leaf and yellow lupin produced more biomass than albus. At three locations, Boyup Brook, Mount Barker and Merredin Heavy row spacing was inversely proportional to biomass and significantly different at all treatment levels. At Merredin Light and Mingenew the response of biomass production to row spacing was not as pronounced. Species biomass production responses to row spacing changed at different locations. Narrow leaf biomass across the row spacings was less affected by site than the other species. Mount Barker was the only site where the 25 cm row biomass of narrow leaf lupin was statistically higher than 50 cm.

Plant width growth rate (pwgr) at 50% flowering

Each species differed in pwgr to flowering, abus slowest and yellow fastest (Table 2). Plants in 100 cm rows grew horizontally at 0.4 cm per day almost twice the rate in 25 cm rows. Hence when plants were placed in rows wider apart they did tend to explore laterally at a faster rate. Pwgr at Boyup Brook was slowest, 0.22 cm/day, Mingenew and Mount Barker the most rapid. The fact that Mt Barker was sown much later than the other sites may have contributed to the high relative growth rate of this southern site. While all species had higher pwgr at wider row spacings albus pwgr was slowest to flowering at all row spacings. At Boyup Brook there was no difference in pwgr at flowering of any species. At Mount Barker and the Merredin Heavy sites albus lupin grew at a slower rate than the other species. At the Merredin Light and Mingenew sites all species grew at different rates albus slowest and yellow lupin fastest. Row spacing and site interacted. At all sites 25 cm rows had the slowest pwgr, in most cases this was significantly different from all other row spacings. At some sites the differences between row spacings where marked, for example at Mingenew pwgr in 100 cm rows was over twice that in 25 cm rows. In contrast the 100 cm row spacing was not significantly different to the 25 cm spacing rate at Boyup Brook. The response of each species to row spacing changed with site. For example albus was most responsive to row spacing at the Mingenew site, pwgr increasing significantly at each wider spacing. Conversely at Boyup Book the rate of plant width growth at 25 and 100 cm were statistically the same.

Final % area coverage

Each species on average covered a significantly different area of the ground. Narrow leaf, yellow and albus covered 81, 78 and 65% of the ground respectively (Table 2). Row spacing had a large effect on area cover, as expected. Twenty-five, 50, 75 and 100 cm rows covered 98, 83, 65 and 53% of the ground respectively. All sites had statistical differences; Boyup Brook 86%, Mount Barker 79%, Mingenew 75%, Merredin Light 72% and Merredin Heavy 62%. As row spacing increased differences in the species ability to cover the ground became prominent. In 25 cm rows all species covered close to 100% of the ground. At 50 cm and wider albus lupin ground coverage was less than the other species. At 75 cm and wider yellow lupin ground coverage was less than narrow leaf lupin. At Boyup Brook and Mount Barker all species covered different amounts of ground, albus lowest and narrow leaf highest. At the other sites yellow and narrow leaf species covered similar ground, more than albus. Coverage was highest at Boyup Brook, the 50, 75 and 100 cm rows with significantly more coverage than at any other site. Mount Barker grew significantly more cover at the 50, 75 and 100 cm spacings than all sites apart from Boyup Brook. There was a significant interaction of the species responding differently to row spacing across the sites. However, the lowest final ground area coverage of all species occurred at Merredin Heavy in 100 cm rows. Albus, yellow and narrow leaf with 31%, 39 and 38% ground cover respectively.

Harvest height (lowest main stem pod)

Pods of albus plants were closet to the ground then narrow leaf then yellow, 32, 35, and 41 cm respectively. Plants in the 25 cm rows had lower pod height than the other row spacings, 34 cm. Plants in the 75 cm rows had their pods highest from the ground, 38 cm. All sites except the two at Merredin had significantly different final plant heights. Plants at Merredin trials had pods lowest to the ground, 26 cm and Boyup Brook highest 46 cm. At Boyup Brook and Mount Barker pods of yellow

lupin were further from the ground than albus or narrow leaf. At Merredin Heavy albus pods were closer to the ground than those of both narrow leaf and yellow lupin. At the remaining two sites all species had different pod heights albus lowest and yellow highest.

Yield

Narrow leaf lupin yielded higher than the other species, it is more widely adapted than yellow or albus lupin. Albus yielded 64 per cent and yellow 57 per cent of narrow leaf lupin (Table 3). Twenty-five centimetre rows yielded higher than all other spacings and the 100 cm rows lower than all other spacings. Note that there was a location by row spacing interaction and the higher yielding southern sites had more leverage on this response, this is discussed below. The 100 cm row spacing yielded 57 per cent of the 25 cm row spacing. Yield from the various locations ranged from 543 kg/ha at Merredin Heavy to 1586 kg/ha at Boyup Brook. The Merredin sites had similar yields, lower than all other sites. All the other sites had significantly different yields, Boyup Brook highest then Mount Barker then Mingenew. As a percentage of the 25 cm rows when averaged across sites yellow lupin yield declined less than the other species. However the species by row spacing interaction was not significant. This was surprising given the very different plant growth responses to row spacing recorded from each species. The species responded to the various locations differently as would be expected given they are naturally adapted to different soils. Narrow leaf lupin yield was higher than the other species at all locations and was more uniform across the sites. The lowest yielding narrow site was 45 per cent of the highest, compared to 25 and 31 per cent for albus and yellow respectively. Narrow leaf lupin yielded significantly more than both other species at all sites except Boyup Brook where albus yield was statistically the same. At Merredin Heavy and Merredin Light albus and yellow had similar yields. At Mount Barker and Boyup Brook albus yielded significantly more than yellow; albus yielded far better at the southern sites. Yellow lupin yielded poorest on the heavy soil at Merredin. It was hypothesised that in northern areas there would be less of a yield response to wide rows compared to southern sites where narrow rows are required to ensure early crop vigour. The results show this to be the case. Averaged across species at the Merredin heavy site there was no significant difference in yield of any row spacing. At the Mingenew and Merredin Light sites yield of all spacings except 100 cm were the same, 100 cm yield was significantly lower. In contrast at Boyup Brook and Mount Barker 25 cm rows yielded significantly more than all other row spacings. Note that because the southern sites yielded better than the northern sites the trend of high highest yield at 25 cm translated to the row spacing main effect response, as indicated above. There was no significant species by row spacing by location interaction.

CONCLUSIONS

Averaged across species yield declined when sowing in 50 cm rows compared to 25 cm rows at southern sites. While albus lupin plants grew more slowly in wide rows and there was a trend that yellow lupin yields were more stable with row spacing there was no significant difference of species yield response to row spacing. The three way interaction of main effects was not significant indicating that narrow leaf, yellow and albus lupin can be grown in rows up to 50 cm in the central and northern wheatbelt without compromising yield. When comparing the two trials at Merredin on the different soil types it was evident that wide rows were better used on heavy soils at this site, see the paper "The interaction of lupin species, row spacing and soil type" published in this booklet for further information.

Table 1. Vegetative and 50% flowering biomass (g/m²), harvest height (lowest pod, cm), harvest index

Species	Row (cm)	Vegetative biomass					50% Flowering biomass				
		BB	MB	MH	ML	MI	BB	MB	MH	ML	MI
Albus	25	120	21.9	112.0	62.9	136.0	531.6	444.8	274.9	256.1	210.5
	50	86.8	17.3	61.8	64.4	131.3	478.1	357.5	228.8	168.5	158.0
	75	76.5	18.0	70.5	54.4	99.0	397.0	291.8	164.6	159.4	192.7
	100	45.3	13.0	62.2	51.3	73.7	246.1	204.1	121.0	153.7	121.4
NLL	25	109	19.0	123.5	107.8	199.5	734.2	620.4	361.1	427.0	310.5
	50	84.6	19.7	117.5	75.1	243.6	768.6	523.1	353.5	339.9	423.0
	75	78.4	12.7	75.0	76.9	210.0	523.7	346.2	295.6	355.9	457.2
	100	36.2	12.9	76.2	72.3	135.3	377.4	425.6	288.6	323.9	321.5
Yellow	25	92.7	15.3	126.4	111.5	185.2	654.5	425.1	290.7	444.4	400.1
	50	83.7	15.3	76.3	79.5	219.1	495.7	305.2	232.3	337.5	382.8
	75	61.0	13.0	89.3	78.1	186.2	468.2	277.0	268.7	318.4	366.5
	100	53.2	9.9	74.9	69.0	115.1	394.2	207.7	155.2	264.6	274.1
Species						**7.2					**21.1
Row spacing						**8.3					**24
Location						**9.3					**27.2
Species*row						14.3					42.2
Species*location						**16					**47.1
Row spacing*location						**18.5					**54.4
Species*row spacing*location						32.1					*94.3

Table 2. Establishment (p/m²), Final row width (cm), plant width growth rate (cm/day), Final coverage (% area)

Species	Row (cm)	Establishment					PWGR 50% flower					Final coverage				
		BB	MB	MH	ML	MI	BB	MB	MH	ML	MI	BB	MB	MH	ML	MI
Albus	25	36.2	40.8	40.5	37.7	41.8	0.193	0.241	0.251	0.222	0.152	99.4	100.0	97.8	100.0	77.8
	50	34.4	44.6	32.9	33.7	30.2	0.226	0.367	0.286	0.255	0.253	89.7	87.0	56.9	66.9	54.1
	75	34.1	29.4	24.7	31.7	35.6	0.281	0.450	0.280	0.262	0.386	75.1	60.3	37.1	44.6	49.7
	100	18.6	34.5	27.9	32.9	27.3	0.164	0.436	0.324	0.282	0.537	55.6	44.5	30.6	34.6	41.6
NLL	25	47.6	52.9	49.3	29.9	43.4	0.199	0.251	0.254	0.268	0.302	100.0	100.0	91.5	100.0	100.0
	50	47.5	57.3	41.9	29.0	38.7	0.289	0.415	0.325	0.307	0.508	99.4	90.6	70.5	83.8	97.1
	75	42.9	28.8	34.5	30.8	39.0	0.201	0.558	0.363	0.315	0.296	92.5	77.2	56.7	66.1	75.7
	100	19.2	50.5	39.4	30.4	28.4	0.197	0.571	0.345	0.349	0.649	73.0	71.2	39.4	53.4	71.4
Yellow	25	41.4	42.8	37.8	34.4	36.5	0.203	0.277	0.254	0.313	0.305	100.0	100.0	100.0	100.0	100.0
	50	38.1	37.3	28.7	32.1	31.3	0.253	0.398	0.325	0.308	0.527	95.9	90.1	71.6	89.5	96.5
	75	42.7	22.8	20.3	29.0	35.5	0.217	0.492	0.331	0.343	0.523	82.5	62.4	53.5	66.8	70.8
	100	27.5	22.0	21.6	30.0	21.4	0.258	0.532	0.358	0.365	0.625	68.8	59.6	38.3	52.6	62.8
Species						**2.0					**0.013					**1.7
Row spacing						**2.3					**0.015					**1.9
Location						**2.6					**0.017					**2.2
Species*row						4.0					*0.026					**3.4
Species*location						**4.5					**0.029					**3.7
Row spacing*location						**5.0					**0.034					**4.3
Species*row spacing*location						9.0					**0.058					**7.5

Table 3. Yield (kg/ha)

Species	Row spacing	BB		MB		MH		ML		MI		Row spacing average	Species average
		YD	% 25 cm	YD	% 25 cm	YD	% 25 cm	YD	% 25 cm	YD	% 25 cm		
Albus	25	2015	100	1743	100	462	100	641	100	677	100	1241	877
	50	1803	89	1335	77	418	90	556	87	739	109	1086	
	75	1605	80	1153	66	409	89	517	81	588	87	986	
	100	1123	56	843	48	333	72	316	49	261	39	704	
NLL	25	2519	100	2398	100	810	100	1181	100	1629	100		1362
	50	1645	65	2025	84	1037	128	1041	88	1228	75		
	75	2113	84	1404	59	789	97	980	83	1524	94		
	100	1222	49	1580	66	705	87	551	47	856	53		
Yellow	25	1337	100	1067	100	362	100	717	100	1051	100		774
	50	1492	112	956	90	376	104	739	70	906	86		
	75	1374	103	512	48	382	106	607	58	831	79		
	100	791	59	712	67	433	120	375	36	464	44		
Site average		1045		1311		543		685		896			
Species													**110
Row spacing													**127
Location													**142
Species*row													220
Species*location													**246
Row spacing*location													*284
Species*rowspacing*location													491

The interaction of lupin species row spacing and soil type

Martin Harries, Bob French, Laurie Maiolo and **Jo Walker**, Department of Agriculture and Food, Western Australia

BACKGROUND

Angustifolius lupins have been proven to yield well in wide rows of 50 cm throughout much of the Western Australian lupin growing area. The use of wide rows may increase harvestability (increase main stem pod height), delay the onset of terminal drought and allow the use of alternative weed management options such as shielded spraying. Anecdotal observations indicated that wide rows may provide better yield stability than narrow rows on heavy textured soils. There is also interest in assessing the suitability of alternative lupin species, luteus/yellow and albus to wide row cropping to determine if the same advantages observed in angustifolius translate to these species.

METHODS

Two trials were located on the Merredin Department of Agriculture and Food Research Station. The sites had distinctly different textured soils and were within few kilometres of each other. Sowing was on 24 May and 25 May. Treatments sown at each site included 4 row spacings; 25, 50, 75 and 100 cm and three lupin species; *L. angustifolius*, *L. albus* and *L. luteus*. These treatments were arranged factorially, 12 treatments, into four randomised complete blocks. Plant density, height, width, biomass, plant height, pod height and yield were measured.

RESULTS

Establishment

Plant population was sparser and less uniform than desired. Both sites had similar overall establishment, 32 and 33 plants per square meter compared to the target density of 45 plants per square meter. Narrow leaf and albus established better than yellows, by 3.5 and 6 plants per square meter respectively. Establishment was better in 25 cm than wider rows.

Biomass production

Biomass production was measured on 5 September and 6 October. At the first time of sampling there were significant differences for all treatments, but not their interactions (Table 1). Albus lupin produced less biomass than narrow leaf or yellows. There was a trend for reduced biomass with wider row spacing. The only significant response was that 25 cm row plots produced more biomass than wider row plots. The heavy soil produced more biomass than the lighter soil type at this early sampling. At the second time of sampling there were highly significant differences resulting from all treatments and the interaction between species and row spacing. Narrow leaf produced the most biomass, then yellow, then albus. Plants in the 25 cm rows produced the most biomass, 50 and 75 cm were statistically the same and 100 cm rows produced less biomass than all other spacings. The light soil produced more biomass than heavy soil. This change from the earlier observation is explained by growth rate data below. The species responded differently across the two sites/soil types. Albus biomass was similar at both sites. Narrow leaf biomass was statistically different between the two sites, higher on the light soil. Yellow lupins also produced more biomass on the light soil. The response of yellow lupin to soil type was far greater than the other two species, indicating that yellow lupins are poorly adapted to the heavy soil compared to the other species.

Single plant biomass

This was recorded at the same times as biomass production. Plant weight on 5 September differed between species and row spacing. Yellow lupin plants were heavier than the other two species and plants in the 25 cm rows were heavier than all the other row spacings. On 6 October there were highly significant differences caused by all treatments and the interaction between species and row spacing. Albus plants were lighter than narrow leaf and yellow. Plants grown in 25 cm rows were heavier than those in all other row spacings. Plants on the light soil were heavier than those on the heavy soil. Weight of albus and narrow leaf did not change with soil type. Yellow lupin plants on the heavy soil were lighter than those on the sand, indicating poor adaptation to heavy soils.

Plant height

Final plant height was affected by species and row spacing. Yellow, narrow leaf and Albus all had significantly different final heights 54, 47 and 42 cm respectively. The 25 cm row plants were significantly shorter, 2, 4 and 4 cm than the 50, 75 and 100 cm spacings respectively.

Plant width

Final plant/row width was highly significantly affected by all treatments and also by interactions of species and row spacing and species and soil type. Albus lupin plants were narrower than the other two species. Plant width increased proportionally with row spacing. Twenty-five centimetre row plants were thinner than plants at all other row spacings. Plants grown in 50 cm rows were thinner than those grown in the 75 and 100 cm rows. Plants on the heavy soil were approximately 25 per cent thinner than those on the light soil. The species reacted differently to the row spacings. All species were narrowest in the 25 cm rows where they covered the entire row. Albus lupin plant width was approximately 30 cm at the 50, 75 and 100 cm row spacings. Narrow leaf and yellow lupin continued to increase plant width in response to the widening of rows from 50 to 75 cm but not from 75 to 100 cm. At 33 days after sowing the rate of plant width growth was only affected by row spacing. Plants grown in 25 and 50 cm rows had slower rates of horizontal growth than 75 and 100 cm plants.

Ground cover

Ground cover was measured as the percentage of ground area covered and rate as percentage of ground area covered per day. This variable was significantly affected by all treatments and treatments combinations except the three way interaction. Albus lupin covered less area than the other two species. Ground cover was inversely proportional to row spacing, each spacing significantly different from each other. There was a higher percentage of ground cover on the light soil type. Albus lupin had lower ground coverage than the other species at the 50, 75 and 100 cm row spacings. At both sites/soil types the albus lupins covered less ground than other species. The coverage when sown in 25 cm rows was the same regardless of site. All other row spacing had significantly lower ground coverage at the heavy site.

The rate of area coverage was only affected by row spacing when measured after 33 days. Rates averaged over the growing season reflected the final coverage results.

Harvest height

This was measured as height of main stem pods from the ground. All species had significantly different harvest heights. Albus lupin pods lowest, then narrow leaf, then yellows. Harvest height increased with increasing row spacing up to 75 cm. The difference between 25 cm and 75 and 100 cm was approximately 3.5 cm. Soil type or interactions did not significantly alter harvest height.

Harvest index

Harvest index of yellow lupin was lower than that of the other two species. Row spacing influenced harvest index. The 50 cm and 75 cm rows had a higher harvest index than the other row spacings. It was unusual that harvest index declined at the 100 cm row spacing. This occurred because maximum biomass production at the light site was similar for 50 cm and wider rows but yield declined dramatically at the 100 cm spacing. In many other similar row spacing trials harvest index has consistently increased with row spacings out to 100 cm. Other variables did not significantly influence harvest index.

Yield

Yields were low due to the dry season however all of the main effects resulted in highly significantly different yields. Narrow leafed lupins yielded higher than the other species, approximately double the yield of the other species at both sites when averaged across the row spacings. Averaged across all other variables 25 and 50 cm rows yielded almost exactly the same while yields dropped at 75 and further at 100 cm. The lighter soil site yielded higher than the heavy soil site.

Interactions also occurred. Narrow leaf and yellow lupins had statistically the same yields at 25 and 50 cm row spacings. Albus lupin reacted differently to row spacing with 25 cm yielding highest and yields declining progressively and significantly at each wider spacing, averaged across the sites.

The species all yielded better in the lighter soil. Yellow lupins were most responsive to soil type however; this interaction was not quite statistically significant (F prob 0.055).

There was a highly significant interaction of soil type and row spacing. Yields at 25, 50 and 75 cm on the heavy soil were statistically the same. Yield was highest on the heavy soil at 50 cm and declined only at the very wide spacing of 100 cm to be approximately 80% of the 50 cm row yield. On the lighter soil yield declined significantly at 75 cm and at 100 cm yield declined dramatically to approximately 50% of the 25 cm spacing yield.

There were no significant three way interactions. All species had more stable yield with row spacing in the heavier soil type than on the lighter soil.

Grain quality and yield components

This data was not available at time of printing please contact the author for more information.

CONCLUSIONS

Narrow leaf lupin was the highest yielding species at both sites, approximately double the yield of the other species. Averaged across all other variables in the trial yield declined at spacings wider than 50 cm. Plants on the light site had greater lateral and horizontal growth late in the season resulting in the light site yielding 128% of the heavy site.

The response to row spacing was markedly different between the soil types. Wide rows yielded better relative to narrow rows on the heavy soil compared to the light soil. This supports the hypothesis that wider rows were better used on heavy soils.

Species growth and yield responded differently to row spacing, when averaged across the sites. Albus lupin was less capable of exploring the inter row space and as a result yield dropped significantly at any spacing wider than 25 cm. Narrow leaf and yellow lupin plants were more vigorous both horizontally and vertically consequently yields did not decline until plants were grown in rows of wider than 50 cm, averaged across both sites.

This year at the Merredin heavy soils site narrow leaf lupin sown in wide rows of 75 cm and yellow lupins sown in wide rows of 100 cm yielded statistically they same as 25 cm rows. Rows wider than 50 cm on light sandy soils compromised yield of these species. Albus lupin is less suited to production in rows wider than 25 cm on light soils compared to heavy soils. On the heavy soil increasing row spacing to 75 cm had little effect on albus yield. Yellow lupin is poorly suited to growth on heavy soils.

Table 1. Establishment (plants/m^2), Plant dry weights (g), Biomass production (g/m^2), Lodging %, Lowest pod height (cm), harvest index

Species	Row spacing	Establishment		BM g/m^2 5/9		BM g/m^2 6/10		Pt. wt 5/9		Pt. wt 6/10		Lowest pod height		Harvest index	
		Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
Albus	25	40.5	37.7	112.0	62.9	274.9	256.1	2.71	2.01	5.61	6.13	22.4	17.2	0.182	0.279
	50	32.9	33.7	61.8	64.4	228.8	169.5	1.52	1.74	5.00	4.14	23.9	20.8	0.295	0.343
	75	24.7	31.7	70.5	54.4	164.6	159.4	1.71	1.43	4.16	3.48	24.4	20.0	0.188	0.332
	100	27.9	32.9	62.3	51.4	121.0	154.7	1.76	1.74	3.22	4.61	25.7	21.6	0.213	0.204
NLL	25	49.3	29.9	123.5	107.8	361.1	427.0	2.51	2.34	6.89	7.16	27.0	24.7	0.178	0.279
	50	41.9	29.0	117.5	75.1	353.5	340.9	2.20	1.78	6.14	7.22	29.4	24.9	0.242	0.307
	75	34.5	30.8	75.0	76.9	295.6	356.9	1.63	1.75	5.76	7.05	27.4	26.0	0.219	0.274
	100	39.4	30.4	76.2	72.3	288.6	324.9	1.77	1.79	6.30	6.06	28.1	27.1	0.325	0.174
Yellow	25	37.8	34.4	126.4	111.5	290.7	444.4	2.93	2.61	6.14	10.56	25.4	30.2	0.192	0.161
	50	28.7	32.1	76.3	79.5	232.3	338.5	2.27	2.57	5.00	7.67	26.0	33.1	0.221	0.223
	75	20.3	29.0	89.3	78.1	268.7	318.4	2.26	2.51	5.06	8.04	29.4	34.5	0.259	0.190
	100	21.6	30.0	74.9	69.0	155.2	265.6	1.94	2.29	4.190	5.920	26.9	32.3	0.229	0.144
Species			*4.023		**10.68		**25.71		**0.255		**0.735		**1.213		*0.03237
Row spacing			**4.645		**12.34		**29.69		**0.294		**0.848		*1.40		*0.03737
Soil type			3.28		*8.72		**20.99		0.21		**0.6		0.99		0.02643
Species*row			8.05		21.37		51.4		0.51		1.47		2.43		0.06474
Species*soil type			5.69		15.11		*36.36		0.36		**1.039		1.72		0.04577
Row spacing*soil type			6.57		17.45		42		0.42		1.2		1.98		0.05286
Species*row spacing*soil type			11.4		30.22		72.7		0.72		2.08		3.43		0.09155

* Significant $p < 0.05$.
** Highly significant, $p < 0.001$.

Table 2. Plant growth rates (cm/day), Ground cover rate (% area per day), Final plant height and row width (cm), Final ground cover (% ground area)

Species	Row spacing	Ht rate 31 [+]das		Row width rate 33 das		Ground cover rate 33 das		Final pt ht		Final row width		Final % ground cover	
		Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy	Light
Albus	25	0.2473	0.2020	0.2380	0.2270	0.9520	0.9090	39.7	38.5	24.7	28.4	97.8	100.0
	50	0.2540	0.2298	0.1230	0.3110	0.2460	0.6210	45.3	38.2	28.4	33.4	56.9	66.9
	75	0.2594	0.2462	0.4150	0.3830	0.5540	0.5100	44.0	41.0	27.8	33.4	37.1	44.6
	100	0.2755	0.2576	0.4350	0.3430	0.4350	0.3430	45.4	40.4	30.6	34.6	30.6	34.6
NLL	25	0.2836	0.2336	0.2020	0.2100	0.8060	0.8410	44.5	44.6	23.6	32.9	91.5	100.0
	50	0.2970	0.2677	0.1980	0.2900	0.3950	0.5800	46.3	46.4	35.3	41.9	70.5	83.8
	75	0.3078	0.2866	0.4900	0.4370	0.6530	0.5830	51.3	47.7	42.5	49.6	56.7	66.1
	100	0.3011	0.2841	0.3890	0.5080	0.5940	0.5080	46.6	47.9	39.4	53.4	39.4	53.4
Yellow	25	0.1962	0.1604	0.1960	0.1860	0.7820	0.7420	47.4	55.7	28.5	35.4	100.0	100.0
	50	0.1962	0.1730	0.1290	0.2560	0.2580	0.5110	49.7	57.2	35.8	44.8	71.6	89.5
	75	0.2043	0.1881	0.4310	0.3750	0.5750	0.5000	53.7	58.0	40.1	50.1	53.5	66.8
	100	0.1922	0.1730	0.5750	0.3120	0.5750	0.3130	53.3	59.7	38.3	52.6	38.3	52.6
Species			**0.00979		0.0618		0.0951		**1.774		**1.765		**2.41
Row spacing			**0.0113		**0.0714		**0.1099		**2.048		**2.038		**2.783
Soil type			**0.00799		0.0505		0.0777		1.448		**1.441		**1.968
Species*row			0.0196		0.1237		0.1903		3.547		**3.531		**4.821
Species*soil type			0.0138		0.0874		0.1345		2.508		*2.496		*3.409
Row spacing*soil type			0.016		0.101		0.1554		2.896		2.88		*3.936
Species*row spacing*soil type			0.0277		0.1749		0.2691		5.016		4.99		6.818

* Significant $p < 0.05$.
** Highly significant, $p < 0.001$.
[+] Days after sowing.

Table 3. Yield (kg/ha)

Species	Row spacing	Heavy soil	Light soil	Row spacing average	Species average
Albus	25	462	641	696	457
	50	418	556	695	
	75	409	517	614	
	100	333	316	452	887
NLL	25	810	1181		
	50	1037	1041		
	75	789	980		
	100	705	551		
Yellow	25	362	717		499
	50	376	739		
	75	382	607		
	100	433	375		
Soil type average		543	685		
Species					**55.6
Row spacing					**64.2
Soil type					**45.4
Species*row					*111.2
Species*soil type					78.6
Row spacing*soil type					**90.8
Species*row spacing*soil type					157.3

* Significant $p < 0.05$.
** Highly significant, $p < 0.001$.

The effects of row spacing and crop density on competitiveness of lupins with wild radish

Bob French and **Laurie Maiolo**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Lupins are more competitive with wild radish at high than at low crop densities. However, even at densities above 100 lupin plants/m² wild radish can reduce lupin grain yield by up to 40% and is able to set significant amounts of seed if it is not controlled.
- Lupin row spacing had no clear effect on competitiveness with wild radish. Any effect was only at crop densities of 80 plants/m² and above.
- Growers should keep lupin densities above 40 plants/m² to minimise competition from wild radish but this will only be a small part of integrated weed management for wild radish in lupins.

BACKGROUND

The increasing prevalence of herbicide resistance in important weeds of lupins means that integrated weed management (IWM) packages are becoming increasingly important for lupin growers. Since lupins have a reputation for not being a competitive crop we have been searching for ways to make them more competitive. Increasing lupin row spacing from 20 to 60 cm reduces lupin competitiveness against annual ryegrass, but raising crop density increases it (French and Maiolo 2006). We describe here a trial designed to investigate the effect of row spacing and crop density on the competitiveness of lupins with wild radish.

METHOD

Mandelup lupins were sown in 25 or 50 cm rows at crop densities of 0, 10, 20, 40, 80, or 120 plants/m² at Wongan Hills Research Station on a site with a background population of wild radish. The trial was sown on 29 May but emergence was delayed by dry conditions during June. Half of the plots were sprayed with Brodal after radish seedlings emerged to give weed-free control treatments. There were two 50 cm row treatments: in one the plots were cultivated at seeding halfway between the rows by the seeding tines; in the other the inter row was left undisturbed.

RESULTS

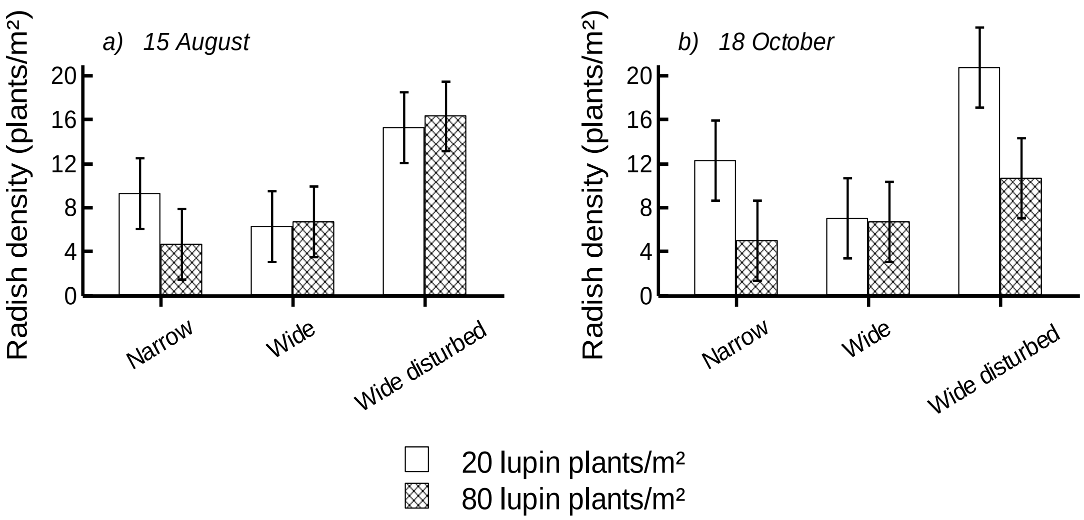

Figure 1. Effects of row spacing and crop density on wild radish density in lupins at Wongan Hills on two different dates in 2006. Vertical bars indicate lsd at P = 0.05.

Average wild radish density across the site in treatments not sprayed with Brodal was 10-11 plants/m², and in the Brodal treatments was less than 1 plant/m². Neither row spacing nor crop density had any significant effect on wild radish density, nor on the survival of wild radish plants from mid-August to crop maturity (Figure 1). Wild radish density was quite variable across the site – Figure 1 gives the impression that the wide disturbed treatment had a higher radish density than the wide and narrow treatments, but this was not statistically significant.

Row spacing had no effect on wild radish biomass production, but increasing crop density reduced it dramatically. There was only about a third as much wild radish present when the lupin density was 120 plants/m² as when there were no lupins (Figure 2). There seemed to be more suppression of wild radish growth in narrow compared to wide rows at high crop density than at low density, but it is difficult to be sure given the variability of the data.

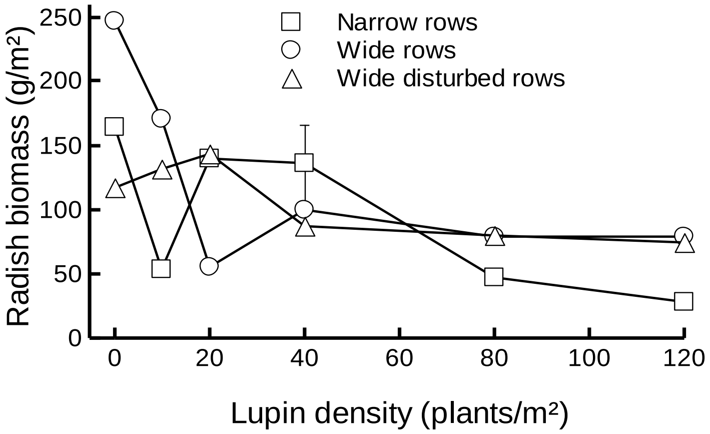

Figure 2. Dependence of wild radish biomass on lupin plant density. Measurements made on 18 October 2006. Vertical bar indicates lsd at P = 0.05.

Competition from wild radish suppressed lupin growth less at high than at low lupin densities (Figure 3). This was also reflected in grain yield which continued to increase with density to higher densities in the presence of wild radish than in its absence (Figure 4). Competition from wild radish reduced lupin yield by 54% when crop density was 20 plants/m², but only by 44% when it was 80 plants/m². And lupin yield was higher at 80 than at 20 plants/m² in the absence of wild radish as well. Row spacing did not influence lupin biomass production or grain yield in this trial.

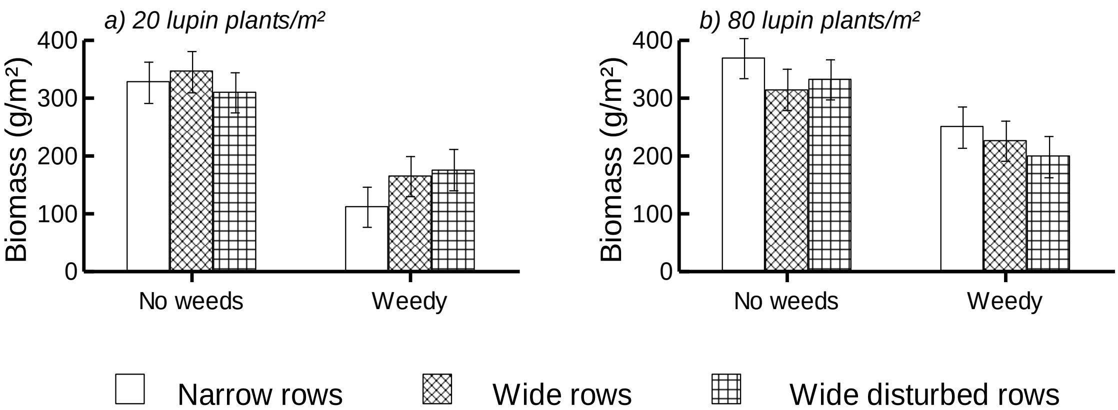

Figure 3. Effects of row spacing and competition from wild radish on maximum biomass production by lupins at two different densities at Wongan Hills in 2006. Measurements made on 18 October 2006. Vertical bars indicate lsd at P = 0.05.

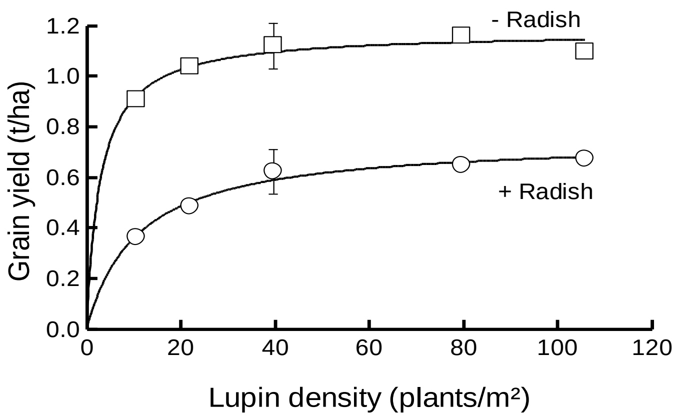

Figure 4. Lupin grain yield response to crop density in the presence and absence of competition from wild radish. Vertical bars indicate lsd at P = 0.05.

Row spacing might be expected to affect the spatial distribution of weeds. In particular, the greater intensity of interplant competition within wide compared to narrow rows might suppress weeds close to the row more than ones further away. Figure 5 shows that neither row spacing nor proximity to the row had any effect on wild radish biomass measured at maximum crop biomass. There was actually more radish growing close to the rows than would be expected if it was evenly distributed. The proportion of total radish biomass growing within 5 cm of the crop rows was 0.59, 0.40 and 0.48 respectively for narrow, wide and wide disturbed rows, compared to expected values of 0.4, 0.2 and 0.2.

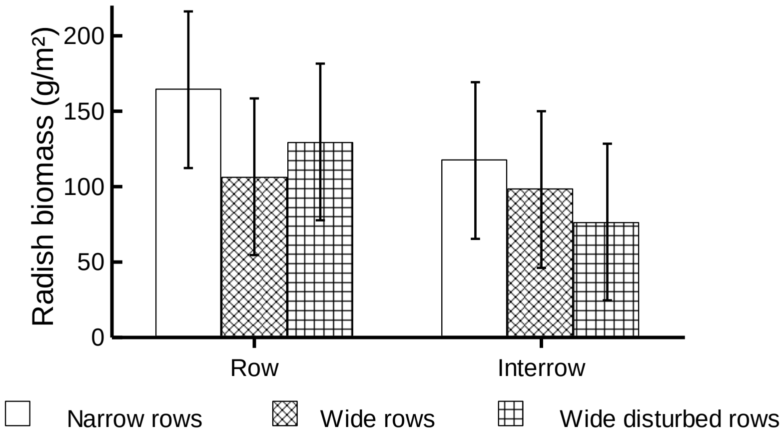

Figure 5. Biomass of wild radish plants within 5 cm of the lupin row (Row) or further away (Interrow) on 18 October 2006. Vertical bars indicate lsd at P = 0.05. Data are presented for 40 plants/m² density treatment only.

CONCLUSION

An average wild radish population of 10-11 plants/m² caused a large reduction in lupin yield. The yield reduction was smaller at high than at low crop density, but even at more than 100 lupin plants/m² the yield reduction was about 40%. The greater competitiveness of dense treatments also suppressed wild radish growth, which would lead to less wild radish seed being carried over into the next rotational phase, but substantial amounts of wild radish were present even at very high crop densities. This means that lupin crop competitiveness cannot be increased sufficiently, at least not by manipulating crop density or row spacing, to replace chemical means of wild radish control. But keeping crop densities above 40 plants/m² could minimise the severity of wild radish blowouts, and may be helpful in conjunction with other components of an integrated weed management strategy.

Row spacing had no clear effect on the competitiveness of lupins with wild radish, except that at high densities crop densities lupins in narrow rows appeared more competitive than lupins in wide rows. There was no effect of the position of wild radish plants in relation to crop rows on how much competition they experienced from the crop at the plant densities normally recommended for lupin

crops, even in wide rows that would have resulted in denser rows. The fact that a high proportion of radish biomass can be very close to the crop row may have implications for systems for controlling wild radish by interrow spraying in wide row crops.

KEY WORDS

lupin, crop density, row spacing, radish, competition, weed management

ACKNOWLEDGMENTS

Chris Matthews, Shari Dougall and other Wongan Hills RSU staff for managing the trial.

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Project No.: DAW 00099

Paper reviewed by: Dr Shahab Pathan

The effect of time of sowing and radish weed density on lupin yield

Martin Harries and **Jo Walker**, Department of Agriculture and Food, Western Australia

BACKGROUND

The practice of dry sowing was promoted heavily in the 1980s and early 1990s. Many growers are reluctant to delay sowing, particularly in lower rainfall areas, because of the yield losses that are incurred. Consequently there is still a large proportion of the states lupin crop that is dry sown. Under a dry sowing regime selective herbicides are relied on to control almost all the weeds. Weeds, particularly ryegrass and radish, are developing resistances to many selective herbicides and are becoming increasingly difficult to control. Wet sowing or delayed sowing ensures the first germination of weeds are effectively controlled by mechanical tillage and non-selective herbicides.

This trial analysed yield loss resulting from delaying sowing and yield loss resulting from crop competition with wild radish. The aim was to asses the relationships between time of sowing and radish density on lupin yield. By doing this we can better understand how to maximise yield considering time of sowing and weed density.

METHOD

The trial design included two factors; three times of sowing, 25 May, 2 June and 6 July and five radish densities 0, 3, 6, 12 and 24 plants/m^2.

The trial was sown at Mullewa and Wongan Hills Department of Agriculture and Food Research Stations. This was done because it was anticipated that different environments would alter the interaction between time of sowing and radish density on lupin yield. The Mullewa trial was abandoned due to drought. Times of sowing were blocked within each replicate to facilitate management. Plots were 1.75 m wide and 18 m long. The soil at the Wongan Hills site that is reported in this paper was a deep yellow sand.

Radish was de-hulled and top-dressed as the plots were seeded. No herbicides were applied to control broad leafed weeds. Broad leafed weeds other than radish were hand weeded and radish was hand weeded from the nil radish control plots. Permanent quadrates were established in the plots so that a sub sample of the plot could be monitored accurately and hand harvested.

Measurements taken included plant density, dry matter, hand harvested yield. These are discussed below.

RESULTS

Establishment

Lupins established well at all times of sowing; 50, 43 and 45 plants per square meter for time of sowing one, two and three respectively. Time of sowing one did have higher numbers of plants per square metre $P < 0.001$. Radish established well and distinct differences in populations were achieved (Table 1). Counts of radish from hand harvested plots were 0, 3.8, 5.3, 9.4, and 14.2 radish per square meter for the 0, 3, 6, 12 and 24 plant per square meter treatments respectively. Hence populations followed the intended trend and were reasonably close to what was targeted.

Biomass production

Time of sowing had little effect on lupin dry matter production when measured on 27 September and at final hand harvest. Increasing ryegrass density had a negative impact on lupin biomass $P < 0.001$ (Table 1). Radish biomass differed between density treatments $P < 0.001$ and correlated closely with plant density, as expected. For the 0, 3, 6, 12 and 24 plant per square meter treatments dry matter production at the end of the season was 0, 171, 189, 250 and 331 g/m^2 respectively.

Hand harvested yield

Lupin yield decreased at time of sowing three compared to times of sowing one and two $P < 0.001$ (Table 1). Yield losses in kg/ha/day were calculated. For the period between the first and second times of sowing (25 May and 2 June) the rate of yield loss was 14 kg/ha/day. The rate of yield loss for the period between the second and third times of sowing (2 June and 6 July) was 9 kg/ha/day. Conditions were very dry between these two sowings and yield decline per day was less than might typically occur at this time of year.

Effect of radish density on lupin yield was clear. As radish plant numbers and radish biomass increased lupin yield was reduced. Linear regressions were calculated to describe the response of lupin yield to radish plant density for each time of sowing. Time of sowing one $y = -0.0559x + 1.40$ (R2 0.77), two $y = -0.0468x + 1.31$ (R2 0.87), three $y = -0.0329 + 1.01$ R2 (0.80) (Table 2, Figure 1). Linear regressions were also calculated to describe the response of lupin yield to radish biomass for each time of sowing. Time of sowing one $y = -0.0024x + 1.52$ (R2 0.77), two $y = -0.0017x + 1.40$ (R2 0.99), three $y = -0.0017 + 1.01$ (R2 0.67).

There was no significant interaction between radish density and time of sowing on yield loss (Table 1). The percentage yield losses due to increasing radish population from the uninfested control were similar at all times of sowing (Table 2). However, because later times of sowing have lower yield potential less actual grain was lost due to radish infestation. Hence with the later sowing there was less financial benefit to be gained from delaying sowing for radish control.

Yield loss caused by one radish plant per square meter at times of sowing one and two was about 50 kg/ha (Table 2). Considering that yield loss per day in this period approximately 15 kg/ha the yield loss caused by one radish per square meter was equivalent to the loss from delaying sowing by three or four days. Yield loss caused by one radish plant per square meter at time of sowing three was about 30 kg/ha (Table 2). Considering that yield loss per day in this period was approximately 10 kg/ha the yield loss caused by one radish per square meter was equivalent to the loss from delaying sowing by three days.

CONCLUSIONS

This trial effectively measured the yield losses from delayed sowing and yield losses from wild radish. A few wild radish caused a large reduction in yield. There was about 4% yield reduction for each radish plant per square meter. Even with a sparse population of radish, one plant per square meter delaying sowing by three to four days was warranted. These relationships will change depending on the location and season. However, it is clear that as radish plants become more difficult to control with selective herbicides reducing radish populations at seeding by a few plants per square meter will offset yield losses incurred by delaying sowing. The results also confirm that any alternative weed control measures trialled to control radish need to have a very high level of efficacy if substantial yield loss is to be avoided.

Table 1. Establishment (plants/m^2), biomass production (g/m^2), yield (t/ha)

Time of sowing	Target radish density	Lupin						Radish	
		Establish-ment p/m^2	Density p/m^2 27-9	Dry weight g/m^2 27-9	Density p/m^2 11-8	Hand harvest DW g/m^2	Hand harvest Yield t/ha	Hand harvest density p/m^2	Hand harvest DW g/m^2
1	0	51.5	56.3	236.8	53.1	399.0	1.605	0.0	0.0
1	3	45.8	60.3	193.1	50.5	273.3	1.011	2.8	129.8
1	6	51.9	52.2	220.0	48.0	302.0	1.146	5.0	225.5
1	12	47.6	53.6	215.0	47.9	258.5	0.918	7.8	227.8
1	24	51.9	52.2	212.6	46.3	202.5	0.705	13.8	342.0
2	0	43.0	54.9	238.5	48.5	346.5	1.388	0.0	0.0
2	3	42.5	50.4	225.5	48.6	298.5	1.104	3.5	164.0
2	6	43.1	54.0	221.9	48.4	282.0	1.024	6.0	247.8
2	12	45.6	54.0	182.8	46.5	233.3	0.762	8.8	358.3
2	24	40.5	51.8	167.9	47.9	220.5	0.762	13.8	377.0
3	0	44.1	56.3	203.9	51.5	307.5	1.023	0.0	0.0
3	3	44.8	54.9	220.5	49.4	238.5	0.729	5.3	219.8
3	6	44.5	45.9	175.1	46.9	291.8	0.949	5.0	93.5
3	12	46.2	47.7	201.2	46.3	178.0	0.521	11.8	164.8
3	24	43.4	54.0	201.6	44.1	200.3	0.590	15.0	275.0
lsd 5% TOS		hs (3.294)	ns	ns	ns	ns	hs (0.1698)	ns	ns
lsd 5% Radish density		ns	ns	ns	ns	hs (49.17	hs (0.2193)	hs (3.137)	hs (74.5)
lsd 5% interaction							ns		

hs - $p < 0.001$; s - $p < 0.05$; ns - not significant.

Table 2. The estimated effect of radish plant density on lupin yield (Hand harvested)

Radish density p/m^2	Yield loss kg/ha		
	TOS 1	TOS 2	TOS 3
0	0	0	0
1	56 (4)*	46 (4)	32 (3)
2	111 (8)	93 (7)	65 (7)
3	167 (12)	140 (11)	98 (10)
4	223 (16)	187 (14)	131 (13)
5	279 (20)	234 (18)	164 (16)
6	335 (24)	280 (21)	197 (20)
8	447 (32)	374 (29)	263 (26)
10	559 (40)	468 (36)	329 (33)
12	670 (48)	561 (43)	394 (39)
14	782 (56)	655 (50)	460 (46)

* Figures in brackets are % yield reduction from control.

Interaction of time of sowing and weed management in lupins

Martin Harries and **Jo Walker**, Department of Agriculture and Food, Western Australia

BACKGROUND

Growers need to know the effect of altering time of sowing and sowing tactic (dry vs wet sown) on costs in terms of lupin yield and the benefits in terms of weed control. Sowing time and weed burden interact to affect final yield. This interaction of weed burden and sowing time on yield is dynamic and dependant on environment. Trials were sown with the Mingenew Irwin and Liebe groups in an attempt to better understand effect of dry and wet sowing on weed burden and yield over two differing rainfall zones.

It was intended to use a shielded sprayer to control weeds in some plots, however due to the season this treatment was not undertaken. The aim was to see if weeds could be effectively controlled in dry sown crops using a shielded sprayer. If this can be achieved it gives the option to dry sow without sacrificing weed control.

METHODS

Treatments included three sowing tactics/times and two row spacings. The three seeding tactics were dry sown, sown immediately after the break of the season and delay sown after the break. The two row spacings were 25 cm and 50 cm. At each time of sowing two 50 cm rows and one 25 cm row was seeded per replicate. A 50 cm and a 25 cm plot were to be managed using conventional, using traditional broadcast herbicides, and the second 50 cm plot was to be managed using a shielded sprayer. Due to the dry season (124 mm growing season rain) crop growth was poor and no post emergent herbicides were applied. Consequently the analysed results are a factorial of the three times of sowing and the two row spacings.

The trial was seeded into a sandy grading to a loam at a depth of 30-40 cm, pH 5.0 ($CaCl_2$) at the surface increasing to 5.8 ($CaCl_2$) at 30 cm. Seeding dates were 28 April (dry), 17 May (the day after 14.5 mm of rain) and 30 May (Delayed after the break). Four replicates were sown. Fifty centimetre plots were 2.0 metres wide and 18 meters long (36 m^2) and 25 cm plots were 1.75 m wide by 18 m long (31.5 m^2). Measurements taken included; weed germination prior to seeding, establishment, post emergent weed density, ryegrass density and biomass and lupin biomass. These are discussed below.

RESULTS

Results presented are from Buntine, the trial seeded at Mingenew was abandoned.

There were significant differences in the numbers of lupins established at each time of sowing, ($P < 0.001$) (Table 1). The second time of sowing, sowing soon after the break, gave the poorest establishment. This most probably occurred because the seeding operation dried the soil in a marginal moisture situation. The third time of sowing had the best establishment because it was sown into the best, wettest, seeding conditions.

The trial was designed to achieve a range of weed populations. This was achieved using the different seeding strategies (Table 1, Figure 1). Weed populations prior to seeding were lowest when dry sown and highest when sowing was delayed ($P < 0.001$). Hence by delaying sowing a higher proportion of the weed seed bank was controlled by knockdown herbicides and tillage at seeding. Conversely when weed populations were measured in August dry sown plots had the highest weed populations and the late sown plots the lowest ($P < 0.001$). The dry sown plots had almost five times the weed population of the delayed sown plots (Figure 1). At the end of the season all the ryegrass from the plots was harvested and weighed. Again the dry sown plots contained more ryegrass plants (Table 1). There was a clear trend that the earlier the plots were sown the more ryegrass biomass they contained (Table 1).

Lupins were hand harvested. The final lupin dry matter (Table 1) includes the weight of whole plants with seed. Seed yield was too low to be worth threshing the plants. Biomass of the last time of sowing tended lower than the preceding two times of sowing. This was obvious throughout the trial, the third time of sowing plants were visually much smaller than the earlier sown treatments. While individual plants were smaller in the third time of sowing the better establishment compared to other treatments compensated for this. There were no significant differences in final lupin dry matter.

Row spacing did not significantly influence any of the variables measured.

CONCLUSION

Delaying sowing allowed better weed control prior to seeding which resulted in lower weed populations throughout the year. The yield penalty resulting from delayed sowing was not significant this year, however yields were very low. This trial will be repeated in 2007 with the aim of including shielded spraying treatments.

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Table 1. Weeds density (plants/m^2), Establishment (plants/m^2), Ryegrass density (plants/plot), Plant weight (g), Dry matter production (g/m^2)

Sowing time	Row spacing (cm)	Weeds density prior to seeding (Plants/m^2)	Establishment 18/6 (Plants/m^2)	Weed density 3/8th (Plants/m^2)	Ryegrass 26/9			Lupin	
					Plants per plot	Plant dry wt (g)	Total DM (g/m^2)	Final plant dry wt (g)	Final DM (g/m^2)
Dry	25	1.3	43.2	22.0	319.0	1.8	16.1	2.5	205.0
Dry	50	1.3	39.9	23.8	356.0	1.4	15.8	2.1	138.5
On the break	25	9.5	34.5	10.3	147.0	2.3	11.6	2.1	107.5
On the break	50	10.0	28.8	16.3	176.0	2.7	14.0	2.6	125.0
Delayed after the break	25	12.8	58.9	1.5	152.0	1.4	5.8	1.4	151.5
Delayed after the break	50	12.0	52.8	7.0	157.0	1.6	6.0	1.5	132.5
lsd 5% Sowing time		hs (3.175)	hs (8.31)	hs (8.42)	hs (89.6)	s (0.875)	ns	ns	ns
lsd 5% Row spacing		ns	ns	ns	ns	ns	ns	ns	ns

hs - $p < 0.001$; s - $p < 0.05$; ns - not significant.

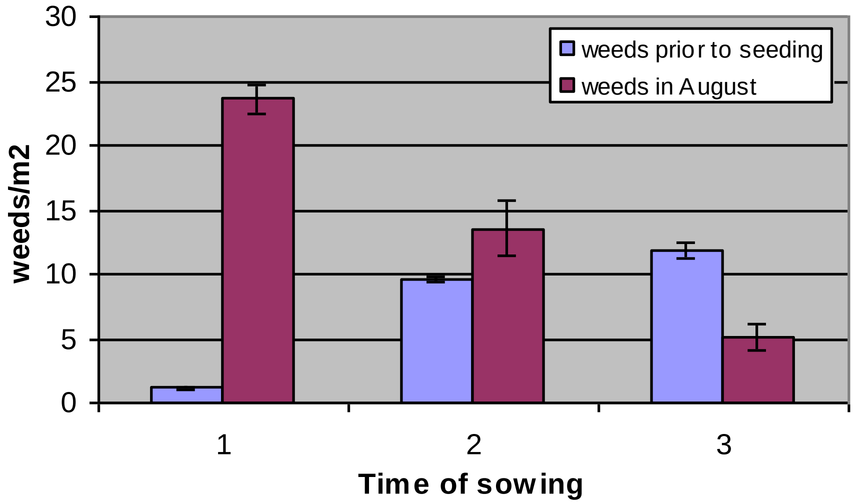

Figure 1. Weed populations prior to each time of sowing and in August.

Delayed sowing as a strategy to manage annual ryegrass

Bob French and **Laurie Maiolo**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Delaying lupin sowing for nine days after the break of the season at Merredin in 2006 did not reduce annual ryegrass density, presumably due to the soil surface drying out rapidly after the break so that few weeds germinated before the second sowing.
- The yield penalty for delayed sowing was greater when the weed burden was high than when it was low.
- Mandelup and Belara lupins were more competitive against annual ryegrass than Tanjil lupins, and they suffered a smaller yield penalty for delayed sowing.
- Relying on delayed sowing to improve weed control is a risky strategy at Merredin because of the likelihood of little weed germination in an acceptable time period following the break.

BACKGROUND

The development of widespread resistance to selective herbicides in weeds such as annual ryegrass has meant that lupins have changed from being a phase in the rotation where growers can dramatically reduce grass numbers to one where grass numbers can increase catastrophically. This is because lupins are not very competitive against weeds, and because the strong emphasis on sowing them early places heavy reliance for weed control on selective herbicides, which may fail. One means that has been suggested for reducing the reliance on selective herbicides at the same time as minimising weed build-up in lupin phases of rotations is to delay sowing for up to a week after the season breaks. This is supposed to allow a first flush of weeds to germinate which can then be controlled with non-selective herbicides prior to sowing. Such a strategy involves a trade-off between the reduced yield potential delaying sowing entails and the higher yield due to reduced weed competition. Reduced weed seed set is another benefit. This trade-off implies that it would be a more valuable strategy in high weed than low weed backgrounds.

The trial described in this paper was designed to test whether delaying sowing would reduce ryegrass numbers sufficiently to compensate for the loss in yield potential due to delayed sowing, and to compare the response in low and high weed backgrounds.

METHOD

In October 2005 sections of a weedy wheat crop were sprayed out with 2 L/ha Roundup to prevent weed seed set. These areas became the low weed burden treatments in 2006 while unsprayed areas became the high weed burden treatments. In 2006 Mandelup, Belara, and Tanjil lupins were sown on 17 May, the day after 17 mm rain fell. The second sowing date was on 26 May, 2 days after 30 mm rain fell. 2.0 L/ha Spray.Seed® and 2.0 L/ha Simazine were applied prior to each sowing and the site had previously been sprayed with Roundup® Power Max, Garlon DS® and Hammer® to control wild radish that had germinated in the wet summer. The only post-emergent herbicide applied was Brodal®, until half of each plot was crop-topped with 800 mL/ha Gramoxone® on 16 October.

RESULTS

Seed set control in 2005 had a large effect on ryegrass density. On 21 July the average density in low weed burden treatments was 14 plants/m^2, compared to 43 plants/m^2 in high weed burden treatments. Cultivar and sowing time had no effect on weed density at this stage.

By 7 October, the delayed sowing treatment actually contained a greater density of ryegrass plants than lupins sown on the break (Figure 1a). However, ryegrass plants in the delayed sowing treatment were smaller than in lupins sown on the break and there was no effect of sowing time on the density of ryegrass heads at this stage. There were significantly more ryegrass heads in Tanjil than in Belara or Mandelup though (Figure 1b).

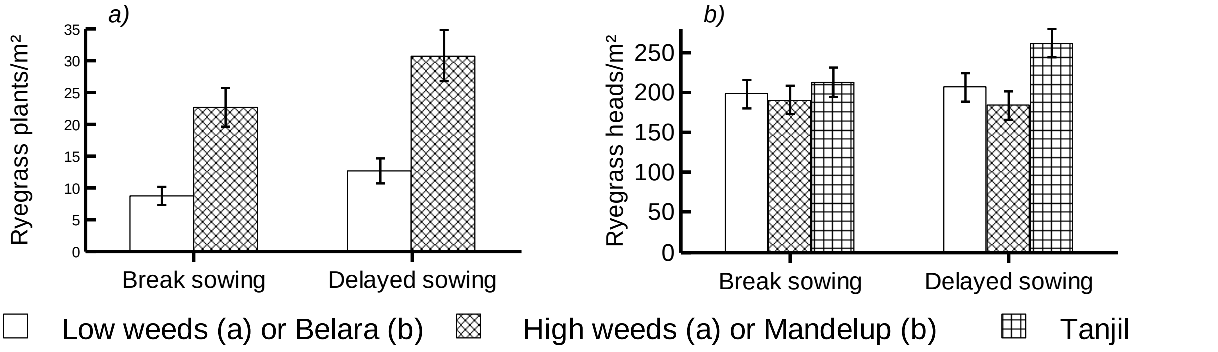

Figure 1. Effects of seed set manipulation in 2005 and delayed sowing on ryegrass density in lupins (a) and effects of cultivar and delayed sowing on ryegrass head number (b). Vertical bars indicate lsd at P = 0.05. Measurements made on 7 October 2006.

Competition from ryegrass significantly reduced lupin biomass production (Figure 2a) but there was no interaction with cultivar or sowing time. Mandelup and Belara produced more biomass than Tanjil though, especially in the delayed sowing treatment. Delaying sowing did not have a significant effect on ryegrass biomass at crop maturity, but there was less ryegrass biomass in Mandelup and Belara than in Tanjil (Figure 2b).

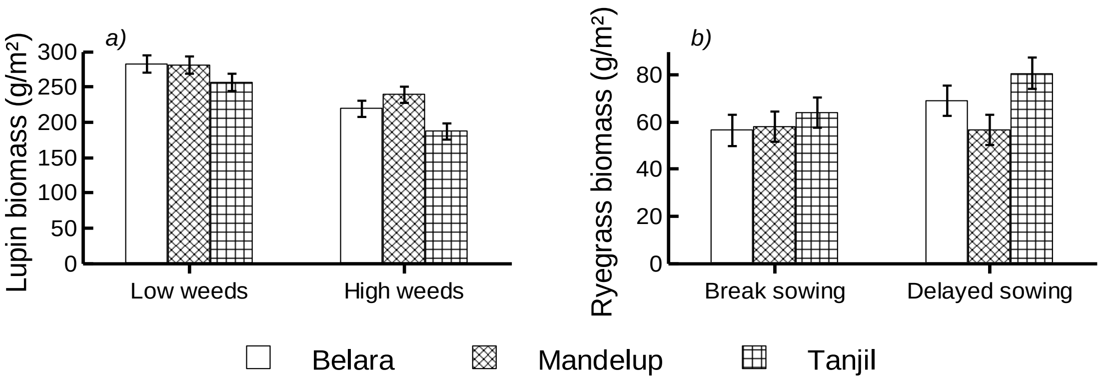

Figure 2. Effects of cultivar and weed burden on lupin biomass (a) and of cultivar and delayed sowing on ryegrass biomass (b). Vertical bars indicate lsd at P = 0.05. Measurements made at crop maturity.

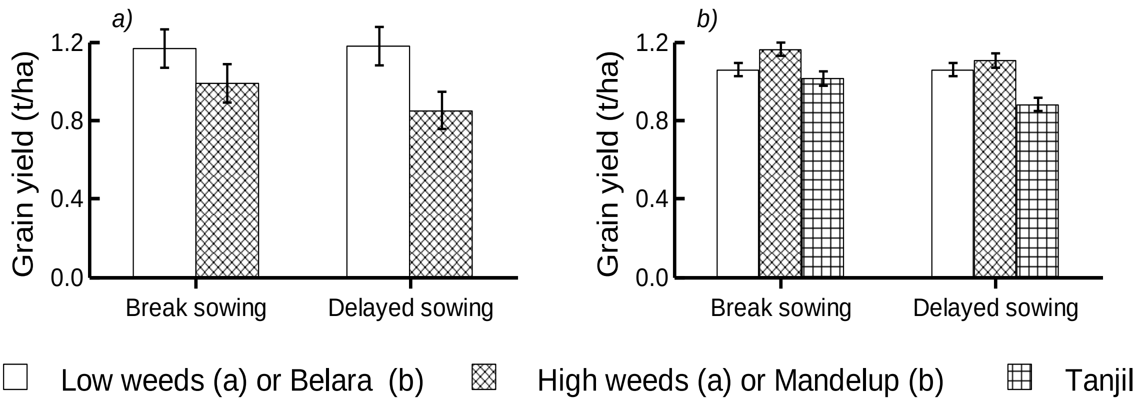

Figure 3. Effects of delayed sowing and weed burden (a) and delayed sowing and cultivar (b) on lupin grain yield. Vertical bars indicate lsd at P = 0.05.

In this trial delaying sowing for a week after the break had no effect on grain yield under a low weed burden, but resulted in a 138 kg/ha yield penalty under a high weed burden (Figure 3a). Grain yield in the early maturing cultivars Belara and Mandelup was insensitive to delayed sowing, but the later maturing Tanjil suffered a significant yield penalty (Figure 3b). Crop topping had no effect on grain yield in this trial. Only incomplete data on ryegrass seed production were available when this paper

was prepared. They show, as expected, large effects of weed burden and crop-topping, but any effects of delaying sowing or cultivar are not clear. We hope they will become clearer when sample processing is complete.

DISCUSSION

The strategy of delaying sowing lupins to improve weed control did not work in this trial, emphasising the risky nature of the strategy. Delaying sowing for nine days led to no reduction in weed density and, in fact, by the end of the season there may have been more ryegrass in the delayed sowing treatments, suggesting that delaying sowing reduces the competitiveness of lupins against ryegrass. The lack of any improvement in weed control is probably due to there being no follow-up rain after the first sowing until two days before the second sowing, leaving the soil surface dry most of this time so that there was little opportunity for weeds close to the soil surface to germinate. Alternatively, the summer rain experienced in 2006 followed by dry weather in April and early May may have induced abnormal dormancy in the ryegrass that prevented it from germinating in the week following the break (S. Pathan, pers. comm.).

Because weed control did not change, there was a yield penalty for delayed sowing in the high weed burden treatment, but not in the low weed burden treatment. This is the opposite of what we expected to find, and would mean that a grower following our strategy would have lost money. These results do not mean that delaying sowing for a week after the break during May carries no yield penalty in a weed-free situation. The crop modelling described in French (2007) shows that yield penalties for lupins can be close to, or sometimes even less than, zero. This does not happen often, but it is likely that seed bed conditions similar to those experienced at Merredin in 2006 will occur frequently, and that relying on a short sowing delay to improve weed control is a risky business. How often favourable seedbed conditions for weed germination occur after the break, and for how long, and whether this varies appreciably between wheatbelt locations, are questions that could best be answered using crop modelling, as long as those favourable conditions are clearly specified. Another risk of the strategy of delaying sowing to improve weed control is that seed bed conditions might not be suitable for sowing a week after the break, and that the grower might be forced into a much longer sowing delay than a week, which will entail a much larger yield penalty (French 2007).

There were some interesting differences between cultivars. The data on ryegrass biomass showed that Tanjil was less competitive against annual ryegrass than Belara or Mandelup. Data on lupin biomass and grain yield also pointed in this direction, but the effects on these variables failed to reach statistical significance. Tanjil is also less competitive against wild radish than Mandelup (Pathan *et al*. 2006). Tanjil was also more sensitive than Belara or Mandelup to delayed sowing. These are other reasons to avoid Tanjil in areas without a high anthracnose risk.

KEY WORDS

lupin, sowing time, annual ryegrass, competition, weed burden, integrated weed management

ACKNOWLEDGMENTS

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Paper reviewed by: Shahab Pathan

Is delayed sowing a good strategy for weed management in lupins?

Bob French, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- The simulated median yield penalty for delaying lupin sowing for one week after the break of the season is equivalent to the yield loss caused by competition from 20 to 68 ryegrass plants/m² or one to three radish plants/m².
- Expected weed densities need to be at least this high to make delaying sowing for weed control a worthwhile strategy if grain yield maximisation is an important criterion.
- The expected yield penalty for delayed sowing was smaller at Mingenew than at Buntine or Merredin, so the improvement in weed control necessary to compensate for the yield penalty is not as great at Mingenew.
- There may be other benefits from improved weed control that make delaying sowing worthwhile.
- There is a significant risk of not getting a second sowing opportunity one week after the break of the season.

BACKGROUND

Dry sowing lupins has been a widespread practice in Western Australia. Its strengths include ensuring the crop germinates when the season breaks and that sowing lupins does not interfere with sowing other crops. However, it is a strategy that heavily depends on in-crop herbicides for weed control. It served the industry well when cheap effective selective herbicides were available for the major weeds of lupins, although it did encourage herbicide resistance to develop in these weeds. Now cheap effective herbicides are no longer available and we wish to delay resistance to our remaining herbicides developing for as long as possible. Is dry sowing still appropriate?

Department of Agriculture and Food officers have recently been encouraging growers to plant lupins into moist soil, which improves the activity of pre-emergent simazine, and even to delay sowing for up to a week following the break, which allows weeds germinating during this time to be controlled by non-selective methods (Harries and Walker 2007a). But any improvement in weed control must be traded off against reduced yield potential, the fact that you may want to sow other crops at the same time, and the risk that the soil may be too dry to sow into after the delay.

In this paper I model the yield penalty for delaying sowing after the break at Merredin, Buntine and Mingenew, and compare this to yield reductions expected from competition with wild radish and annual ryegrass. I also model the likelihood of missing a second sowing opportunity at these locations.

METHOD

Lupin yields were simulated using APSIM 4.2, with some parameter modifications based on my unpublished data, for each year from 1901 to 2004 at Merredin and Mingenew, and from 1930 to 2004 at Buntine. I used weather data from the patched-point dataset maintained by the Queensland Department of Natural Resources and Mines. Soil properties at Merredin and Mingenew were based on my unpublished data, and at Buntine on those supplied with APSIM. Three types of simulation were run. For the first two Mandelup lupins were sown on the break or 7 days later. The break in this context is the first day between 15 April and 15 June when there was at least 5 mm extractable soil water in the top 5 cm of soil, and at least 10 mm in the top 20 cm. The third simulation identified as the next sowing opportunity by waiting 7 days after the break and then choosing the first day when the same soil moisture criteria were satisfied.

The effects of weed competition were analysed using the following equation:

(0.1) $$Y = \frac{Y_0}{(1+\beta x)}$$

where Y is crop yield, Y_0 is yield in the absence of weeds, x is weed density, and β is a competition coefficient. The value of β for wild radish was derived from data of Harries and Walker (2007b) and Pathan *et al.* (2006), and for annual ryegrass from my own unpublished data and other data from C. Zaicou.

RESULTS AND DISCUSSION

Simulating sowing time response

Yield potential was much higher at Mingenew than at Buntine or Merredin (Table 1) and the yield penalty for delayed sowing was also smaller, both in absolute and relative terms. The figures in Table 1 are summarised as medians, but they come from rather skewed distributions: Figure 1 shows the distributions of yield for Merredin.

Table 1. Median values for lupin yield when sown on the break and one week after the break, yield penalty for delaying sowing a week, and days until the next sowing opportunity after the break, ignoring opportunities within one week. Note that the median yield penalty is not the same as the difference between the median yields on the break and one week after. This arises because of the very skewed distribution of yield penalties

	Yield on break (kg/ha)	Yield 1 week after break (kg/ha)	Yield penalty (kg/ha)	Days to next sowing opportunity
Mingenew	3.08	2.78	0.12	14
Buntine	1.50	1.39	0.20	18
Merredin	1.50	1.34	0.18	10

Yield reduction from weed competition

Figure 2 shows how yield responded to wild radish density in two experiments (Pathan *et al.* 2006, Harries and Walker 2007) with curves described by equation (0.1) fitted. The values of β for wild radish derived from these data ranged from 0.015 to 0.096, with a mean of 0.056. The mean value for annual ryegrass from one of my unpublished trials and a trial of C. Zaicou was 0.0022 Subtracting equation (0.1) from Y_0 and rearranging gives the following expression for the yield penalty ΔY:

(0.2) $$\Delta Y = Y_0\left(\frac{\beta x}{1+\beta x}\right)$$

Table 2. Wild radish and annual ryegrass densities that would cause the same yield loss as delaying sowing by one week at three locations in the wheatbelt. These were calculated using the median yield penalties given in Table 1 and equation (0.2)

	Wild radish (plants/m²)	Annual ryegrass (plants/m²)
Mingenew	0.7	19
Buntine	2.7	68
Merredin	2.4	62

Using the mean values of β we can calculate the weed density that would cause the same yield loss as delaying sowing by one week. Table 2 shows that the yield penalty for a one week sowing delay is about the same as the yield loss (0.2) predicts would be caused by competition from 19 to 68 ryegrass plants/m², or 1 to 3 radish plants/m². The equivalent weed densities are higher at Merredin and Buntine than at Mingenew.

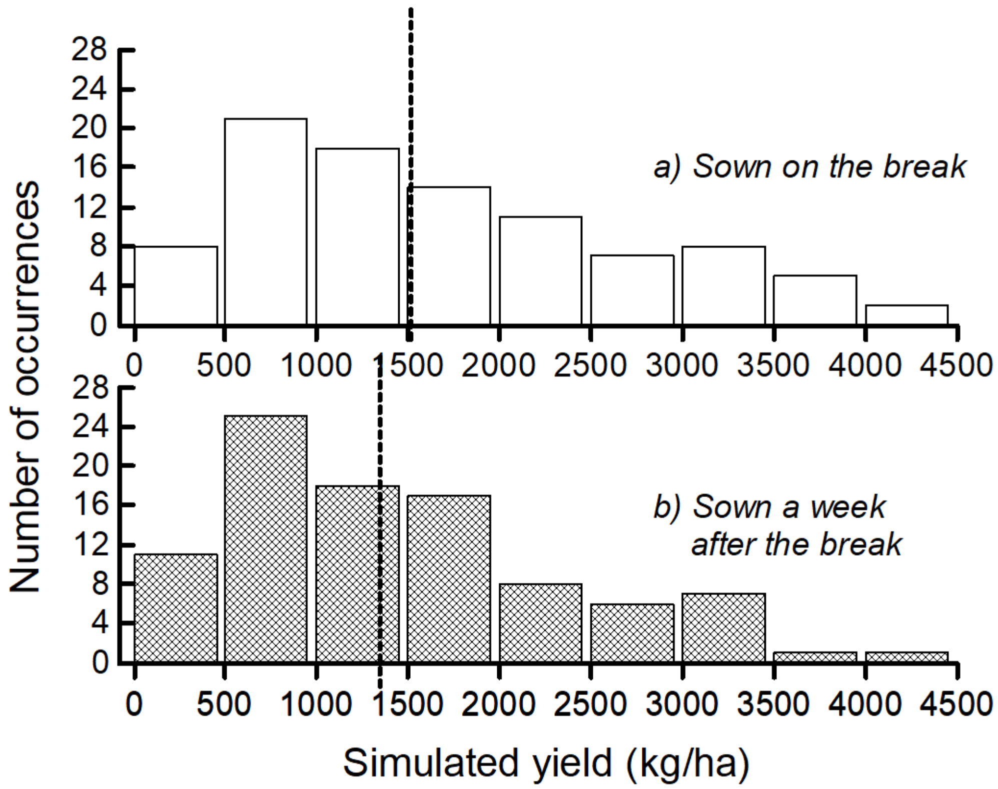

Figure 1. **Distribution of simulated lupin yields from 1901 to 2004 at Merredin when sown on the break of the season or a week after the break. Dotted lines show the median value.**

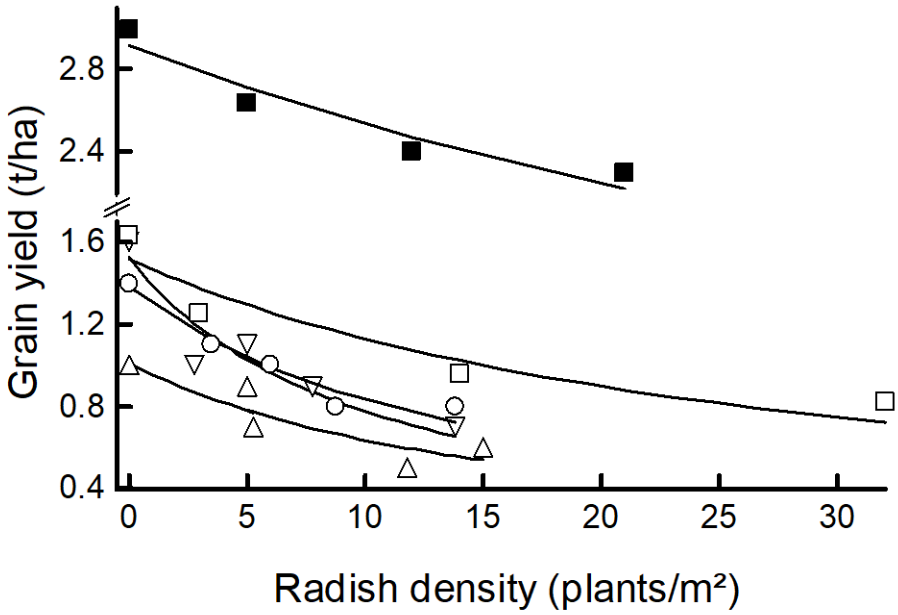

Figure 2. **Fitted response curves (equation (0.1)) of yield loss in Mandelup lupins as a function of wild radish density. Square symbols show data from Pathan *et al.* (2006) and other symbols from Harries and Walker (2007b).**

DISCUSSION

To compensate for the reduced yield potential due to delaying sowing for a week would require ryegrass densities to be reduced by at least 60 plants/m², or radish densities by at least 2 plants/m², in low rainfall areas, so if background weed burdens are not at least this high reduced competition will not compensate for the loss of yield potential from delayed sowing. When selective herbicides are still effective it is difficult to imagine ryegrass control improvements of this magnitude from delayed sowing, but it is realistic to expect radish control improvements of this magnitude. The necessary improvement in weed control at Mingenew is much smaller: less than 20 ryegrass plants/m² and less than 1 radish plants/m² and should often be achievable.

There may be other benefits of improved weed control apart from removing competitive effects on grain yield. There may be savings in costs of selective herbicides and, perhaps more importantly, reduced weed seed production leading to lower weed burdens in following crops. These would need to be considered in a completely rigorous analysis of the value of delayed sowing as a weed management tool.

There are also other risks associated with delaying sowing apart from reduced yield potential. A major one is the risk that seedbed conditions will not be suitable a week after the break. Even at Mingenew there was a 50% chance that a second sowing opportunity would not occur until more than two weeks after the break, and at Buntine until nearly 3 weeks after the break. Surprisingly, the likelihood of a long delay until the second sowing opportunity was no greater at Merredin than at Mingenew. You might therefore be more wary about delaying sowing to manage weeds at Buntine than at Merredin or Mingenew.

How dependant these results are on the particular definition of the break and the next sowing opportunity is not clear. It may be rash to only require 10 mm soil moisture for a break in mid-April, and it may be over-restrictive to require 5 mm in the top 5 cm of the profile for a second sowing opportunity. However, alternative scenarios could easily be analysed using the framework outlined here.

KEY WORDS

lupin, sowing time, APSIM, wild radish, annual ryegrass, competition

ACKNOWLEDGMENTS

Bill Bowden made helpful comments on a draft of this paper and Christine Zaicou allowed me to use her data on ryegrass competition with lupins.

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Paper reviewed by: Martin Harries

Lupins aren't lupins when it comes to simazine

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KEY MESSAGES

- Mandelup and Andromeda showed similar tolerance to simazine at high rates of application.
- Pootalong and Gungurru show similar tolerance to simazine as Mandelup at moderate rates of application but less tolerance at higher rates of application.
- Danja and P26961 (pearl lupin) show the least tolerance to simazine.

INTRODUCTION

Comparisons of herbicide tolerance between species can sometimes be complicated by rainfall and soil type. For example, narrow-leafed lupin is adapted to more acid and sandier soils than albus lupin. Conducting a herbicide tolerance trial on an acid sand may, therefore, favour the growth of narrow-leafed lupin over albus lupin, which may in turn, confound the results of tolerance to herbicides. Similarly, if separate trials are conducted on soil types or in rainfall zones that are ideal for the individual species, then, the interaction of the herbicide with different clay contents or moisture availabilities at the separate sites again confounds comparisons between species. These effects are mitigated if plants are grown under controlled conditions in the glasshouse.

We have developed a simple protocol using plants grown in pots in the glasshouse to give an indication of the tolerance of lupin to simazine. This protocol can be used to provide a simple assessment of the tolerance of potential new varieties early in their development.

AIMS

Determine the tolerance of new lupin varieties and species to simazine relative to standard varieties.

METHOD

Treatments consisted of 5 simazine rates (0.0, 0.1, 0.2, 0.3, 0.4 µg simazine/g soil), eight genotypes (*Lupinus albus* (cultivar: Andromeda), *L. angustifolius* (cultivar: Belara, Danja, Gungurru, Mandelup, Tanjil), *L. mutabilis* (line: P26961 (pearl lupin)) and *L. luteus* (cultivar: Pootalong) and three replications. Pots contained 2,750 g of sand and were sealed at the bottom to prevent drainage. Full basal nutrients (except N) were applied in solution to the soil surface of each pot. Simazine was applied as a suspension of Simagranz® (89.7% simazine) also to the soil surface. After the nutrients and simazine had dried they were mixed throughout the soil by shaking. Ten seeds per pot were sown and each seed was inoculated with a pinch of Group G, peat-based inoculum. The water content of pots was maintained at field capacity by regularly watering to weight.

At four weeks after sowing the plants were scored for the severity of scorching on leaves then, the total number of plants emerging were counted and harvested.

RESULTS

Simazine had no effect on the emergence of plants except for Pootalong ($P < 0.05$). On average about eight Pootalong plants emerged per pot at the low rates of simazine application whereas about 5.5 plants per pot emerged at the high rates.

The severity of leaf scorching increased ($P < 0.01$) as the rate of simazine increased (Table 1). The most severe scorching occurred at the highest rate of simazine application where Danja, Gungurru, Tanjil and P26961 had the highest score. The score of symptoms in Mandelup and Pootalong at the highest rate of simazine application was nearly half that for Danja, Gungurru, Tanjil and P26961. For the first three rates of simazine application however, the score for symptoms in Gungurru was the same as Mandelup.

Table 1. Score of leaf scorching four weeks after sowing in response to simazine application. Plants scored on a 1 to 5 scale. 1 = no symptoms; 5 = dead plants

Genotype	Rate of simazine application (µg simazine/g soil)				
	0	0.1	0.2	0.3	0.4
Andromeda	1.0	1.3	2.0	3.0	3.3
Belara	1.0	1.3	1.3	3.0	3.3
Danja	1.3	1.0	2.3	4.3	5.0
Gungurru	1.0	1.0	1.3	3.3	4.7
Mandelup	1.0	1.0	1.3	2.0	2.7
P26961	1.0	1.0	2.3	3.3	4.7
Pootalong	1.0	1.3	2.0	1.7	2.7
Tanjil	1.3	1.0	1.7	2.7	5.0
lsd 5%	0.95				
cv%	27.0				

At the highest rate of simazine, the dry weight of shoot of plants was 30% to 70% of the weight when no simazine was applied (Figure 1). The weight of Mandelup and Andromeda decreased the least, whereas Pootalong and P26961 decreased the most (P = 0.07). Tanjil, Danja and P26961 produced lower dry weights of shoots than Mandelup at most rates of simazine application. Pootalong and Gungurru produced the same dry weight of shoots as Mandelup for the first three rates of simazine application and then lower dry weights of shoots at the last two rate of simazine.

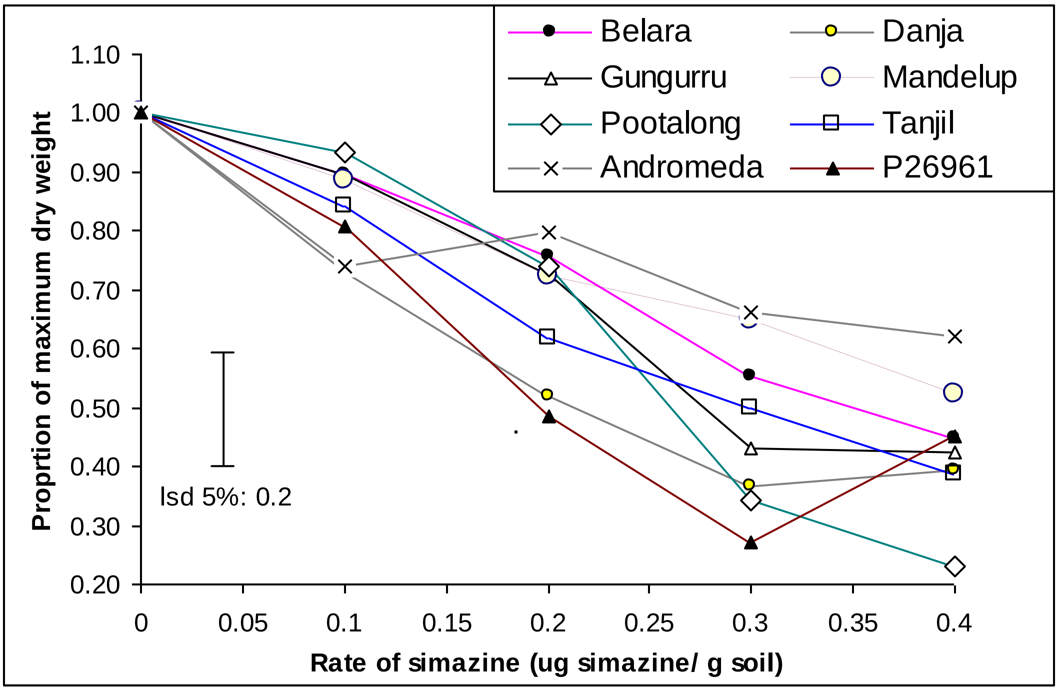

Figure 1. Dry weight of shoots of plants as a proportion of the maximum dry weight in response to simazine application.

CONCLUSION

Mandelup and Andromeda showed the highest levels of tolerance to simazine, which in these trials was higher than that for Gungurru and Belara. Anecdotal reports have previously suggested that Gungurru was reasonably tolerant of simazine and more tolerant than Belara. This was not evident in this trail with the tolerance of both Gungurru and Belara being about the same.

The large decline in the dry weight of shoots of Gungurru and Pootalong when rates of simazine higher than 0.2 µg/g were applied may indicate that the margin of tolerance to simazine for these two genotypes is narrower than for Mandelup. Pootalong showed a similar response in herbicide screening trials at Eradu in 2005 (Dhammu, 2006). Pootalong also did not show strong symptoms of simazine damage (scorching) despite a large reduction in growth. Crops of Pootalong therefore may be more at risk from over application of simazine given its lower margin of tolerance to the herbicide but a lack of obvious indications of damage.

Weed control through the application of simazine will be difficult with the pearl lupin line P26961 if it is released as a variety. This line showed similar levels of tolerance to simazine as Danja, a variety on which simazine application has been problematic. Only one genotype of pearl lupin was tested and we do not know if this genotype is indicative of the other genotypes of this species that are being developed for release as new varieties for WA. Pearl lupin, however, was more sensitivity than other lupin species to most herbicides tested on lupins in Wongan Hills during 2005 (GRDC project DAW0134, Harmohinder Dhammu personal communication; seed was a mixture of advanced lines of pearl lupin).

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Seed yield and anthracnose resistance of Tanjil mutants tolerant to metribuzin

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KEY MESSAGES

- Mutation breeding is an effective way to improve lupin tolerance to herbicide. Two metribuzin tolerant mutants of Tanjil origin (Tanjil-AZ-33 and Tanjil-AZ-55) showed consistent tolerance to metribuzin in the field. Tanjil-AZ-33 produced seed yield close to Mandelup, but significantly higher than Tanjil when metribuzin was applied. Seed yield of two mutants was comparable to Tanjil at regional sites in the absence of metribuzin. Both Tanjil-AZ-33 and Tanjil-AZ-55 showed high level of resistance to anthracnose in the disease nursery.

AIMS

- To evaluate seed yield of metribuzin-tolerant mutants against leading cultivars in the presence or absence of metribuzin.
- To assess anthracnose resistance of the mutants.

METHOD

Two mutant lines (Tanjil-AZ-33 and Tanjil-AZ-55) were compared with cultivars of Tanjil and Mandelup for seed yield in the presence or absence of metribuzin and anthracnose resistance. For measurement of seed yield in the presence of metribuzin, the four varieties were sown on 26 May 2006 in Shenton Park Field Station of UWA in a randomised block design with 4 replicates. The plot size was 3.6 m^2 (1.5 x 2.4) with a seeding rate at 50 seeds/m^2. Metribuzin at 300 g/ha was applied on 7 July 2006 to 6-8 leaf stage lupin plants with boom spray fitted on a motorbike with output of 72 L/ha. Scores of herbicide damage were recorded at 3 weeks after spray. Plants were grown with irrigation to supplement low season rainfall. Plants of each plot were harvested by hand on 4 December 2006, threshed by machine and seed yield obtained.

For seed yield measured in the absence of metribuzin at regional sites, trial preparation and management was the standard of field evaluation of breeding materials by the lupin breeding program.

Anthracnose resistance screening was conducted in the disease nursery at the Medina Research Station and followed the same protocols as used to screen all the breeding material from the Lupin breeding program.

RESULTS

Seed yield

Seed yield of mutant line Tanjil-AZ-33 was 4.23 t/ha under irrigation, very close to that of Mandelup, but more than twice that of Tanjil when they were subject to metribuzin at 300 g/ha during 6-8 leaf stage (Table 1). Both mutant lines showed no leaf damage from metribuzin at 3 weeks after application whilst Tanjil was severely damaged.

Seed yield of these two mutants lines were comparable to Tanjil at Merredin, Wongan Hills and Badgingarra in the absence of metribuzin (Table 2).

Anthracnose resistance

The mutation process did not alter the anthracnose resistance as the mutant lines had the same level of resistance as Tanjil. The mutants were highly resistant to anthracnose in disease nursery at Medina with scores of 6.5 and 7, similar to Tanjil (Table 2).

Table 1. Seed yield of metribuzin tolerant mutants subject to 300 g/ha metribuzin in the field at Shenton Park in 2006

Genotype	Seed yield (t/ha)	Visual damage score against metribuzin[A]
Tanjil-AZ33	4.23	0
Tanjil-AZ55	2.62	0
Tanjil	1.86	3
Mandelup	4.63	0
lsd (P < 0.05)	*1.19*	

[A] Damage score against metribuzin with 0 = no symptom, 3 = most plants had scorch on first 6 leaves and 5 = plant dead.

Table 2. Anthracnose resistance and seed yield (t/ha) of mutant lines in the absence of metribuzin at regional sites in 2006

Variety	Anthracnose resistance score[A]	Badgingarra	Merredin	Wongan Hills
Mandelup	6	1.14	1.38	1.52
Tanjil	7	1.08	1.12	1.29
Tanjil-AZ-33	6.5	1.05	1.01	1.26
Tanjil-AZ-55	7	0.99	0.99	1.27

[A] Disease resistance was evaluated in disease nursery at Medina Research Station in 2006. 1 = plants severely damaged, 9 = plants immune.

DISCUSSION

The field trial at Shenton Park demonstrated that in the presence of metribuzin the yield of the mutant line Tanjil-AZ-33 was comparable to Mandelup, whereas the yield of Tanjil was reduced to half that of the mutant line. This line has similar seed yield to Tanjil in the absence of metribuzin and also the high level of anthracnose resistance as Tanjil. These facts indicate that the mutation process has not altered Tanjil's yield capacity and anthracnose resistance, but has substantially improved its metribuzin tolerance. Tanjil-AZ-33 proves to be a valuable addition to the breeding program. It holds the promise to be released directly as a cultivar, but that requires further evaluation of seed yield and quality traits.

The two mutants (Tanjil-AZ-33 and Tanjil-AZ-55) of Tanjil origin showed consistent tolerance to metribuzin in the field as well in the glasshouse (Si *et al*. 2006). It is expected that they would yield higher than Tanjil at high rate of metribuzin. As they both have similar yield as Tanjil in the regional trials, the low yield of Tanjil –AZ-55 at Shenton Park could be site-specific with irrigation. Therefore, this mutant still holds the potential to be further evaluated at different regions.

KEY WORDS

lupin, herbicide tolerance, anthracnose resistance, seed yield, mutation breeding

ACKNOWLEDGMENTS

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Project No.: UWA 00097

Paper reviewed by: Tanveer Khan

The effect of herbicides on nodulation in lupins

Lorne Mills[1], Harmohinder Dhammu[2] and **Beng Tan[1]**, [1]Curtin University of Technology and [2]Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Propyzamide and DOW-1 significantly reduced the dry weight of nodules in Tanjil.
- Nodule mass was correlated to foliage and root mass in most of the comparisons, but not with total nitrogen content of the foliage.
- Yield was significantly correlated to nodule dry weight in Tanjil only.

AIM

To evaluate whether herbicides reduce nodulation in lupins, as lupins being a leguminous crop contribute some biologically fixed nitrogen to the succeeding cereal crop in rotation.

METHOD

Two narrow leafed lupin varieties (Tanjil and Mandelup) were sown on 3 July 2006 at the Wongan Hills Research Station on a shallow sandy duplex soil in 3 m x 10 m plots replicated three times. The herbicide treatments (Fig 1) were applied randomly before crop seeding (BS), immediately post planting (IPP), 2, 4, 6 and 8 leaf stage on 2 July, 3 July, 1 August, 8 August, 18 August, and 25 August 2006, respectively. Basal Simazine at 2 L/ha was applied to all treated plots except for the diuron and DOW-1 treatments.

The key months for rainfall were markedly lower in May, June and July, and it did not rain significantly enough to begin seeding until the 28 June. After the trial was seeded (3 July), there was no significant rainfall until 25 July when 9.6 mm precipitation was recorded. (Note: Only 5.4 mm rainfall was recorded between the two July dates.)

The trials were sampled at the budding stage on 6 of September, 65 days after seeding (DAS), and then at the beginning of pod formation stage on 5 October, 94 DAS. Five representative plants were visually selected and dug from each plot. The nodules were then cut from the roots, and the foliage was separated from the root portion of each plant. A sub sample of 5 nodules were selected from each plot sample for dissected to determine if the nodules were biologically effective (pink = effective, green = ineffective). All portions were placed in the oven at 60°C for at least 48 hours, and then weighed afterwards. Foliage samples taken at 94 DAS were tested for total nitrogen content using a Near Infra-Red machine, and the Kjeldahl Method.

RESULTS

Samples taken 65 DAS showed no significant differences between the dry weights of nodules of two lupin varieties ($\alpha = 0.05$, $p = 0.433$) in the untreated control plots. Propyzamide significantly reduced the dry weight of nodules in Tanjil (58.2%). Simazine 4 L/ha and Brodal® + Lexone® + simazine also caused more than 40% reduction in Tanjil nodule weight, but marginally missed the level of significance ($\alpha = 0.05$, lsd = 44.0%). Sub-sampled nodules were found to be effective in all plots.

Samples taken 94 DAS also showed no significant difference in nodule dry weight between Tanjil and Mandelup ($\alpha = 0.05$, $p = 0.511$). Only DOW-1 reduced Tanjil nodule weight significantly (60.7%) as compared to its control. Nodules were found to be effective in all plots.

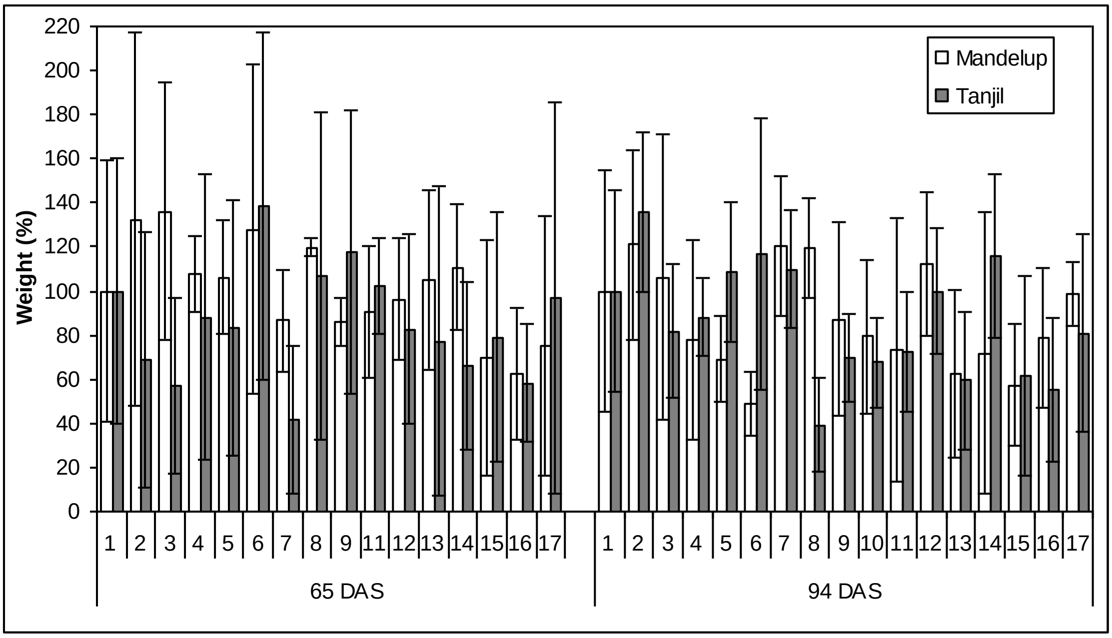

Figure 1. Comparison of nodule weights 65 DAS and 94 DAS. (Note: Data has been scaled so that both control groups equal 100%.) Treatments: 1 - Control, 2 - Simazine 2 L, 3 - Simazine 4 L, 4 - Diuron 3 L, 5 - Simazine 2 L + Atrazine 1 L, 6 - Diuron 1 L + Lexone® 133 g, 7 - Propyzamide as Edge® 2 kg, 8 - DOW-1 150 g, 9 - Brodal® 200 mL, 10 - Sniper® 50 g, 11 - Lexone® 150 g, 12 - Lexone® 250 g, 13 - Brodal® 100 mL + Lexone® 100 g, 14 - Brodal® 100 mL + Eclipse® 6 g, 15 - Brodal® 100 mL + Simazine 500 mL, 16 - Brodal® 100 mL + Lexone® 150 g + Simazine 500 mL, 17 - Eclipse® 10 g/ha. Timing 1-6 BS, 7 IPP, 8-12 at 2 leaf, 13-15 at 4 leaf, 16 at 6 leaf and 17 at 8 leaf stage. Analysis of the nitrogen tests found no significant differences between the herbicide treatments or varieties except Sniper® reduced total nitrogen content by 8.0% in Mandelup compared to the control. Further the correlation between nodule dry weight and total nitrogen for each variety was not significant (Table 1).

Table 1. Correlations of nodule dry weight compared to foliage dry weight, root dry weight, total nitrogen and yield at 65 DAS and 94 DAS

Sampling time	Variety	Comparison	Correlation	Significance	r (a = 0.05)
65 DAS	Mandelup	Nodule vs Foliage	0.221	NS	0.245
		Nodule vs Roots	0.27	S	
	Tanjil	Nodule vs Foliage	0.646	S	
		Nodule vs Roots	0.551	S	
65 DAS	Mandelup	Nodule vs Yield	0.04	NS	0.254
	Tanjil	Nodule vs Yield	0.319	S	
94 DAS	Mandelup	Nodule vs Foliage	0.495	S	0.245
		Nodule vs Roots	0.485	S	
	Tanjil	Nodule vs Foliage	0.553	S	
		Nodule vs Roots	0.526	S	
94 DAS	Mandelup	Nodule vs Nitrogen	-0.042	NS	0.285
	Tanjil	Nodule vs Nitrogen	-0.252	NS	
94 DAS	Mandelup	Nodule vs Yield	0.23	NS	0.291
	Tanjil	Nodule vs Yield	0.406	S	

Nodule dry weight in Tanjil was significantly correlated with foliage and root dry weights 65 DAS. However, nodule dry weight in Mandelup was only significantly correlated with root dry weight. Nodule dry weight for both Tanjil and Mandelup were correlated with the dry weight of foliage and roots of the same variety 94 DAS. Foliage and roots appeared to have the strongest correlation for both varieties at 65 DAS and 94 DAS. Yield was significantly correlated with dry weight of nodules in Tanjil only (Table 1).

DISCUSSION AND CONCLUSION

Overseas research has indicated that herbicides can adversely affect the efficiency of legume-rhizobium symbiosis in leguminous plants. This particularly so for the nodulation processes and nitrogenase activity. Previous research with triazine herbicides have discovered that the detrimental effects are due to a decreased supply of photosynthates to the roots rather than to direct effects on nodulation and nitrogen fixation (Bertholet and Clark 1985; DeFelipe *et al*. 1987 and Kao and Wang 1981). Contrary to this, in the present study, two or three way mixes of Lexone® with Brodal® and or simazine caused significant reduction in foliage and root dry weight both in Mandelup and Tanjil 65 DAS, but there was no significant effect on dry weight of nodules.

The rainfall pattern in 2006 season was unusual compared with previous years. The late start of the season, coupled with the lack of rain within the few weeks after seeding could have possibly negatively affected the establishment and growth of the lupins, the amount of nodulation, and also the amount of herbicide activity. Previous research has shown that soybean injury from metribuzin application increased as the level of simulated rainfall increased. It was inferred that an increase in herbicidal activity with an increase in moisture content would certainly be expected with metribuzin having a solubility of 1220 ppm (Coble and Schrader 1973; Bertholet and Clark 1985).

It was hypothesised that the application of herbicides will decrease the amount of nodulation. This was found to be partially correct, as some herbicide treatments did in fact significantly decrease nodulation. However, it was also found that some treatments increased it. Reasons for this was possibly due to some infestation of weeds pressuring lupins in the control plots, and because of the high amount of variation within the results due to unusual weather conditions (Figure 1). So overall the data did not show as many statistically significant differences as first anticipated.

In future, to make it more practical to assess, the trial should have smaller plots with less treatments, and more samples should be taken per plot (around 10 or more). This would also make it more practical to weed the plot on a regular basis. Because the weather conditions during this trial did not represent the patterns of a ‘normal’ growing season, the trial should be run over several years in order to take such variability’s into account.

KEY WORDS

herbicide, nodule, lupin, nitrogen

ACKNOWLEDGMENTS

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Project No.: DAW 0134

Paper reviewed by: Dr Peter White

Effects of fertiliser placements and watering regimes on lupin growth and seed yield in the central grain belt of Western Australia

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KEY MESSAGES

- Irrigation increased lupin dry weight and seed yield, and the 10 mm/week irrigation was more efficient than the 40 mm/4 weeks despite the same amount of water being applied in both cases.
- The yield increase by irrigation was largely due to an increase in the number of lateral pods and seed size.
- Placing fertilisers either shallow (7 cm), deep (18 cm) or splitting (half of the amount at each depth) had small effects on growth and seed yield in the dry 2006 season.
- There was no interaction between fertiliser placement and irrigation, indicating that reduced availability of the topsoil nutrients in a dry season may not be a major factor limiting lupin yields.

AIMS

In the low to medium rainfall zones of Western Australia, surface soil layer dries out rapidly between rains, particularly late in the growing season; consequently, nutrient uptake by plants from the dry but nutrient-rich topsoil may be restricted. This may have adverse effects on lupin yields as this species is more dependent on nutrient uptake late in the season for grain filling compared with cereals. The 2006 field trial at Corrigin examined the effects of fertiliser placement on lupin growth and seed yield in the rain-fed crops and those supplemented with 10 mm of irrigation/week or 40 mm/4 weeks, simulating three season types (rain-fed, frequent small rain events, less frequent but bigger rain events).

METHOD

Field site and growing conditions

The trial site was located near north of Corrigin (mean annual rainfall of 355 mm and mean May to October rainfall of 253 mm). A pre-sowing survey of the site in early 2005 (prior to the first season of trials) showed the following extractable nutrient levels (mg/kg): 26 P, 54 K and 18 S at 0-10 cm; 7 P, 22 K and 8 S at 10-20 cm; and 5 P, 39 K and 4 S at 20-30 cm. Soil pH ca was 5.0 at 0-10 cm, 4.7 at 10-20 cm and 5.4 at 20-30 cm, i.e. a minimal effect of soil acidity. Soil bulk density (g/cm^3) was 1.01 at 0-10 cm, 1.51 at 10-20 cm, 1.71 at 20-40 cm, 1.94 at 40-60 cm and 2.01 at 60-80 cm.

Trial treatments

Narrow-leafed lupin cv. Mandelup was sown on 2 June 2006. The trial had four fertiliser placements (nil fertiliser, shallow – 7 cm, deep – 18 cm or split with half at each depth). The rates of fertilisers (kg/ha) at sowing were 19.3 P, 10.9 K, 15.9 S, 0.2 Cu and 0.3 Zn. Drip irrigation was applied from early August to mid October. It was a split-plot design, where the watering treatments (rain-fed, 10 mm/week or 40 mm/4 weeks) were allocated to main plots and the fertiliser placements to subplots in three blocks, totalling 36 plots. Each plot had an area of 1.4 m by 27 m and comprised eight rows at a row space of 17.5 cm.

Measurements

A weather station was installed at the field site, recording daily rainfall over the growing season. Soil water content (w/w) at the fertiliser depth of three watering treatments was measured by taking soil cores (diameter 5 cm) at 0-5, 5-10, 10-15, 15-20, 20-25 cm before each application of 40 mm/4 weeks was due.

Plant densities of all 36 plots were recorded at 39 days after sowing (DAS). Dry weight of plant tops was measured by cutting 30 plants/plot at 39 and 60 DAS, and four 0.18 m^2 quadrats/plot at 82, 102 and 126 DAS. At 165 DAS, 20 plants/plot were randomly taken for recording the number of pods on the main stems and branches, seeds per pod and average seed weight, followed by machine harvest of each plot for grain yield.

RESULTS

As shown in Figure 1 the month of May (prior to sowing) had a rainfall of 10.2 mm, and it was dry in the early (sowing to late July) and late growing season (mid September to final harvest). In contrast, 73.6 mm rainfall was recorded from late July to mid September, which was equivalent to 84% of total rainfall (87.5 mm) over the whole period of plant growth. In addition to rainfall, the 10 mm/week plots were irrigated 12 times between August and October, while the 40 mm/4 weeks plots were irrigated three times over the same period. The two irrigation treatments had the same amount of water applied (120 mm), despite different watering schedules. It was expected that the 10 mm/week irrigation would wet the surface 10-cm soil weekly, compared with monthly wetting to greater depth by 40 mm/4 weeks. At the depth of 0–10 cm, soil water content in the end of the 40 mm/4 weeks cycle was similar to the rain-fed plots (5.8% in mid season, 2% in late season), but higher in the 10 mm/week plots (6.5% in mid season, 3% in late season). At 10–25 cm, both irrigated plots had higher soil water contents than the rain-fed plot in mid season, whereas the 10 mm/week plot was wetter than the rain-fed and 40 mm/4 weeks plots in the late season.

The shallow and split fertiliser placements induced early growth vigour (39 DAS), and the plants with the deep placement caught up at the next harvest (60 DAS). All fertiliser placements, including the control, had similar shoot dry weight at 82 and 102 DAS, compared with less dry weight of the control at 126 DAS and final harvest (Figure 2a). Irrigation treatments started at 60 DAS, but the irrigation effects on growth were not evident until 126 DAS and final harvest. Plants treated with 10 mm/week irrigation produced more dry weight than did the 40 mm/4 weeks (Figure 2b). There was no interaction of fertiliser placement with irrigation for shoot dry weight over the growing season.

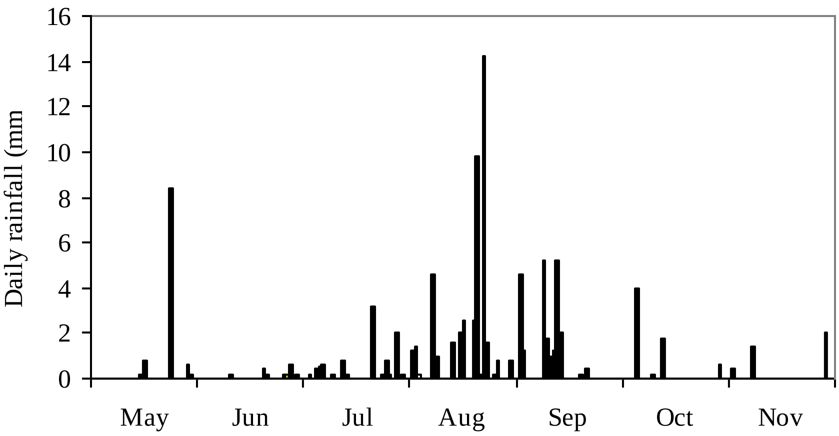

Figure 1. Daily rainfall in the 2006 growth season at Corrigin.

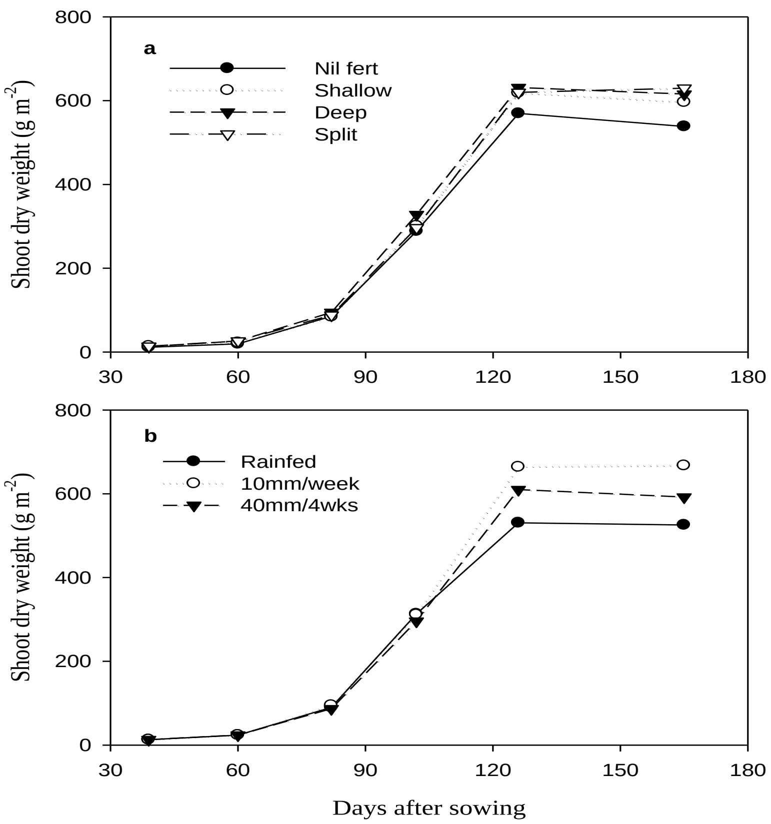

Figure 2. Growth response of narrow-leafed lupin cv. Mandelup to fertiliser placements (a) and watering regimes (b). There was no significant interaction of placement with water.

Yield components were significantly influenced by three watering treatments but not by fertiliser placements. Compared with the rain-fed plots, the irrigated plots increased seed yield by increasing pod number on the branches and seed size, but not pod number on the main stems or seed number per pod (Table 1). Moreover, the 10 mm/week treatment had higher seed yield than the 40 mm/4 weeks treatment. No interactions of fertiliser placement by water treatment were found for yield components and seed yield.

Table 1. Yield components of narrow-leafed lupin cv. Mandelup treated with four fertiliser placements and three watering regimes. There were no interaction effects

Treatment	Main stem pods ($/m^2$)	Branch pods ($/m^2$)	Seed number (/pod)	Seed size (mg)	Seed wt (g/m^2)
Rain-fed	225	182 c	3.5	126 c	187 c
10 mm/week	220	326 a	3.4	144 a	238 a
40 mm/4 wks	197	277 b	3.5	131 b	212 b
Nil fertiliser	194	253	3.4	136	212
Shallow	218	267	3.5	133	213
Deep	247	256	3.5	133	216
Split	196	273	3.5	131	211

In the watering treatments, means with different letters were different at $P = 0.05$.

CONCLUSION

The 2006 lupin trial in Corrigin had three watering regimes for simulating three season types. Irrigation increased shoot dry weight and seed yield, and the 10 mm/week irrigation produced more dry weight and yield than the 40 mm/4 weeks. This was probably because the weekly irrigation had maintained the fertiliser depth (0–25 cm) moist and thus would have increased nutrient uptake by

plants. The yield increase was obtained with an increase in pod number from the branches and increased seed size, but without effects on pod number on the main stems and seed number per pod. Hence, the irrigation enhanced branch growth and pod set, and grain filling in terminal drought. The non-responsive fertiliser placement and the lack of placement-by-water interaction in the trial may suggest that fertiliser placement does not play a major role in lupin growth and yield under very dry conditions.

KEY WORDS

lupins, fertiliser placement, irrigation, plant growth, grain yield

ACKNOWLEDGMENTS

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Development of a forecasting model for Bean yellow mosaic virus in lupins

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BACKGROUND

Narrow Leafed Lupin (*Lupinus angustifolius*) is an important grain legume crop for the Western Australian grainbelt with up to 1.0 million hectares sown annually. Bean yellow mosaic virus (BYMV) is an aphid borne virus which can result in significant yield loss. We are developing a risk forecasting system for the BYMV-lupin pathosystem in order to help growers determine the necessity of control methods in any given season.

AIMS

- Develop an effective risk forecasting system for BYMV in lupins.
- Provide these forecasts in a timely manner via a web-based delivery system.
- Allow growers to determine the necessity of applying control measures.

METHOD

Forecasting models for ‘green-bridge’ diseases, such as the disease BYMV causes, rely on daily temperature, rainfall and evaporation data to function effectively. Generally, the input of this data is a time consuming exercise. As such forecasts generally focus on large areas, and are not run regularly. We have developed a framework which has allowed the automation of this data retrieval, facilitating higher resolution forecasting on a much shorter timescale. The first model under development which utilises this framework forecasts Bean Yellow Mosaic Virus (BYMV) risk in lupin crops.

BYMV is a non-persistently aphid-borne virus. It principle reservoir is infected sub. clover pastures in which it survives over summer, and is seed transmitted. Infection of crops relies on the presence of a BYMV-infected pasture adjacent to the lupin paddock, and an aphid population sufficient to spread the infection.

Our model consists of four sub models:

- A greenness model, which utilises meteorological data to estimate pasture capacity for aphid populations.
- A ‘background’ aphid model, which uses this information from the ‘greenness’ model to estimate the numbers of aphids present in the adjacent pasture.
- A ‘crop’ aphid model, which relies on the ‘background’ aphid model producing emigrant aphids, providing an initial population for the crop aphid model.
- A crop infection model, which uses background/crop aphid levels to estimate the number of infective aphids present within the crop throughout the year, allowing us to forecast of expected crop infection levels.

The greenness sub-model utilises daily temperature, rainfall and evaporation data to determine the greenness level. Temperature determines the increase rate of greenness using an inverse polynomial function (Figure 1A.). Rainfall and evaporation are used to determine the fraction of plant available water, which is then used to calculate the maximum capacity of greenness using a sigmoidal function (Figure 1B.).

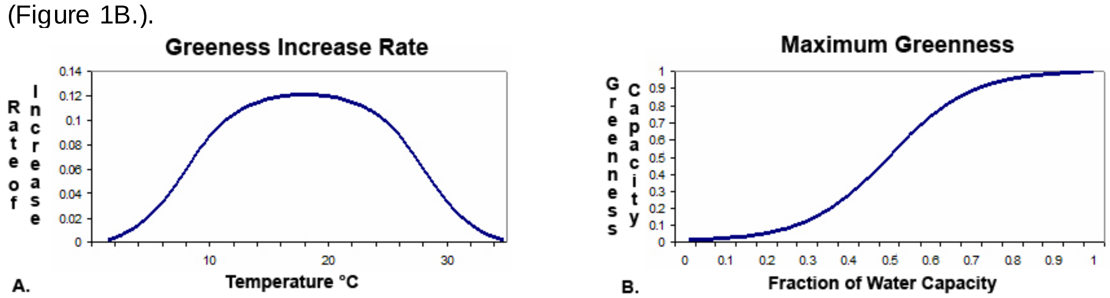

Figure 1: A. Function used to determine greenness increase rate, B. Function used to determine greenness capacity

The greenness level is then used to limit the number of aphids which may be supported. The increase rates of the aphid populations are dependent on temperature (Dixon, 1997). Aphids migrate from the pasture into the crop in a density dependent manner.

Infection is brought into the lupin crop via infective aphids, with the probability an aphid is carrying BYMV dependent on the level of greenness and the location being modelled. The non-persistent nature of the virus in its aphid host results in an 'edge-effect' on infection in the crop, as shown in Figure 2 (Jones, 2005). As a result of this the populations of lupins and aphids are divided into 'perimeter' and 'interior' populations. Aphids travel from the pasture to the crop 'perimeter', then from the crop 'perimeter' to the crop 'interior'. The probability that an aphid moving from the pasture to the 'perimeter' is infective is determined by the greenness and location of the pasture, and the probability that an aphid moving from the 'perimeter' to the 'interior' is infective is determined by the infection level of the 'perimeter'.

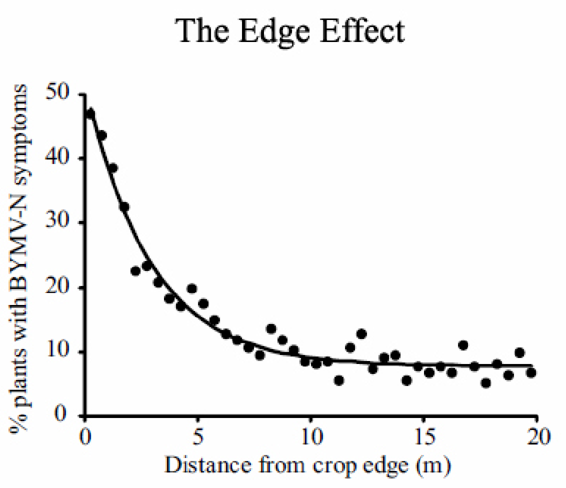

Figure 2: The edge-effect of crop infection caused by the non-persistent nature of BYMV in its vector

Once a plant has been infected with BYMV there is a period before the infection becomes systemic, after which the plant can act as a viral source before it dies. Every day the plant is infected and remains alive its potential yield is decreased.

The infection levels of the 'perimeter' and 'interior' crop populations are combined to provide an infection level/yield loss prediction for the location being modelled.

In order to provide seasonal forecasts we need to implement some form of predictive modelling. To do this we utilise an archive of over 50 years meteorological data. By taking the meteorological data for the season to date (e.g. Jan., Feb., Mar.), and filling the remaining months with data from a year in the archive (e.g. Apr., May, Jun., Jul., Aug., Sept., Oct., Nov., Dec.,) we can create a 'model year' of data with which to base our analysis. We create a 'model year' for every year in the database and run the model on each. From this set of ~50 results we select our 'best-case', 'most-likely', and 'worst-case' forecast scenarios. These scenarios are presented as maps of infection risk/potential yield loss for the grainbelt of Western Australia.

DISCUSSION

The sub-models used in our forecasts are currently being validated with observed data (trial and survey data) collected in previous years. Validation should be completed in time to allow for a forecast for the 2007 growing season. The risk maps will be available online from the Department of Agriculture and Food's website (http://www.agric.wa.gov.au).

ACKNOWLEDGMENTS

We thank Australian Research Council for the funding through an ARC-Linkage project (LP0560884), and also The Department of Agriculture and Food, Western Australia for additional funding.

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Manufacturing of lupin tempe

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BACKGROUND

Lupin has been cultivated in different parts of the world for many centuries. Western Australia today leads the world in its production and export. For the lupin industry to be sustainable the farm gate value of lupin needs to be increased. One way of achieving this end is to develop new and innovative applications for it as a food or food ingredient. Until to now lupin has been used predominantly as an animal feed. Food applications for lupin appear limited even though research has been carried out in the past on its use as a food ingredient.

Tempe is a traditional Indonesian fermented food product that is normally made with soybean by fermentation by Rhizopus mould species. Lupin tempe manufactured with a selected micro-organism capable of fermenting lupin showed similar consumer acceptability to that of soy tempe.

AIMS

- To develop an inoculum for the fermentation of lupin tempe.
- To develop a fermentation technique for the manufacture of lupin tempe.

METHOD

Traditional and branded inoculums were collected from different parts of Indonesia. Moulds from the collected samples were isolated and typical colonies were picked and re-inoculated until a pure culture was obtained. From the isolated micro-organisms an inoculum was selected based on optimum lupin fermentation. Previous studies had shown that the lupin tempe deteriorated faster compared to soy tempe developing an ammonia odour. The reason for such a fermentation characteristic was thought to be the lack of fermentable sugars in lupin as compared to soy bean. To overcome this different fermentation aids were added. The effects of fermentation aids tapioca, $CaSO_4$ and glucose at different concentrations on tempe manufacturing were investigated.

Lupin was mixed with soybean at 0, 20, 30, 40, 50, 60, 80 and 100%. Mycelia growth was evaluated at 24 hour intervals for 72 hours to determine the mould growth. The consumer acceptability of lupin tempe and soybean tempe samples were evaluated with using 80 untrained panellists. The study was conducted in Indonesia. The physico-chemical and microbial changes during the fermentation were also determined. Firmness of tempe samples was measured by a Mechanical Fruit Firmness Tester FT 323 (QA supplies, LLC. Virginia). Mycelia growth and colour were assessed visually by a trained panel of judges and scored on a scale of 1 (very poor) to 10 (excellent).

RESULTS

A total 17 tempe mould types were isolated and identified. The majority of the moulds were *Rhizopus oligosporus* and *Mucor* sp. The results indicated that the lupin fermentation ability and the tempe quality of the inoculum IIIUWS1 was better than all the other inoculums. As a result, inoculum IIIUWS1 was selected for lupin tempe manufacturing.

All tempe samples had good quality until the second day. On the third day the quality of the lupin tempe changed significantly.

The addition of 2-4% tapioca and 0.5% glucose in to the lupin enhanced the rate of microbial growth.

Figure 1, shows the change in moisture content, firmness and microbial growth at different lupin inclusion rates after 72 hours of fermentation. With an increase in the lupin content the microbial growth and firmness decreased and the moisture content increased. The Indonesian Industry

Standards for soy bean tempe states that it should have a maximum moisture content of 65%. Lupin:soy bean ratio of 60:40 achieved a moisture content of less than 65% and a firmness of 3.38-3.53 (kg) which is similar to soy bean tempe.

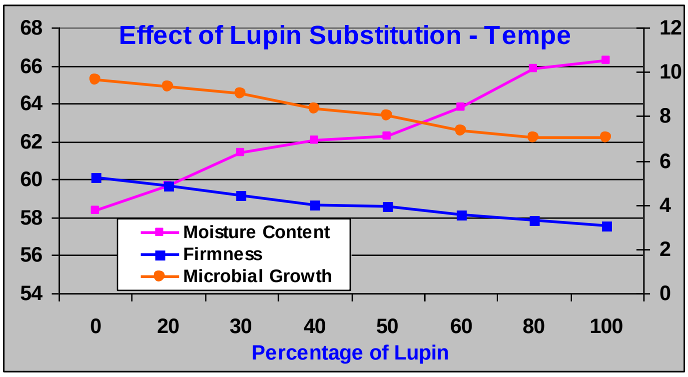

Figure 1. **Effects of soy bean substitution on lupin tempe after a 72 hour fermentation.**

Five different lupin, lupin-soy and soy tempe samples were selected for sensory evaluation (Table 1). The panel consisted of 80 untrained members selected from the Indonesian general public. The attributes evaluated were appearance, taste, texture and overall acceptability. A nine point hedonic scale test with 1 = Dislike extremely to 9 = Like extremely was used in the study. The results for the different attributes are shown in Table 1.

Table 1. **Sample used in the sensory evaluation and results**

Soy (%)	Lupin (%)	Tapioca (%)	Appearance	Taste	Texture	Overall acceptability
0	100	4	6.6	6.4	6.5	6.4
40	60	0	6.7	6.7	6.7	6.6
40	60	2	6.4	6.6	6.7	6.8
40	60	4	6.9	6.7	6.7	6.8
100	0	0	6.8	6.8	7.0	6.8

The sensory scores for lupin tempe with 40% soy bean and 4% tapioca added were very similar to the standard soy tempe indicating the panellists could not detect a significant difference.

CONCLUSIONS

- The developed inoculum is capable of fermenting lupin for the manufacture of lupin tempe.
- Lupin tempe with similar quality characteristics to standard soy tempe can be manufactured up to 60% lupin incorporation.
- Addition of tapioca at 2-4% improved the lupin tempe quality by increasing the rate of microbial growth.

KEY WORDS

lupin, tempe, lupin tempe, soy bean

ACKNOWLEDGEMENTS

Authors wish to thanks the Grain Foods CRC for the financial support, Curtin University of Technology and Indonesian Institute of Sciences for the in-kind contributions.

The impact of lupin based ingredients in ice cream

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KEY MESSAGES

- Defatted lupin flour and lupin protein isolates were incorporated into ice creams to replace either 100% or 50% of egg and skim milk powder in the ice cream formulation. Defatted lupin flour fortified ice creams were deemed unacceptable due to the presence of strong unpleasant flavours but ice creams containing lupin protein isolate did not significantly differ to the control ice cream with respect to sensory characteristics. Some differences in physical and chemical characteristics were demonstrated. This study showed that lupin protein isolates can be incorporated into ice cream formulations without compromising sensory, chemical or physical quality.

AIM

To determine the impact of the addition of defatted lupin flour or lupin protein isolates on physical, chemical and sensory properties of ice cream when compared to a control ice cream formulation.

METHOD

Defatted lupin flour was obtained from Weston Milling. Lupin protein isolates were extracted from defatted lupin flour using alkaline extraction followed by isoelectric precipitation, as described by Chih (2004). Defatted lupin flour and lupin protein isolates were analysed for moisture and protein content immediately before ice cream making.

Ice cream was produced using the Scoop Factory Ice Cream and Frozen Dessert Maker, model ICM10, Breville. Defatted lupin flour or lupin protein isolates were incorporated into ice cream formulations at either 100% or 50% replacement of egg and skim milk powder in a standard ice cream formulation (Control). Five types of ice cream were produced in total (Table 1).

Table 1. Ice cream formulations

Ingredients	Control	Lupin flour (100%)	Lupin flour (50%)	Lupin protein Isolate (100%)	Lupin protein Isolate (50%)
Cream (mL)	416.7	416.7	416.7	416.7	416.7
Sugar (g)	104.2	104.2	104.2	104.2	104.2
Vanilla essence (mL)	2.1	2.1	2.1	2.1	2.1
Skim milk powder (g)	20.8	--	10.4	--	10.4
Egg (g)	50	--	25	--	25
Water (g)	104.2	139.0	121.5	87.8	96.1
Lupin Flour (g)	--	36.0[a]	18.0[b]	--	--
Lupin protein isolate (g)	--	--	--	69.6[c]	34.8[d]
TOTAL MIX	698.0	698.0	697.9	680.4	689.3

[a]Provides 3.5 g moisture and 12.9 g protein; [b]Provides 1.8 g moisture and 6.5 g protein; [c]Provides 54.3 g moisture and 12.9 g protein; [d]Provides 27.2 g moisture and 6.5 g protein.

Chemical analysis of moisture, fat and protein were carried out according to the Official Methods of Analysis of AOAC (AOAC International 1996) for ice cream and frozen dessert. Physical parameters measured were overrun, firmness, viscosity and ice crystal size. Overrun is a significant quality parameter in ice cream as it influences texture and colour of the ice cream:

$$\text{Overrun (\%)} = \frac{(\text{Weight of mix} - \text{weight of same volume of ice cream}) \times 100\%}{\text{Weight of same volume of ice cream}}$$

Firmness of ice cream was measured as the force used to penetrate the frozen samples to a depth of 20 mm at a speed of 2 mm/s, as carried out by Abd El-Rahman *et al*. (1997) using the TA.XT2i Texture Analyser (Texture Technologies Corp., USA). Viscosity of mix was measured using a Brookfield viscometer (Model DV-1, Brookfield Engineering Laboratories, Inc., USA) as described by Abd El-Rahman *et al*. (1997). Crystal size was measured using a micrometer (Model 147-103, Mitutoyo, Japan).

Fifty-four consumer panellists participated in the sensory evaluation. Only the Control, Lupin Protein Isolate (100%) and Lupin Protein Isolate (50%) ice creams were used in the sensory evaluation as the flavour and taste of Lupin Flour ice creams were found to be unacceptable by experienced sensory judges when evaluated during the production phase. The three ice creams to be presented to consumer panels were coded with random 3-digit numbers. Unstructured line scales were used to record panellists' impressions of colour, iciness, mouth-feel, firmness, sweetness, flavour, odour and overall acceptability.

RESULTS

The ice creams fortified with defatted lupin flour were excluded from the sensory evaluation due to their strong flavour. The flavours of these ice creams were described as 'beany', 'green grass' and 'soybean milk flavour'. Nevertheless, chemical and physical tests were carried out on the ice creams. Lupin flour (100%) had a significantly lower fat content ($P < 0.05$), higher total solids ($P < 0.001$), higher viscosity ($P < 0.001$) and greater firmness ($P < 0.05$) than the control. Lupin flour (50%) had a higher total solids ($P < 0.001$) and greater firmness ($P < 0.05$) than the control.

Ice creams containing lupin protein isolates were not significantly different in sensory characteristics to the control with respect to colour, iciness, mouth-feel, firmness, sweetness, flavour, odour and overall acceptability. Physical characteristics showed that whilst Lupin Protein Isolate (50%) had no significant difference to the control, Lupin Protein Isolate (100%) had significantly greater firmness ($P < 0.01$) and larger crystal size ($P < 0.01$) compared to the control. Chemical composition was not significantly different with respect to fat content between the control and test ice creams, but Lupin Protein Isolate (100%) had a higher protein content ($P < 0.05$) and Lupin Protein Isolate (50%) had a higher total solids content ($P < 0.01$) compared to the control.

CONCLUSION

One of the greatest limitations of adding lupin fractions into food products is the impact of flavour. In the present study, adverse flavours were not detected by consumer panellists in ice creams containing lupin protein isolates. However, the beany flavour in lupin flour fortified ice creams was distinct and did not blend well with the traditional ingredients used in ice cream. Further processing such as protein isolation is essential if lupin is to be used in foods such as ice cream. Future studies should focus on protein enrichment by increasing the concentration of lupin protein isolates in ice creams to different magnitudes. In addition, concurrent fat reduction could result in an exciting novel, functional frozen dessert which caters to the modern lifestyle.

KEY WORDS

lupin protein isolates, lupin flour, functional food, ice cream

ACKNOWLEDGMENTS

This project was supported by Curtin University of Technology, Weston Milling and the Chemistry Centre (WA)

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The acceptability of muffins substituted with varying concentrations of lupin flour

Anthony James, Don Elani Jayawardena and **Vijay Jayasena**, Curtin University of Technology, Perth WA

KEY MESSAGES

- Presently in Australia lupins are grown primarily to be used in animal feed. However their nutritional composition, being high in fibre and protein, warrants their inclusion to a greater extent as part of a healthy diet in humans. It remains important therefore to determine suitable food products to which lupin, in the form of lupin flour could be added without any loss in acceptability. Flour from Australian Sweet Lupin (ASL) (*Lupinus angustifolius*) was substituted for wheat flour at 5%, 10%, 20%, and 30% in the preparation of muffins. Physical tests revealed that substitution of up to 20% ASL did not affect height or volume compared to control wheat flour muffins; however moisture content was significantly higher in all lupin incorporated muffins compared to control muffins. Sensory analysis evaluation (n = 72) revealed that substitution with either 10% or 20% ASL resulted in a significant improvement in all sensory parameters compared to control.

AIM

To determine the maximum acceptable level of lupin flour substitution for wheat flour in muffins.

METHOD

ASL flour derived from *Lupinus angustifolius* (41% protein; 6.5% fat; 28% dietary fibre; less than 1% starch; 9% moisture) was from Irwin Valley Pty Ltd, Lumill Cereamex, Australia. Soft biscuit flour (wheat flour) was from Weston Milling, Western Australia. The standard control muffins contained 100 g wheat flour, 50 g sucrose, 20 g vegetable shortening, 72 g whole milk, 30 g beaten liquid egg, 5 g water, 8.5 g baking powder, 0.5 g baking soda, 2.3 g salt, 0.25 g SSL, 0.25 g sorbic acid, 3.5 g starch. Muffins containing ASL were substituted at 5%, 10%, 20%, 30% (w/w) for the wheat flour component of the muffins.

The muffins were prepared by combining the flour, sugar, baking powder, baking soda, starch, sorbic acid and salt manually for 1 min. The beaten liquid eggs, SSL, water and milk and vegetable shortening were mixed separately. The two mixtures were then combined and approximately 65 g of batter was used for each muffin. The muffins were baked in a preheated oven at 205ºC for 22 min.

The height of all muffins was measured by cutting the muffins into half and measuring the distance from top to bottom. The volume was determined using rapeseed displacement according to the approved method 10-05 (AACC 2000). Moisture content was determined using the AOAC Official Method 931.04 (AOAC, 1996).

Sensory analysis was conducted using 72 consumer panellists. The control and 5%, 10%, 20%, and 30% lupin muffins were presented coded using random 3-digit numbers. The panellists were asked to rate the muffins based on overall appearance (top crust shape, crust colour, crumb colour); texture (compressibility, crust tenderness, crumbliness at initial bite, crumbliness after chewing, crumb tenderness, mouth feel moistness, adhesiveness); taste, shape and overall acceptability. Acceptance testing was performed using a 9-point hedonic scale marked from 1 – dislike extremely to 9 – like extremely.

RESULTS

The results from the physical tests showed that muffins substituted with 5%, 10%, and 20% ASL were not different from control muffins for either height or volume, however substitution with 30% ASL resulted in a significantly reduced height and volume compared to control muffins ($P < 0.05$). Moisture content was found to be significantly higher across all concentrations of ASL substituted muffins compared to control muffins ($P < 0.05$).

Analysis of the sensory evaluation data (Table 1) revealed that the taste of the 5%, 10%, and 20% ASL substituted muffins was rated better than the control muffins ($P < 0.05$), however the taste of the 30% ASL substituted muffins were rated the same as the control muffins. The texture of the 10%, and 20% ASL substituted muffins was rated better than the control muffin ($P < 0.05$), however the texture of the 5%, and 30% ASL substituted muffins were rated the same as the control muffins. The shape of the 10%, 20%, and 30% ASL substituted muffins was deemed better than the control muffins ($P < 0.05$), however the shape of the 5% ASL substituted muffin was not different from control. In terms of overall appearance the 10%, 20%, 30% ASL substituted muffins were rated better than control muffins ($P < 0.05$), whereas the 5% ASL substituted muffin was not different from control for overall appearance. Finally all the concentrations of ASL substituted muffins were rated better in terms of overall acceptability than the control muffins ($P < 0.05$).

Table 1. Summary of sensory evaluation of lupin incorporated muffins. Shown are means ± standard error of hedonic ratings for sensory analysis from 1 = dislike extremely to 9 = like extremely. Values for lupin incorporated muffins that were significantly different from those obtained for the control muffins are indicated by * (P < 0.05)

	Taste	Texture	Shape	Overall appearance	Overall acceptability
Control	4.8 ± 0.1	4.9 ± 0.1	4.7 ± 0.1	4.2 ± 0.2	4.7 ± 0.1
5% ASL	5.4 ± 0.1*	5.2 ± 0.1	4.5 ± 0.1	4.6 ± 0.2	5.3 ± 0.1*
10% ASL	5.3 ± 0.1*	5.5 ± 0.1*	5.5 ± 0.1*	5.4 ± 0.2*	5.4 ± 0.1*
20% ASL	5.2 ± 0.1*	5.5 ± 0.1*	5.7 ± 0.1*	5.5 ± 0.2*	5.5 ± 0.1*
30% ASL	4.9 ± 0.1	5.2 ± 0.1	5.8 ± 0.1*	5.7 ± 0.2*	5.1 ± 0.1*

Overall from both sensory and physical data it appears that substitution of ASL up to 20% does not decrease the quality of muffins compared to control 100% wheat flour muffins. Rather substitution with either 10% or 20% ASL actually improved all sensory parameters compared to control, and resulted in a muffin with greater moisture.

CONCLUSIONS

Muffins represent a good food product to incorporate ASL without any deterioration of quality when incorporated up to 20% of the flour component. The improved sensory appeal of incorporation at levels of either 10% or 20% ASL coupled with the increased fibre and protein content of lupin flour compared to wheat flour represents an important opportunity for the use of ASL.

KEY WORDS

lupin flour, functional food, muffin

ACKNOWLEDGMENTS

This project was supported by Midwest Development Corporation, Curtin University of Technology and Grain Foods CRC.

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PULSES

Chickpea variety evaluation

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KEY MESSAGES

- Seed yield of chickpea varieties and lines were poor at most sites in 2006 due to low rainfall during the growing season, particularly in the northern cropping region.
- Sonali, Genesis 510 and Kyabra were the highest yielding chickpea varieties in 2006.
- The effort of breeding programs to improve ascochyta blight resistance is now evident in the new breeding lines being promoted to CVT/NVT trials from both National and WA programs.
- Advanced breeding lines (CICA0503, CICA0603, WACPEA2136 and WACPE2115) with improved ascochyta blight resistance and seed quality are showing potential in Western Australia (WA).
- The yield data must be viewed with caution as a large number of lines entered these trials for the first time. 2006 was an extra-ordinarily dry season with low yields at all sites excepting Bolgart where delayed sowing in early July makes it atypical of normal practices.

AIMS

- To evaluate the yield potential of chickpea varieties and pre-release lines across a range of regional environments in WA.
- To identify specific environments that chickpea varieties and pre-release lines are best targeted.

METHOD

Chickpea varieties and advanced breeding lines were evaluated for yield at five sites in 2006 (Mingenew, Carnamah, Dalwallinu, Bolgart and Merredin). Five other sites were planned, but were not planted due to poor moisture conditions at sowing (Morawa, Mullewa and Mukinbudin), or were not harvested due to drought (Coorow and Muresk). Evaluation included 11 varieties and 39 breeding lines. Breeding lines included in the National Variety Testing (NVT) trials can be identified by their 'CICA' prefix followed by a series of four numbers indicating the year of promotion to NVT ('06' for 2006) and entry number (01 to 10). Lines from the WA program have a prefix 'WACPE' followed by numbers. Trials were sown in field plots (generally 20 m long x 1.44 m wide) with three replications. Trials received the recommended fungicide management package for ascochyta blight. Plots were machine harvested to determine seed yield. Yield was analysed using REML methods, but results presented here are from preliminary analysis.

RESULTS AND DISCUSSION

The growing season rainfall was well below average through much of the State, particularly in the northern region where the majority of the chickpea variety trials were located. Poor moisture in autumn at Morawa, Mullewa and Mukinbudin prevented trials being sown, while lack of rain after sowing reduced crop growth at Muresk and Coorow where the trials could not be harvested. In general, the mean yield of trials were poor (< 600 kg/ha), except at Bolgart (1251 kg/ha) where mild spring conditions prevailed (Table 1). Disease pressure was low in 2006 and no ascochyta blight was recorded in these trials.

Genesis 510, Genesis 509, Genesis 836, Sonali and Kyabra produced the greatest yields of the commercial varieties (Table 1). Sonali was released for its partial resistance to ascochyta blight and chilling tolerance, and has been a consistently high yielding variety over the past few years. Genesis 510 has also been consistently high yielding in WA, has greater ascochyta blight resistance compared to Sonali and Genesis 836, and generally exhibits better adaptation and yield than Genesis 509. Sonali, Genesis 509 and Genesis 510 do not have seed quality as good as Howzat. Despite performing well in 2006, Kyabra has limited ascochyta blight resistance and was released specifically for production in southern Queensland. It is unlikely that Kyabra will produce profitable yields in southern Australian conditions under ascochyta blight pressure.

A number of breeding lines performed well compared to commercial chickpea varieties. The lines CICA0505 and CICA0503 are currently in seed production for potential release. However resistance of CICA0505 does not appear adequate in Western Australia. CICA0603 also performed extremely well at Carnamah and Merredin, but was not present at other sites. WACPEA2136 and WACPE2115 produced comparatively high yields across sites and have good ascochyta blight resistance, similar to Genesis 510. Based on these results and those from breeding trials in 2005 a few WACPE lines will be targeted for fast tracking; WACPE2115 is most likely to be one of them.

KEY WORDS

chickpea, Cultivar Variety Testing (CVT), National Variety Testing (NVT)

Table 1. Seed yields[1] (% Rupali) of chickpea varieties and breeding lines in CVT/NVT trials 2006 sowing dates in parentheses

Variety/line	Mingenew (1 June)	Carnamah (17 May)	Dalwallinu (18 May)	Bolgart (1 July)	Merredin RS (6 June)	Mean SY % Sonali
Sonali	276	452	501	1483	600	662
Flipper	75	78	84	69	86	78
Genesis 090	68	64	99	89	73	79
Genesis 508	82	47	80	86	75	74
Genesis 509	113	92	98	77	98	96
Genesis 510	117	89	115	101	106	106
Genesis 836	125	89	97	74	108	99
Howzat	118	75	89	85	82	90
Kyabra	103	50	134	104	95	97
Rupali	110	94	67	60	92	85
Yorker	88	67	82	82	71	78
CICA0603	-	109	-	-	126	118
CICA0505	116	96	101	111	118	108
99011-1007	-	103	-	-	113	108
97037-1465	121	110	72	115	107	105
99315-1130	120	94	119	80	104	103
98318-3007	109	76	117	105	103	102
WACPE2136	125	69	86	129	91	100
97020-1489	109	101	95	79	111	99
97020-1727	99	79	116	101	93	98
WACPE2115	123	83	91	89	105	98
97020-1351	111	98	104	82	96	98
98238-01V4050	-	101	-	-	94	98
CICA0503	112	71	89	118	94	97
97039-1415	113	87	91	100	92	97
97144-1118	118	87	93	87	99	97
99004-1203	118	90	83	102	82	95
97020-1488	112	86	89	91	97	95
97020-1561	97	96	95	77	112	95
WACPE2117	114	104	88	67	100	95
WACPE2133	121	83	106	68	93	94
WACPE2135	112	96	84	85	87	93
WACPE2138	-	70	-	-	115	93
WACPE2126	105	75	87	99	96	92

Table 1 continued …

Variety/line	Mingenew (1 June)	Carnamah (17 May)	Dalwallinu (18 May)	Bolgart (1 July)	Merredin RS (6 June)	Mean SY % Sonali
Sonali	276	452	501	1483	600	662
WACPE2116	117	79	99	72	93	92
WACPE2128	121	82	85	90	79	91
97020-1898	108	81	103	79	86	91
WACPE2120	94	76	97	75	97	88
98119-1-5	84	85	89	76	99	87
WACPE2132	105	72	80	80	94	86
97020-1893	97	84	95	58	98	86
WACPE2124	88	53	104	74	104	85
WACPE2119	110	82	69	65	94	84
WACPE2129	102	75	91	59	92	84
97020-1343	88	79	82	89	79	83
WACPE2113	80	68	99	80	89	83
98047-2-12	94	83	78	76	84	83
98346-1-4	87	72	86	84	81	82
WACPE2118	106	60	71	83	92	82
WACPE2121	99	54	76	85	93	81
WACPE2127	96	58	89	74	90	81
WACPE2123	106	55	73	72	89	79
WACPE2122	105	74	71	71	76	79
WACPE2130	87	70	67	63	84	74
WACPE2134	74	61	73	70	62	68
Mean site SY	287	364	456	1251	564	584
SED	25	46	45	212	59	
CV%	11	16	12	21	13	

[1] Seed yield of Sonali and mean site yield presented in kg/ha.

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Advanced breeding trials of desi chickpea

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KEY MESSAGE

- This trial will lead to the selection of 20-30 breeding lines with good yield potential, good quality seed and an ascochyta blight resistance that is greater than the current variety Genesis 836 for 2007 Crop Variety Testing (CVT).

BACKGROUND

The desi chickpea (*Cicer arientinum* L.) is well adapted to a range of fine textured soils of Western Australia and was readily adopted when introduced in the mid 1990s. The areas rose steeply to 80,000 ha in 1999 but with the outbreak of ascochyta blight epidemics it declined sharply and very little chick pea is now grown in the state. With the availability of more resistant varieties there are prospects of resurgence in the crop, but current resistant varieties are poorly adapted to Western Australia and their quality does not match the earlier releases (Sona and Heera) that were unfortunately very susceptible.

In 2005, a new breeding project based on an international partnership between DAFWA, CLIMA, ICRISAT (India) and COGGO was started with the aim of accelerating the development of ascochyta resistant, high quality varieties that are adapted to Western Australia. This paper reports the results from the 2006/2007 season of the advanced breeding lines developed to date through program.

AIMS

- To evaluate advanced breeding lines for yield, seed quality, ascochyta resistance and related agronomic characteristics.
- To select lines for inclusion in the stage 3 CVT trials in 2007.

METHODS

Seventy eight lines, including controls were sown in two replications using spatially balanced row-column design, at four sites. The sowing at Coorow, Dalwallinu and Merredin was on 30 May, 31 May and 1 June, respectively. However, due to the failure of rain, sowing at Bolgart was done very late on 29 June. All sites suffered from drought, but it was most noticeable at Coorow where herbicide sprays failed to control ryegrass. The Coorow site was abandoned due to poor growth and ryegrass infestation. Ascochyta blight was controlled through frequent fungicide sprays and only one plot of the variety Howzat at one site showed negligible amount of infection. The yield data from the remaining three sites were analysed using the statistical package ASREML.

RESULTS

Rainfall at all sites was well below average and plants were stressed throughout the growing season until August and September when significant rainfall allowed the crops to recover at all sites except Coorow. Dalwallinu was most affected by moisture stress, but Merredin also showed clear signs. Bolgart, despite being sown late, showed good growth and rapid development due to the higher rainfall. Failure of October rainfall hastened maturity at all sites. Grain yields were reasonable at Merredin and good at Bolgart, in spite of unusually unfavourable condition, indicating the robustness of desi chickpea in adverse conditions (Table 1). Twelve breeding lines yielded greater across the three sites than the highest yielding control, Sonali. Rupali and Sonali were the earliest flowering lines, but six breeding lines were also in the early flowering group. Sixteen lines flowered earlier than Genesis 836. Four lines matured earlier than the earliest maturing control, Rupali. Some very large seeded lines with attractive seed colour were also identified. All breeding lines showed more ascochyta resistance than Sonali and Rupali and only 3 lines showed less resistance than Genesis 836, indicating the effectiveness of our selection strategy for ascochyta resistance in the earlier stages of breeding. Six lines had a high degree of resistance, similar to Genesis 508, Genesis 509 and

Genesis 510. Preliminary selection has led to the identification of 20 lines with a desirable combination of ascochyta resistance and yield potential (Table 1). Most lines have acceptable seed size and their seed coat colour is better than Sonali. The data will be further examined to identify a few additional lines that may be promoted to the 2007 CVT trials.

KEY WORDS

chickpea, desi, breeding, ascochyta blight, resistance

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Table 1. Flowering score (Fs 1-9; 1 = earliest), maturity score (Ms 1-9; 1 = earliest), yield as % of site mean, seed coat colour (1-9; 9 = darkest, almost black), ascochyta blight reaction (Asco; 0-9, 0 = immune, 1 = most resistant and 9 = most susceptible) and selection score under ascochyta disease epidemic (SND; ascochyta levels as seen at podding stage, 0 = least desirable and 3 = most desirable). Asco and SND were recorded in a disease nursery at Medina and means are based on 3 replications.

Entry	Fs	Ms	Yield % of site mean			100SW	Seed colour	Asco	SND
			Bolgart	Dalwallinu	Merredin				
99-451A-WAD1	5	6	113	110	112	19.8	4.0	3.7	1.8
99-463B-WAD8	6	6	107	125	103	17.8	2.5	4.3	2.2
99-451A-WAD7	6	6	115	105	102	15.9	4.0	4.0	1.8
98244-WAD11	4	7	102	117	102	18.8	4.0	4.7	1.7
98341-WAD3	5	6	108	103	105	13.6	5.0	4.0	2.0
98170-WAD2	2	6	96	124	101	19.4	4.0	4.8	1.8
99-451A-WAD19	6	6	102	108	105	19.9	4.0	5.0	1.8
99207-WAD11	5	6	100	118	100	20.5	5.0	5.3	1.8
99-463B-WAD16	5	6	107	100	104	17.7	3.5	5.0	1.8
99207-WAD2	5	6	100	109	102	16.9	5.0	3.8	2.0
98341-WAD7	5	5	104	100	102	13.8	5.0	4.7	2.0
99186-WAD2	5	6	99	96	106	16.7	4.5	3.7	2.0
99315-WA3	5	7	101	104	101	13.4	3.0	4.8	2.0
99-432C-WAD4	2	6	103	103	97	18.1	4.5	5.0	1.7
98318-4-11	6	6	100	93	99	14.8	4.0	4.5	2.0
99-451A-WAD14	4	7	92	80	107	17.7	4.0	4.8	1.7
99-463B-WAD17	6	7	112	84	95	16.9	4.0	5.2	1.7
99-462A-WAD20	2	4	104	97	92	12.5	3.0	4.3	2.0
99-448B-WAD7	8	7	95	94	94	19.0	4.5	4.8	1.8
98244-WAD21	6	6	103	89	91	16.3	5.0	4.5	2.0
99-462A-WAD18	6	5	102	95	108	13.9	8.0	4.3	2.0
Genesis 510	4	6	108	113	98	14.3	5.0	4.0	2.3
Genesis 509	6	4	98	106	98	13.4	5.0	3.3	2.3
Genesis 836	5	6	103	98	103	15.6	4.0	5.8	1.3
Rupali	1	5	89	114	101	14.2	2.0	6.5	1.0
Sonali	1	6	100	102	106	16.0	6.0	6.7	0.0
Howzat	5	7	105	111	95	18.2	3.5	7.6	0.0
Mean site yield kg/ha			**1084**	**370**	**605**				
CV%			**13.0**	**14.8**	**13.2**				

Ascochyta resistance in chickpea lines in Crop Variety Testing (CVT) of 2006

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KEY MESSAGES

- Breeding for ascochyta blight resistance has been very effective and all WA entries show a level of resistance greater than the current resistant variety Genesis 836.
- The prospect for more releases of new ascochyta resistant varieties that are adapted to WA is very good in medium and long term.

BACKGROUND

Ascochyta blight (*Ascochyta rabiei*) is the most important disease of chickpea in Western Australia (WA) and it had a devastating effect on the chickpea industry. Resistance to ascochyta blight is therefore of utmost importance in new varieties. The WA breeding program places selection for ascochyta resistance as the top priority. Lines entering CVT have undergone several cycles of selection to ensure only those with a high level of resistance enter the trials. This paper reports results of two experiments that monitor ascochyta resistance in the CVT lines.

AIMS

- To monitor yield of desi chickpea lines entering CVT Stage 3 trials of 2006 under ascochyta blight epidemic.
- To monitor reaction to ascochyta blight in a disease nursery of all stage 3 and stage 4 Kabuli and desi chickpea entries of the 2006 CVT.

METHODS

All stage 3 CVT entries including controls were sown in 5 row, 10 m long plots with three replications in a randomised block design at Merredin on 1 June 2006 (Experiment 1). Four weeks after emergence a small amount of chickpea stubble infected with ascochyta blight was placed in the middle of each plot to initiate infection and to simulate natural spread of the disease as it occurs in a paddock situation. Disease is monitored periodically. At maturity, plots were harvested to obtain yield data.

All entries in the stage 3 and stage 4 CVT trials were sown in a disease nursery at Medina on 22 May 2006 (Experiment 2). One month after sowing infected stubble was liberally sprinkled over the entire nursery. Natural winter rainfall was supplemented with overhead watering if prolonged periods without rain occurred. Ascochyta reaction on each plot was recorded on 24 August 2006.

RESULTS

Merredin experienced prolonged dry conditions after sowing. Some good spring rainfall helped the crop but finishing rains failed and in general moisture stress was experienced at almost all stages. The ascochyta epidemic developed despite low rainfall but its severity declined a little due to lack of rains later in the season. The effect of drought made it difficult to make accurate disease assessment and therefore disease reactions were not recorded at Merredin. However, disease reactions were assessed in the Medina Disease Nursery (Table 1). Yields from the Merredin trial can be considered reasonable despite drought conditions. However, yields were quite variable and it is clear that ascochyta resistance had a big role to play. Almost all lines with ascochyta reaction 4 or less produced good yields. The ascochyta reaction amongst the top 10 highest yielding lines ranged from 1.4-3.5. Genesis 508 was, however, amongst the low yielding lines despite its high resistance to ascochyta blight. This may be due to its inherent low yield potential as seen in previous CVT trials and also due to its greater sensitivity to drought. Tyson, Heera and Sona, the susceptible lines, were the lowest yielding. Sona was almost decimated.

At Medina ascochyta blight development was severe and highly susceptible lines were almost dead before disease ratings were recorded. The results confirm that Genesis 508, Genesis 509, Genesis 510 and Kabuli variety Genesis 090 were amongst the moderately resistant lines. Flipper and Yorker, the NSW releases, showed less resistance than Sonali and Rupali. Both Rupali and Sonali were moderately susceptible. Kabuli lines Almaz and Nafice showed useful levels of resistance. It is interesting to note that many WACPE lines (DAFWA program) showed resistance comparable to the best Genesis lines.

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Table 1. Yield from varieties sown at Merredin, under ascochyta epidemic and ascochyta blight reaction scores (0 = no disease to 9 = highly susceptible) in the Medina Disease Nursery in the Stage 3 desi chickpea lines in the 2006 CVT

Variety/line	Yield (kg/ha)	Yield rank	% of mean site yield	Ascochyta reaction
WACPE2116	610	1	177	2.8
WACPE2135	585	2	170	2.6
97020-1488	547	3	159	3.5
97020-1343	545	4	159	2.8
WACPE2134	525	5	153	2.8
WACPE2114	523	6	152	2.9
WACPE2121	519	7	151	3.3
WACPE2136	516	8	150	2.1
97144-1118	510	9	148	3.1
WACPE2129	495	10	144	1.4
WACPE2133	481	11	140	2.3
WACPE2132	478	12	139	4.0
WACPE2127	476	13	138	1.6
Genesis 510	471	14	137	3.0
WACPE2125	451	15	131	2.3
WACPE2118	442	16	129	3.0
97020-1727	432	17	126	2.6
WACPE2126	431	18	125	3.4
WACPE2128	430	19	125	2.9
WACPE2131	426	20	124	2.4
WACPE2113	414	21	120	3.2
WACPE2117	412	22	120	3.4
WACPE2122	410	23	119	3.4
WACPE2123	397	24	116	3.3
97039-1415	394	25	115	4.0
Sonali	393	26	114	4.9
Yorker	391	27	114	6.0
WACPE2112	385	28	112	1.9
Genesis 509	380	29	110	2.3
WACPE2130	371	30	108	2.3
WACPE2115	359	31	105	3.1
WACPE2124	355	32	103	3.6
WACPE2120	351	33	102	2.8
WACPE2119	349	34	101	3.6
Genesis 836	344	35	100	4.2
Rupali	319	36	93	4.7
Flipper	302	37	88	5.6
Howzat	302	38	88	6.3
Genesis 508	273	39	79	2.0
Tyson	211	40	61	8.0
Heera	142	41	41	8.0
Sona	37	42	11	7.5

Table 2. Mean ascochyta reaction (0 = immune to 9 = most susceptible) in the Stage 3 and Stage 4 chickpea lines of the 2006 CVT at Medina, 2006

Variety/line	Ascochyta reaction	Variety/line	Ascochyta reaction	Variety/line	Ascochyta reaction
WACPE2127	2.2	97144-1118	3.8	WACPE2110	4.5
WACPE2112	2.5	WACPE2102	3.8	WACPE2126	4.5
WACPE2136	2.7	WACPE2115	3.8	WACPE2138	4.5
Genesis 508	2.7-3.2	WACPE2120	3.8	CICA0503	4.7
WACPE2125	3.0	WACPE2128	3.8	WACPE2119	4.7
WACPE2130	3.0	FLIP94-79C	4.0	WACPE2108	4.8
WACPE2131	3.0	WACPE2104	4.0	97039-1415	5.0
FLIP97-657-CLIMAS	3.2	WACPE2105	4.0	Nafice	5.0
WACPE2109	3.2	WACPE2106	4.0	WACPE2132	5.0
WACPE2133	3.2	WACPE2118	4.0	Almaz	5.2
Genesis 509	3.2-3.5	98238-01V4050	4.2	WACPE2100	5.2
Flip97-114C	3.3	WACPE2103	4.2	WACPE2107	5.2
WACPE2135	3.3	WACPE2111	4.2	Genesis 836	5.5-5.7
97020-1343	3.5	WACPE2113	4.2	98238-1156	5.7
97020-1727	3.5	99011-1007	4.3	Rupali	6.2
99038-1013	3.5	CICA0603	4.3	Sonali	6.3
S98167-CLIMAS	3.5	WACPE2117	4.3	CICA0505	6.5
WACPE2114	3.5	WACPE2121	4.3	00084-1151	6.8
WACPE2129	3.5	WACPE2122	4.3	Flipper	7.3
WACPE2134	3.5	WACPE2123	4.3	Yorker	7.7
98318-3007	3.7	WACPE2124	4.3	Heera	8.0-8.5
WACPE2116	3.7	97020-1488	4.5	Howzat	8.3-8.7
Genesis 510	3.7-3.8	Genesis 090	4.5		

Yield evaluation of ascochyta blight resistant Kabuli chickpeas

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KEY MESSAGES

- Two new Kabuli chickpea varieties, AlmazA and NaficeA, were released for commercial production in 2006.
- The new varieties are significantly more resistant to ascochyta blight, and have improved seed yield and seed size compared to Kaniva. Both new varieties have similar seed colour and cooking quality to Kaniva.
- For varieties with moderate resistance to ascochyta blight, an integrated disease management package including two strategic applications of fungicide (chlorothalonil 720 g/L applied at 1.0-2.0 L/ha) are recommended to manage disease in Western Australia (WA). The first at four weeks after emergence and a second at full flowering.
- AlmazA and NaficeA should prove to be a profitable pulse option and offer good opportunities for growers in the medium to high rainfall regions of WA and other chickpea growing regions across Australia.

BACKGROUND

Ascochyta blight, caused by Ascochyta rabiei, has caused widespread yield losses in chickpea in Australia and a rapid decline in the area of production. The Australian chickpea industry is largely based on desi chickpea, however there is a potential to increase the area of production of Kabuli chickpea to 200,000 ha with the availability of disease resistant varieties. We developed strategic international collaborations (with ICARDA, Syria and AARI, Turkey) in order to fast track improved, ascochyta blight resistant crossbred lines with improved seed yield and quality. Lines were selected from the world's major Kabuli chickpea improvement programs which were likely to be well adapted to Australian conditions. Two new varieties, AlmazA and NaficeA were released as a result of this research in 2005 and seed was available to growers for the 2006 growing season. One other line has also shown promising seed yield, seed size and ascochyta resistance and requires further evaluation across Australia. National Variety Testing (NVT) trials for Kabuli chickpea are not located in WA, therefore the trials described in this paper were undertaken to complement interstate activities and provide regional information on these lines/varieties.

AIMS

- To compare ascochyta blight reaction of new Kabuli chickpea varieties with commercial standards.
- To evaluate seed yield and seed quality (size and colour) of new Kabuli chickpea varieties and breeding lines in WA.

METHOD

AlmazA, NaficeA, S98167-CLIMAS and FLIP97-657-CLIMAS were included in a chickpea disease nursery at Medina in 2006 to assess their reaction to ascochyta blight. Single row plots (three replicates) were sown on 22 May. Ascochyta blight was incited by inoculating seedlings with infected stubble and spread assisted by overhead irrigation. Plots were visually scored for ascochyta blight reaction on 24 August. Ascochyta blight was scored on a scale of 0 to 9, where 0 = no disease to 9 = all plants dead.

Field trials were planned for four sites (Bolgart, Dongara, Mingenew and Boyup Brook) with four varieties/breeding lines (AlmazA, NaficeA, S98167-CLIMAS and FLIP97-657-CLIMAS). Plots (1.8 m wide by 20 m) were sown with four replications. A preventative application of fungicide was applied 14 August and 9 October (1.8 L/ha chlorothalonil) at Bolgart and 10 August (1.5 L/ha chlorothalonil) at Dongara. No fungicide was applied at Boyup Brook. Plots were machine harvested to determine seed yield at maturity. Seed quality measurements, including seed size, seed size distribution and colour, were not complete at the time of writing.

RESULTS AND DISCUSSION

Ascochyta blight infection was severe at Medina in 2006 and most control plots of Heera were dead at the time of scoring (Table 1). AlmazA and NaficeA exhibited moderate resistance to ascochyta blight compared to Heera (susceptible) and Sonali (moderately susceptible). The breeding lines FLIP97-657-CLIMAS and S98167-CLIMAS showed greater disease resistance than AlmazA and NaficeA.

Mean yields of the trials exceeded 1200 kg/ha at Bolgart and Boyup Brook despite the difficult growing season conditions (Table 1). Bolgart and Boyup Brook received only 54% and 63% of the long term average growing season rainfall (May to October), respectively. Two trials planned for the northern agricultural area were abandoned; the Mingenew site due to inadequate moisture for sowing and the Dongara site due to inadequate moisture through the winter period (38% of long term average).

Chickpea should always be sown according to the integrated crop production recommendations. Varieties with moderate resistance to ascochyta blight may require two strategic fungicide sprays (chlorothalonil 720 g/L applied at 1.0-2.0 L/ha) to assist in disease management under WA conditions. The first early prophylactic application is recommended four weeks after emergence to contain the spread of disease caused by wind blown spores from last year's stubble, seed borne infections or infected trash that has been carried into the paddock, and a second spray should be applied at full flowering to protect the developing pods and minimise the risk of reduced quality. A third spray may be required during pod filling if ascochyta blight becomes evident in the canopy during podding.

AlmazA and NaficeA should prove to be a profitable pulse option and offer good opportunities for growers in the medium to high rainfall regions of WA where large seed sizes are likely to be attained. Although varietal differences influence seed size, large seeds are more likely to be produced in areas with 400-700 mm annual rainfall, deep fertile soils and mild spring conditions favourable to seed filling. The varieties are protected by Plant Breeders Rights (PBR) and seed is available through COGGO Seeds.

Table 1. Ascochyta blight (AB) rating at Medina, and seed yield of Kabuli chickpea varieties/lines at Bolgart and Boyup Brook, 2006 (sowing dates in parentheses)

Variety/line	Medina AB	Bolgart (1 July)	Boyup Brook (31 May)
AlmazA	5.2	1459	1475
NaficeA	5.0	1428	1315
FLIP97-657-CLIMAS	3.2	1561	1037
S98167-CLIMAS	3.5	1670	1119
Genesis 090	4.5	-	-
Heera	8.3	-	-
Sonali	6.3	-	-
Mean	-	1529	1236
lsd 5%	-	304	251
cv%	-	13	14

KEY WORDS

chickpea, Kabuli, ascochyta blight

ACKNOWLEDGMENTS

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Paper reviewed by: Bill MacLeod

Pulse WA Chickpea Industry Survey 2006

Mark Seymour[1], Ian Pritchard[1], Wayne Parker[1] and **Alan Meldrum[2]**, [1]Department of Agriculture and Food, Western Australia, [2]Pulse Australia

BACKGROUND

Production of Desi chickpeas in Western Australia commenced on a wide scale basis in 1995. The area planted climbed to a high of 83,000 hectares in 1999.

Ascochyta Blight (AB) was first detected in 1999 after appearing in the eastern states in 1998. This highly virulent disease spread throughout WA in 1999. None of the varieties grown at the time had any tolerance to the disease.

Despite high prices for chickpeas, $500+, at the time, growers had dropped chickpeas from their rotations completely by 2001. This was most likely due to the high cost of disease control both in terms of management and fungicide cost. In addition, the drought of 2002 forced many growers to increase cereal plantings at the expense of legumes to maintain cash flows. Plantings of chickpeas since 2001 have been less than 10,000 ha.

Breeding for chickpea Ascochyta Blight (AB) tolerance/resistance has resulted in three varieties being available to growers in 2006.

- Sonali – Released in 2004 by Tanveer Khan, DAWA. Moderate tolerance to AB (Rated a 6). Average grain quality and suited to low rainfall areas.
- Rupali – Released in 2004 by Tanveer Khan, DAWA. Moderate tolerance to AB (Rated a 6) with better grain size and colour than Sonali, but yield challenged.
- Genesis 836 – Released by Kristy Hobson, Vic DPI. Good tolerance to AB (Rated a 5) with seed quality similar to Sonali, suited to the medium rainfall areas.

Seed quantities of Genesis 836 is likely to exceed 60 tonnes in 2007. Purchasers of seed are likely to be in bulkup mode for possibly two seasons with commercial quantities unlikely before 2008.

A survey of growers, agricultural consultants and agronomists attitudes toward chickpea growing and management in the WA wheatbelt was conducted early in 2006.

SURVEY OBJECTIVES.

- To understand growers perceived value of sowing chickpeas. What niche do they fill and their current perceptions of chickpeas in relation to yield, rotation value, etc.
- To understand the nature of the barriers to the planting of chickpeas.
- To obtain growers attitudes towards the agronomic components of the chickpea management package, with the view of developing chickpea varieties which can be grown by growers in the Western Australia wheatbelt using their favoured management package.

SURVEY DETAILS

The survey was conducted in the Autumn of 2006. Approximately 100 farmers were contacted in the medium to low rainfall zones of the northern and central agricultural regions. Thirty per cent of those sent the survey responded, perhaps a reflection of how the season was not developing and or a general negative feeling towards the crop and surveys. Once it became evident in early June that the season was going to be particularly dry and late no further attempt was made to contact additional farmers or retrieve so called 'completed' surveys.

SUMMARY OF RESULTS

- Most farmers had cropping (cereal) as their main enterprise – 5 year average wheat yields ranged from 1.0 to 3.2 t/ha, on average 2.0 t/ha.
- Farmers considered 50% of their total farm area to be suitable for growing pulses, 33% of their total farm area suitable for growing chickpea.

- 87% of growers had experience growing chickpeas only 13% had never grown chickpeas. As of the start of the 2006 season only 9% of all growers are still growing them, 78% of all g rowers no longer grow chickpeas, stopping in the years after chickpea AB arrived in WA.
- 65% of growers will not be growing desi chickpea in 2007.
- In 2008 35% of all growers are planning to grow chickpea, 39% are planning not to grow chickpea and 26% are undecided.
- The majority of farmers indicated very positive attitudes to the rotation value of chickpea, they consider chickpea as a diseases break crop for cereals and provide nitrogen for the following cereal crop.
- The obstacles or issues preventing farmers growing chickpea or are a major concern for farmers are, in order of importance:
  - (i) Chickpea AB and associated management – timing of fungicide sprays, number of fungicide sprays, cost of fungicide sprays and subsequent crop risk.
  - (ii) Low yields, variable yields and lack of adaptation to environment of chickpea varieties – farmers want (need) to achieve average chickpea yields over 1.0 to 1.2 t/ha reliably.
  - (iii) Management/agronomy – harvesting, weed control and to a lesser extent insect (native budworm) control.
- Isolating this year's chickpea crop from previous chickpea paddocks was not considered a major problem by farmers.
- The majority of farmers indicated that they would not apply more than two fungicide sprays for the control of chickpea AB regardless of yield potential, application cost or grain value.
- In the timing of fungicide sprays the least preferred timing for a single fungicide application was at flowering for a two spray regime the least preferred timing is 7-10 weeks after emergence and again at flowering.
- Farmers expect to receive over $350/t for chickpea (Desi) grain.
- Chickpea crops cost from $115-250/ha to grow (average $183/ha) – 50% of farmers were unable to answer this question.
- 50 to 60% of farmers who have previously grown chickpea would recommence growing chickpea by 2009 subject to the release of chickpea varieties with an AB resistance of 3 or less.
- Farmers will rapidly adopt new chickpea varieties with an AB resistance of 3 or less.

A complete set of results may be obtained by contacting Ian Pritchard.

Genes from the wild as a valuable genetic resource for chickpea improvement

Heather Clarke[1], **Helen Bowers**[1] and **Kadambot Siddique**[2], [1]Centre for Legumes in Mediterranean Agriculture, [2]Institute of Agriculture, The University of Western Australia

KEY MESSAGES

- Cultivated chickpea has been highly selected and lacks a wide range of genetic diversity.
- *Cicer* species, related to chickpea, grow in a diverse range of habitats and climates.
- Some *Cicer* species are resistant to ascochyta blight and other diseases, some are cold tolerant, some are resistant to insects. These wild *Cicer* sp. are generally more diverse than chickpea.
- Distant relatives cannot be crossed using conventional hybridisation methods in the glasshouse.
- New tissue culture and embryo rescue technology can facilitate these wide crosses in chickpea.

BACKGROUND AND AIMS

Cultivated chickpea belongs to the species *Cicer arietinum*. The species has no known wild populations, so chickpea's closest wild relatives are among other species within the genus Cicer. In order to create improved chickpea cultivars which express multiple disease and abiotic stress resistance, it is necessary to access a large gene pool. Many attempts have been made worldwide to introgress genes from wild Cicer into the cultivar with limited success. Only two annual *Cicer* species, *C. reticulatum* and *C. echinospermum*, are easily hybridised with chickpea using conventional crossing methods. The other six annual species and a large number of perennial species remain an inaccessible source of genes for chickpea improvement. To tackle this problem, an international collaboration was established between CLIMA, the Crop Development Centre at the University of Saskatchewan, Canada and the International Crops Research Institute for the Semi Arid Tropics (ICRISAT), India.

RESULTS

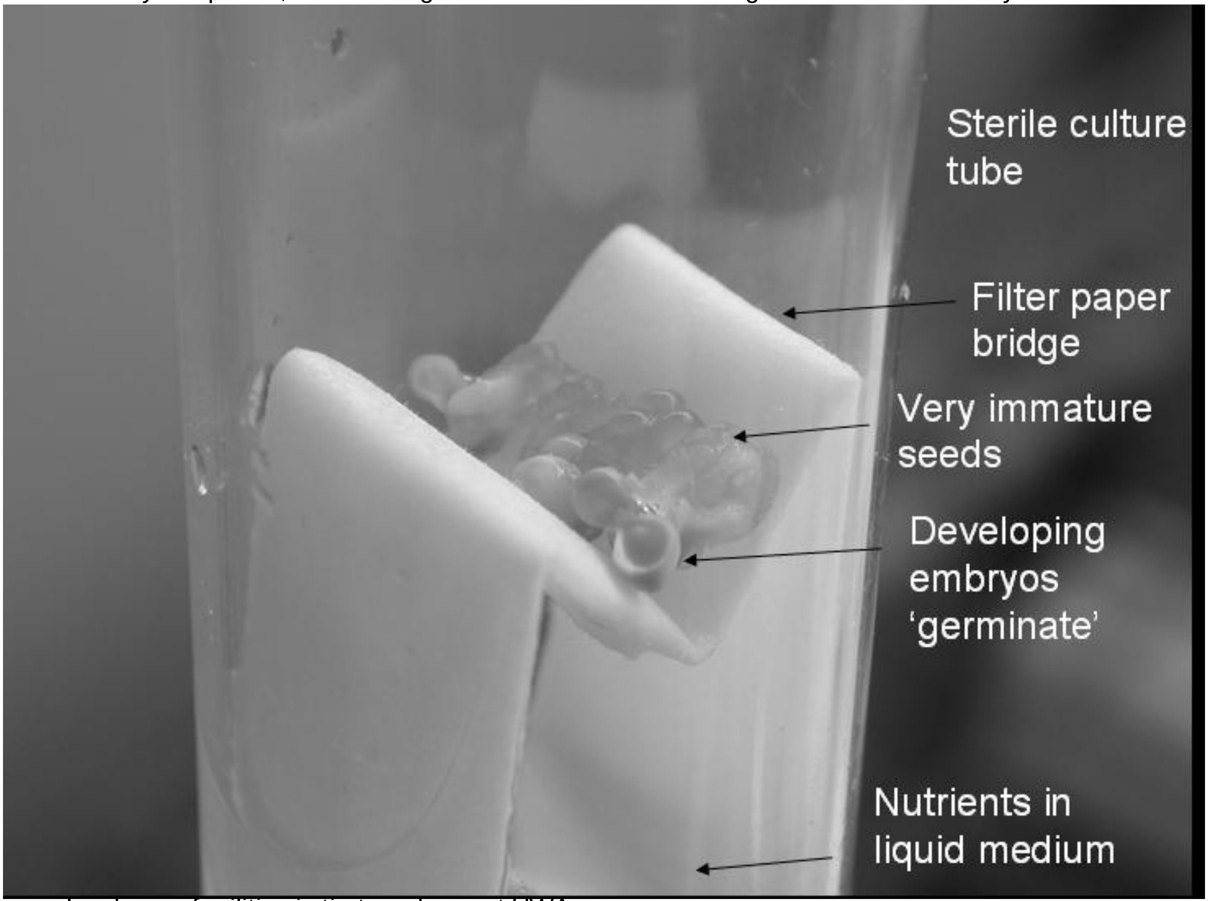
The collaborative project has generated hybrids between cultivated chickpea and accessions of *C. bijugum, C. pinnatifidum* and *C. judaicum*. This achievement was made possible using in vitro technology to rescue immature seeds to tissue culture in the laboratory before they abort from the mother plant in the glasshouse. Without rescue, most hybrids of *C. pinnatifidum* and *C. judaicum* abort from the mother plant 14-21 days after pollination, whereas *C. bijugum* abort as early as seven days. Transfer of techniques, developed at ICRISAT, India, has enabled the successful rescue *in vitro* of 14 day old hybrids between several Australian cultivars and *C. pinnatifidum* at CLIMA. The international collaboration has further developed techniques and complex media for the rescue of very immature hybrids between chickpea and *C. bijugum*. Hybridity of in vitro plantlets has been confirmed using DNA technology.

Detailed microscopic studies of embryo development in immature seeds, comparing the normal development of selfed chickpea seeds with hybrids, identified barriers to chickpea x *C. bijugum* hybrid seed development for the first time. This research helped to identify the best timing to rescue hybrids from the mother plant, as well as providing useful information about embryo development. We also apply plant growth regulators to the flower buds at pollination to promote pod set and to maintain the hybrid pod on the mother plant as long as possible before rescue.

FUTURE DIRECTIONS

A robust system is required to enable breeders to incorporate wide crosses in their chickpea improvement programmes. This project continues to develop reliable protocols which can be applied to any chickpea cultivars for wide crosses. A high incidence of albino progeny, and recalcitrance to rooting in hybrid plantlets in vitro, are two major factors limiting our success in transferring large

numbers of plantlets from controlled conditions in the laboratory to pots in the glasshouse. We are currently examining the causes. In the future, we will also quantify pollen viability and fertility of the flowers of hybrid plants; and investigate the chromosome arrangements of the new hybrids.



our glasshouse facilities in tip top shape at UWA.

Project number: GRDC UWA00091

International screening of chickpea for resistance to Botrytis grey mould

B. MacLeod[1], Dr T. Khan[1], Prof. K.H.M. Siddique[2] and **Dr A. Bakr[3]**, [1]Department of Agriculture and Food, Western Australia, [2]The University of Western Australia, [3]Bangladesh Agricultural Research Institute

KEY MESSAGES

- Screening demonstrated variability in reaction of chickpea germplasm to BGM. Lines were identified which consistently showed less BGM in the high disease pressure situations of the sites in Bangladesh.

AIMS

Botrytis Grey Mould (BGM) of chickpea is caused by *Botrytis cinerea*. Serious epidemics of BGM occurred in desi and Kabuli chickpea crops during 1997 and 1998. However, the following season, 1999, was the first season that ascochyta blight (*Ascochyta rabiei*) occurred in WA crops. Since 2000 BGM has been observed infrequently in all chickpea growing areas in Australia, probably due to a combination of the drier seasons and extensive fungicide spraying for ascochyta blight control. With the release of ascochyta blight resistant varieties of chickpea, and the associated reduction in fungicide sprays, BGM may again become a problem in the northern agricultural region during favourable seasons.

Therefore the aim of this work was to identify sources of BGM resistance in germplasm from chickpea breeding programs in Australia, India and Bangladesh at two BGM disease hot spots in Bangladesh.

METHOD

Since the occurrence of Ascochyta blight in WA, it has become impossible to do BGM field screening of germplasm without the risk of an outbreak of Ascochyta in the trial. This problem was overcome through a collaborative project with Bangladesh funded by the Australian Centre for International Agricultural Research (ACIAR). Bangladesh is an ideal partner in this project as Bangladesh does not suffer epidemics of ascochyta blight, and BGM occurs in chickpea crops annually and often these outbreaks are severe.

Field screening to identify chickpea lines with useful levels of resistance to BGM was conducted in Bangladesh over four seasons. Nearly 500 genotypes were screened in 2002-03, 208 in 2003-04, 200 in 2004-05 and 281 in 2005-06. From the second season onwards, entries in both screening nurseries comprised promising selections from the previous season and new entries supplied from all project partners. Screening was conducted at two locations, Jessore under natural levels of BGM infestation, and at Ishurdi where mist spraying was used to enhance the disease. However, *B. cinerea* spore inoculum was sprayed onto the field screening nurseries in the latter two seasons to further enhance the disease expression.

RESULTS

There were clear differences in reaction to BGM, as measured on a 0-9 rating scale (0 = no BGM symptoms, 9 = all plants dead), at each location in all seasons. Apart from the first season, there was a reasonable correlation (negative) between disease score and seed yield. Some lines with moderate levels of resistance were identified with a consistent reaction across sites and seasons, such as the Australian variety Genesis 836 screened as ICCV96836 (Table 1).

CONCLUSION

There results indicate that breeding chickpea varieties with resistance to BGM is possible; however there is no major sources of resistance which can readily be incorporated. Additionally, results from an associated study of the pathogen, *B. cinerea*, showed that it is also highly variable with broad adaptive potential, therefore improved varieties will need to be used as a component of an integrated management production system to maximise the effectiveness of their resistance.

Table 1. Comparison of Botrytis grey mould disease reactions and yield data for selected genotypes Fover 3 seasons at Ishurdi and Jessore in Bangladesh (yield data was not recorded at Ishurdi in 2002-03 nor in 2005-06)

Entry	BGM Score Bangladesh; two nursery mean 2002-03	Plot yield One nursery Jessore 2002-03	BGM Score Bangladesh; two nursery mean 2003-04	Plot yield Bangladesh; two nursery mean 2003-04	Plot yield, Jessore Bangladesh 2005-06
Amethyst	5	102.5	5.1	70.2	93.0
CDC Desiray	5.5	126.5	5	71.7	56.5
FLIP93-182C	4.5	55.7	*	103.7	10.3
FLIP94-030C	5.5	91.0	5.4	36.2	37.8
FLIP94-088C	3	101.5	5	60.7	*
FLIP94-089C	2.5	26.5	*	*	20.0
FLIP95-053C	5.5	92.9	5	49.4	*
FLIP97-503	*	*	6.6	35.2	*
FLIP97-530	*	*	5	56.5	37.1
FLIP97-537D	*	*	5.9	29.8	*
FLIP97-540C	2.5	18.0	*	*	*
FLIP97-565C	3.5	86.6	5.5	93.9	*
FLIP97-591C	4.5	39.3	*	*	*
FLIP97-656C	4.5	61.5	5	40.0	*
FLIP97-657C	3.5	55.5	4.8	50.5	43.7
FLIP97-695	*	*	5.6	58.8	19.3
Howzat	5	87.7	4.6	56.2	45.7
ICCV96836	4.5	123.4	4.1	125.0	84.5
Jimbour	5	48.1	4.5	60.0	53.7
Paidar 91	*	*	4.2	86.0	100.2
Sona*98PBC4017	6.5	96.1	5.1	101.1	*
Sona*98PBC4019	5	105.0	5.2	67.2	58.4
Tyson-1-35RS2	7	112.8	5.1	64.3	48.1
WACPE2075	5.5	123.8	4.6	86.3	43.7
WACPE2078	*	*	4.8	102.4	*
WACPE2095	6	74.1	5.1	85.0	83.3
WACPE2098	4.5	56.0	5.6	48.6	*

* Entry not assessed in the site or year identified.

KEY WORDS

Botrytis grey mould, chickpea, disease screening

ACKNOWLEDGMENTS

We acknowledge financial support for this work from ACIAR and the collaboration of interstate and international partner organisations.

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Paper reviewed by: Mark Seymour

Balance® in chickpea is safest applied post sowing to a level seed bed

Wayne Parker, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Balance® must be applied after sowing to a level seed bed, before the emergence of the crop. If applied to an uneven or furrowed seed bed rainfall can wash the herbicide into the bottom of furrows where it concentrates and causes damage to the crop. With appropriate application crop damage can be avoided.

BACKGROUND

Chickpea, regardless of variety, has low tolerance to post emergent broadleaf herbicides. As a result there are limited herbicides available to kill broadleaf weeds in crop without reducing crop yield. Balance® was released in 2000 for broadleaf control in chickpea. This coincided with the year many growers stopped growing chickpea. As a result most are unfamiliar with the nuances of the herbicide. Balance® is applied post sowing pre-emergent application onto a level seed bed. It is a soil residual herbicide targeting broadleaf weeds during emergence and for several weeks after application. It offers opportunity to target broadleaf weeds during emergence. If applied correctly there is minimal harm to the emerging crop.

Soil moisture is required to breakdown Balance®. The by products of the breakdown are the active constituents against the germinating weed. Other broadleaf herbicides registered for broadleaf control in chickpea include simazine, metribuzin and diuron. Simazine remains an effective pre sowing herbicide. Metribuzin and diuron are safe post sowing pre-emergent herbicides for control of broadleaf weeds provided soil conditions are ideal.

This demonstration aimed to highlight the extreme best and worst practice in applying Balance®. Best practice involves applying Balance® post sowing, pre-emergent onto a level seed bed. This gives good, consistent coverage to the soil surface and is less likely to form over concentrated bands. Worst practice is applying post sowing on a furrowed seed bed. This allows herbicide to be washed from the surface of the ridge and converge in the furrow.

METHOD

This demonstration was sown on the Mingenew Irwin Group Heavyland trial site 15 km east of Mingenew. The trial was arranged in four replicates of randomised complete blocks. Treatments were factorialised with two times of Balance® application, two chickpea varieties and two soil treatments. Genesis 836 and Genesis 510 were sown leaving one of two soil treatments, furrowed or levelled. Herbicide was applied at 100g/ha either before sowing or post sowing pre-emergent.

RESULTS

Table 1. Mean yield (kg/ha) adjusted for spatial trends, with the eight treatments – two timings of herbicide application by two soil preparations by two varieties

Herbicide Application Timing		Pre sowing		Post sowing	
Soil surface level		Furrowed	Level	Furrowed	Level
Variety	Genesis 510	422	441	388	509
	Genesis 836	404	428	355	506
5% lsd = 93					

CONCLUSION

- In this demonstration highest yield was achieved when applying Balance® to a level seed bed after sowing which is the registered method for its use.
- Balance applied post sowing to a furrowed surface significantly reduces yield. Balance should not be applied in this manner.
- Differences in yield between varieties was not significant. This trial did not indicate either variety to be more or less susceptible to Balance® than the other.
- Yield response to pre sowing application was less than post sowing pre emergent application. This is because of the levels of herbicide in contact with the emerging chickpea. Of the two timing of application options there will be a greater level of Balance in contact with the plant if applied pre-sowing, regardless of post sowing soil preparation. As a result pre sowing application was not the highest yielding treatment in the trial. Balance applied post sowing to a furrowed seedbed exposes the chickpea to the highest concentration of herbicide. Applied post sowing to a level seedbed exposes the chickpea to the lowest concentration of herbicide.

KEY WORDS

chickpea, Balance®, seedbed

ACKNOWLEDGMENTS

Murray Blyth, Greg Brown and Larry Prosser of the Geraldton Research Support Unit helped sow, manage and harvest this demonstration.

Paper reviewed by: Martin Harries

Demonstrations of Genesis 510 chickpea

Wayne Parker, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Genesis 510 offers the highest level of ascochyta tolerance of all released varieties. Effective control of ascochyta can be achieved with one fungicide application.

AIMS

The aim of the demonstrations of chickpea in 2006 was to highlight the disease resistance and agronomic traits of the most recent releases Genesis 836 and Genesis 510.

For chickpea to be grown profitably varieties must have a high level of ascochyta tolerance under Western Australian growing conditions. Genesis 510 offers the highest level of ascochyta tolerance of all released varieties. Initial analysis has been conducted under Victorian conditions, a long season, cool, moist environment, ideal for the spread of ascochyta. Under these conditions effective control has been obtained from one fungicide application. Requiring only one fungicide application allows chickpea to be a profitable crop. Risk associated with growing the crop also decreases with increasing level of resistance. Lower risk and improved profitability are both attractive features to growers.

Seed was supplied to six growers that they might sow small plots using full size machinery then receive assistance in disease, insect and weed management. With the seed was supplied an appropriate amount of the granulated, dry, inoculant ALOSCA. This enabled the demonstrations to be sown dry, in most cases before the wheat, without threat of poor nodulation. The following observations were made throughout a difficult season.

Table 1. Description of chickpea demonstration – Mingenew

Site	***Doug Parker, Pri-inga, Michael's Road, Mingenew***
Treatments	***Genesis 510, Genesis 836, Cassab***
Soil type	***Red clay loam***
Sowing date	***22 May***
Seeding rate	***98 kg/ha***
Comments	**Sown dry into a dry soil, emerged late in July, less than 25 plants per m^2. Unable to harvest, not enough to fill comb front and feed the broad elevator.**

Table 2. Description of chickpea demonstration – Mingenew

Site	*Jane and Perry Kuene, Raymar, East Ajana*
Treatments	*Genesis 510, Genesis 836, Sona*
Soil type	*Red loam*
Sowing date	*28 April*
Seeding rate	*100 kg/ha*
Comments	**Sown at a depth of 10 cm, into a moist soil profile filled by summer thunderstorms. Emergence was staggered as sowing depth was inconsistent across the bar through an uneven paddock surface. Managed to harvest 600 kg/ha of Sona, this the result of combined inactive of soil herbicides and poor in season rainfall.**

Table 3. Description of chickpea demonstration – Mingenew

Site	*Gary North, North's Road, East Pintharuka*
Treatments	*Genesis 510*
Soil type	*Red clay*
Sowing date	*13 May*
Seeding rate	*100 kg/ha*
Comments	**Sown without a breaking rain deep, 10 cm and deeper in places. Parts of each plot managed to get onto moisture, hence a staggered germination, those on moisture were out of the ground before the break of the season and surviving well on the stored moisture from summer thunderstorms. Parts of the plots were good enough to warrant an insecticide to knock off bud worm. A shower of hail smashed the crop after it had reached maturity, estimates of crop yield were taken using 0.1 m^2 quadrats, counting the seed on the soil surface, this gave results of between 50 kg/ha and 500 kg/ha.**

Table 4. Description of chickpea demonstration – Mullewa

Site	*John and Steve Rowe, Mullewa Mingenew Road, Wongoondy*
Treatments	*Genesis 510 and Genesis 836*
Soil type	*Red loam*
Sowing date	*15 May*
Seeding rate	*106 kg/ha*
Comments	**Sown dry with moisture at 55 cm which was never linked up with moisture from subsequent rainfall. The crop was late emerging, plant density was not above 20 plants/m^2. Had a lot of volunteer wheat to compete with as it flowered, trial was unharvestable.**

Table 5. Description of chickpea demonstration – Wubin

Site	*Rob Nankivell, Gunyidi Wubin Road, Wubin*
Treatments	*Replicated plots of Genesis 510, Genesis 836, Genesis 90 and Sona*
Soil type	*Brown loamy duplex*
Sowing date	*31 May*
Seeding rate	*100 kg/ha*
Comments	**Sown into marginal moisture as there had not been a significant break. Resulted in poor emergence with less than 20 plants per m^2. This combined with high number of broadleaf weeds and the trial was crop topped before weed seed set, not able to be harvested prior to final spray top.**

Table 6. Description of chickpea demonstration – Yandanooka

Site	*David and Justin Bagley, Yadanooka Melara Road, Yandanooka*
Treatments	*Genesis 836, Genesis 510*
Soil type	*Crumbling brown clay*
Sowing date	*23 May*
Seeding rate	*100 kg/ha*
Comments	**Demonstration was sown on less than 10 mm of rainfall. Emergence was poor with a strong grass presence obvious later in the season. Grass has out competed the chickpea for moisture and chickpea was not able to be harvested. They were threatening to put the sheep in to graze the weeds out which did not eventuate.**

Field pea 2006

Ian Pritchard, Department of Agriculture and Food, Western Australia

IN REVIEW

2006 saw the DAFWA Pulse Agronomy Project team genuinely excited about the prospects for field pea as it was generally anticipated that field pea for the first time would exceed 100,000 hectares in Western Australia. 2006 would also see for the first time the wide spread evaluation of two new promising field pea lines WAPEA 2211 a recognised Blackspot tolerant line and WAPEA2213 a very early flowering Kaspa type.

Alas the 2006 season for the WA grainbelt was not to be, with a very late start followed by one of the driest seasons on record. As a result many cropping programs which included field peas were curtailed such that the area of field peas remained at 70-80,000 hectares. Pleasingly however many growers had good experiences with Kaspa in 2006 with many crops yielding between 1.2 and 1.8 t/ha, even though it was one of the toughest years on record. It was also pleasing that the 2006 field pea harvest appeared to run as smoothly and efficiently as 'other' crops. In the last two seasons in particular considerable investment has been made into supplying growers with 'how to' information on successfully swathing and harvesting semi-leafless field peas.

Not only was the 2006 season challenging for growers but also for research officers, with a number of trials planned for 2006 not sown hoping for a better 2007 and a number of sown trials having to be repeated in 2007 due to the very poor season.

Included in the following pages are summaries of the research and extension efforts by many organisations and projects, all with the same aim - to establish a sustainable and substantial field pea industry in WA.

FOCUS ON FIELD PEAS 2006 EXTENSION ACTIVITIES

The season, or the actual lack of it, also had a considerable impact on the planned extension activities for 2006. The 2006 season was the third season of the focus on field pea campaign and it was planned to continue on previous years work. The season however dictated that more emphasis was placed on 2006 seasonal issues. It is pleasing to note however that the 2006 season has not reduced the renewed interest and enthusiasm for the new semi leafless field pea varieties like Kaspa.

In February a concurrent presentation was given at the 2006 Agribusiness Crop Updates titled – 'Highlights of Pulse Research in 2005' presented by Ian Pritchard, Pulse extension Officer, DAFWA. During February and March Pulse Agronomy project members gave presentations at the Esperance, Merredin, Narembeen, Katanning and Geraldton regional crop updates.

In the April of 2006 a technical update session was provided for Elders agronomists.

2006 saw the continuation of producing and releasing technical information on semi leafless field peas and information on overcoming barriers to the adoption of field peas:

- Farmnote No. 105 'Swathing semi-leafless field pea' – observations and machinery setup/modifications from growers swathing Kaspa.
- Farmnote No. 144 'A visual guide to key stages in the growth and maturity of field pea' – to aid growers in determining the appropriate timing for the application of herbicides, croptopping, swathing and harvest.

Eight articles were produced for a seasonal column 'Focus on Field pea' within the Farm Weekly Newspaper commencing on 4 May and finishing on 7 September. Article content concentrated on important agronomic information for field pea production, positive solutions to perceived problem issues in field pea production and 2006 seasonal issues/results. The publication of the articles was timed to coincide with the relevant time of season. The articles were released as press releases which were subsequently used by rural papers Statewide; on a number of occasions stories achieved blanket coverage in the rural press and were picked up by the Countryman paper. The articles were also used for local Department of Agriculture and Food Ag-memo articles and Grain Legume News articles.

Eleven radio interviews were undertaken with Radio West Network – Rural Focus with Vin Dawes commencing in May and finishing in September. The interview topics were based on either the soon to be published column article within the Farm Weekly or current seasonal issues giving blanket coverage to the rural community. ABC breakfast sessions and country hour picked up various stories through out the year.

A new CD and DVD were produced – 'Swathing and Harvesting Semi-leafless Field Pea' in time for the Dowerin Machinery Field Days and the Spring field day season. Following the release in 2005 of the 'Successfully harvesting semi-leafless field peas' CD. The new CD and DVD now also incorporates information on swathing and visual guides on field pea/weed maturity. AWB Seeds Ltd purchased 400 copies of the DVD to distribute in Eastern Australia.

Pulse project members attended numerous spring field days/walks from Mullewa/Mingenew in the north of the State to Scaddan in the south of the State. The focus for many of these field days/walks was the performance/harvesting of new semi-leafless varieties like Kaspa in the various rainfall zones.

Field pea variety evaluation

Kerry Regan[1], Rod Hunter[1], Tanveer Khan[1,2] and **Jenny Garlinge[1]**, [1]Department of Agriculture and Food, Western Australia, [2]CLIMA, The University of Western Australia

KEY MESSAGES

- Bundi, white seed type, and Helena, dun seed-type, were the highest ranking field pea varieties in 2006.
- Greater emphasis on semi-leafless, semi-dwarf dun-seed type field pea types with pod shatter resistance is clearly visible in the breeding lines being promoted to CVT/NVT trials.
- Advanced breeding lines (e.g. OZP0601 and OZP0602) with earlier flowering than Kaspa are showing excellent potential for shorter season and low rainfall regions of WA.

AIMS

- To evaluate the yield potential of field pea varieties and pre-release lines across a range of regional environments in WA.
- To identify specific environments that field pea varieties and pre-release lines are best targeted.

METHOD

Field pea varieties and advanced breeding lines were evaluated for yield at 10 sites in 2006. Five other sites were planned but unable to be included in this report. The site at Mullewa was not planted due to poor moisture conditions at sowing, poor and variable yields were supplied from trials at Newdegate and Jacup. Results from Bolgart and Katanning were not available at the time of writing. Evaluation included a range of semi-leafless (SL) and conventional trailing leaf type (C), white and dun seeded field pea varieties and lines. Breeding lines included in the National Variety Testing (NVT) trials can be identified by their 'OZP' prefix followed by a series of four numbers indicating the year of promotion to NVT ('06' for 2006) and entry number (01 to 10). Due to lack of seed supplies in 2006, OZP0604 was not included in this series of trials, and a number of other lines had insufficient supplies to be sown at more than one or two sites. Trials were sown in field plots (generally 20 m long x 1.44 m wide) with three replications. Plots were machine harvested to determine seed yield. Yield was analysed using REML methods, but results presented here are from preliminary analysis.

RESULTS AND DISCUSSION

The growing season rainfall was below average at all sites, particularly during the winter period and in the northern cropping regions. This resulted in some trials not sown (Mullewa), not harvested (Jacup) or producing poor and variable yields (Mingenew, Dalwallinu, Ardath and Newdegate). On average, mean yields varied from 302 kg/ha at Newdegate (data not presented) to 1843 kg/ha at Kunjin (Table 1). Broad varietal/breeding line comparisons were difficult in 2006 due to the lack of consistent entries across sites.

Helena, Dunwa and Kaspa all performed well in 2006, but Kaspa was not as outstanding as last season. Kaspa is relatively late flowering and generally considered more suited to medium rainfall longer season regions; conditions which were not experienced in WA during 2006. The white seeded variety Bundi, which has early flowering but otherwise similar to Kaspa, performed extremely well in 2006 across all sites, except Dalwallinu. Many of the breeding lines ranked higher for yield than Kaspa. Two new OZP lines (OZP0601 and OZP0602) performed well at Pingrup and Merredin. They were also outstanding in field pea breeding trials (see section on "Breeding highlights of the Australian Field Pea Improvement Program") and produced consistently high yields in interstate breeding trials (VIC, SA and NSW). These two lines have similar characteristics to Kaspa (dun seed-type, semi-leafless, semi-dwarf with pod shatter resistance), but earlier flowering and maturity and offer excellent alternatives to Kaspa in low rainfall and short season environments. Breeding line 96-286*1-16 performed well at Ardath, Scaddan, Pingrup and Merredin and has been identified to have good resistance to bacterial blight in 2006. The line identified with improved blackspot resistance in 2004/05 (WAPEA2211), performed relatively well at Dalwallinu and Scaddan, but generally produced about

10% less yield than Kaspa. Generally, the dry conditions in 2006 were not favourable for WAPEA2211, which is later flowering than Kaspa. An early flowering selection of Kaspa (WAPEA2213) produced an average mean seed yield similar to Kaspa.

KEY WORDS

field pea, Cultivar Variety Testing (CVT), National Variety Testing (NVT)

ACKNOWLEDGMENTS

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Table 1. Seed yields[1] (% Kaspa) of field pea varieties and breeding lines in CVT/NVT 2006 (sowing date in parentheses)

Variety/line	Leaf type[2]	Seed type	Muresk (5 July)	Mingenew (25 May)	Dalwallinu (18 May)	Ardath (9 June)	Kunjin (29 June)	Scaddan (25 May)	Pingrup (22 June)	Merredin R.S. (6 June)	Mt Madden (31 May)	S. Gums (23 May)	Mean % Kaspa
Kaspa	SL	Dun	841	481	523	607	844	1571	947	1365	1334	932	945 (10)[3]
Bundi	SL	White	113	138	65	105	120	119	119	111	137	131	116 (10)
Dunwa	C	Dun	101	105	89	83	98	112	105	103	104	100	100 (10)
Helena	C	Dun	115	115	89	92	109	116	117	91	110	110	106 (10)
Moonlight	SL	White	100	100	102	117	109	100	94	101	123	106	105 (10)
Parafield	C	Dun	100	86	89	100	102	112	104	83	96	101	97 (10)
Sturt	SL	White	106	96	94	108	125	106	112	83	106	96	103 (10)
Yarrum	SL	Dun	-	79	67	98	-	108	111	100	103	118	98 (8)
WAPEA2211	SL	Dun	83	60	129	85	75	114	88	96	83	87	90 (10)
WAPEA2212	SL	Dun	-	-	-	95	-	121	112	103	-	-	108 (4)
WAPEA2213	SL	Dun	-	-	-	100	-	103	103	93	-	-	100 (4)
OZP0601	SL	Dun	-	-	-	-	-	-	112	115	-	-	114 (2)
OZP0602	SL	Dun	-	-	-	-	-	-	106	130	-	-	118 (2)
OZP0603	SL	Dun	-	-	-	86	-	-	95	112	-	-	98 (3)
OZP0605	SL	Dun	-	-	-	-	-	-	104	89	-	-	97 (2)
OZP0606	SL	Dun	-	-	-	-	-	-	104	97	-	-	100 (2)
96-286*1-16	SL	Dun	-	-	-	105	-	144	103	109	-	-	115 (4)
01-511-7	SL	Dun	-	-	-	-	-	116	100	118	-	-	112 (3)
96-286*1-11	SL	Dun	-	-	-	93	-	141	-	102	-	-	112 (3)
01-227-20	SL	White	-	-	-	-	-	-	110	108	-	-	109 (2)
97-033-1-6	SL	Dun	-	-	-	-	-	-	109	-	-	-	109 (1)
89-036*3-6	SL	Dun	-	-	110	96	-	-	109	99	117	-	106 (5)
96-286*1-9	SL	Dun	-	-	-	97	-	128	96	103	-	-	106 (4)
96-286*1	SL	Dun	107	81	-	85	107	114	-	117	93	120	103 (8)
01-226-6	SL	Dun	-	-	-	-	-	-	95	106	-	-	101 (2)
01-309-6	SL	Dun	-	-	-	-	-	-	90	94	-	-	92 (2)
Mean site SY			846	447	499	590	863	1843	970	1431	1442	1029	
SED			47	50	61	83	65	132	63	184	70	84	
CV%			7	13	15	17	9	9	8	16	6	11	

[1] Seed yield of Kaspa and mean site yield presented in kg/ha; [2] Leaf type: C = conventional trailing type and SL = semi leafless; [3] Number of trials that the varieties was included in 2006.

Breeding highlights of the Australian Field Pea Improvement Program (AFPIP)

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KEY MESSAGES

- Dunwa and Kaspa were the highest ranking varieties for yield with dun seed type.
- The field pea lines OZP0601 and OZP0602 showed excellent yield potential in WA and were also consistent performers in Vic, SA and NSW.
- OZP0601 and OZP0602 have similar characteristics to Kaspa, but earlier flowering and maturity and offer excellent alternatives to Kaspa in lower rainfall and short season environments.
- Sturt and Bundi were the highest ranking varieties for yield with white seed type.
- Some of the breeding lines with improved blackspot (WAPEA2211) and bacterial blight (96-286*1-16, 99-228*12 and 97-015*2-5) resistance are showing potential in advanced breeding trials.
- Breeding progress is rapidly being made by incorporation of powdery mildew, PSbMV and BLRV virus resistance, and improved seedling tolerance to boron and salt.
- Evaluating germplasm at an early breeding stage in WA assists to identify and capture adapted field pea lines suitable for the western region and other low rainfall regions across Australia that can be progressed towards commercial release.

BACKGROUND

Field pea breeding in Australia is undertaken by the Australian Field Pea Improvement Program (AFPIP), a sub-program of Pulse Breeding Australia (PBA). The AFPIP sub-program is based at Horsham, Victoria (VIC) with collaborators in New South Wales (NSW), South Australia (SA) and Western Australia (WA). The main objective of AFPIP is to expand the field pea industry in Australia through the development of new varieties with broad adaptation across Australia and also with suitable adaptation for specific production regions of Australia. The first five years of this program is expected to have an increased focus on developing semi-leafless, dun type varieties with non-shattering pods (Kaspa ideotype) that will increase crop expansion and production in the more marginal soil and lower rainfall (< 350 mm annual) cropping environments within WA, SA, Victoria and NSW. In these environments, field peas are often the best-adapted grain legume option. Western Australia is responsible for evaluating breeding lines being developed by the program, and undertaking a breeding and screening component for field pea blackspot resistance. This summary describes the yield evaluation component of the research. For a summary on blackspot resistance, see Khan *et al.* (2007) in this booklet.

AIMS

- To develop improved field pea varieties for Australia.
- To identify breeding lines with improved and stable yield, appropriate phenology, lodging and pod shatter resistance at harvest and improved disease resistance in WA.

METHOD

Yield evaluation of field pea breeding lines included three series of trials, stage 1 (S1), stage 2 (S2) and stage 3 (S3) and range from early generation (S1) through to more advanced lines (S3). Stage 1 trials were located at six primary sites across Australia. In WA, S1 trials were located at Merredin Research Station and included approximately 850 breeding lines and control varieties. The S2 trials were located at Merredin, Pingrup and Scaddan and included 204 dun seed, 60 white seed and 120 trailing type breeding lines. The S3 trials were located at Merredin, Pingrup, Scaddan and Dalwallinu

and included 90 breeding lines and varieties of various seed and plant types. The S3 trials include breeding lines entered in the National Variety Testing (NVT) trials, and can be identified by their 'OZP' prefixes (e.g. OZP0601). The trials were sown in plots 1.2 m wide x 10 m long and machine harvested for yield and seed quality (mean seed weight and seed type). Visual scores of emergence, early vigour, flowering, podding, maturity, lodging and agronomic type (selection) were made during the growing season. The S2 and S3 trials were sown in replicated plots, but the S1 trials were unreplicated with grid controls. Seed yields were analysed using REML methods. Results of S2 trials were not available at the time of writing.

RESULTS

The growing season was exceptionally dry through much of the State, particularly during the May-July period and in the northern cropping regions. Dalwallinu was the worst affected site with yields less than 500 kg/ha (not presented). The trials at Merredin received about 60 mm of much needed rainfall in September, which provided enough moisture to carry crop growth through to maturity. Despite the difficult weather experienced, yield performance across the other three sites was remarkably good (mean yield > 1200 kg/ha) demonstrating the robustness of field pea in adverse conditions.

The mean yield of S1 trials was 1265 kg/ha (data not presented). Kaspa and Parafield averaged 1433 and 1412 kg/ha, respectively. The trials were quite variable (CV = 20-26%), but a number of breeding lines exhibited good yields and excellent agronomic characteristics. Based on the yield, seed quality and visual scores from this and interstate trials, the most promising lines will be progressed to S2 testing in 2007.

Mean yields of S3 trials ranged from 1225 kg/ha at Scaddan to 1563 kg/ha at Pingrup (Table 1). Kaspa performed well again in 2006 despite the dry season, but a number of other varieties (Dunwa, Sturt and Bundi) and breeding lines also excelled. In particular, OZP0601 (01-230-5) and OZP0602 (01-256-10) showed excellent potential in WA and were also consistent performers in Victoria, SA and NSW in 2006. Both of these lines have similar characteristics to Kaspa (dun seed-type, semi-leafless, semi-dwarf with pod shatter resistance), but earlier flowering and maturity. Potentially, OZP0601 and OZP0602 offer excellent alternatives to Kaspa in lower rainfall and short season environments. Seed production of these OZP lines commenced in 2006. Superior new semi-dwarf dun type field pea varieties for WA will be available to growers by 2010.

Sturt and Bundi produced the greatest yields of the white seeded field pea varieties. Snowpeak and Moonlight did not perform well at any site in 2006. Bundi (tested as 89-036*9-8) is an earlier flowering sister line of Kaspa, which was commercialised in 2005. This variety is targeted for the mallee regions of Victoria, and has produced greater yields than Moonlight and Snowpeak in WA. Sturt has a conventional trailing leaf type and has exhibited excellent yields and broad adaptation across southern Australia.

DISCUSSION

Breeding progress continues towards pyramiding desirable traits that will improve crop reliability and yield potential in lower rainfall environments. In particular Kaspa type germplasm has been rapidly enhanced by incorporation of powdery mildew, PSbMV and BLRV virus resistance and improved seedling tolerance to boron and salt. Germplasm with various levels of enhancement were in advanced levels of testing in 2006 and showing broad adaptation.

Glasshouse screening (SA) together with field observations (NSW) in 2006 indicate that over 90% of S2 and S3 breeding lines have adequate levels of resistance to downy mildew and over 70% of early generation lines are completely resistant or are segregating for major gene resistance to powdery mildew. Field screening for blackspot resistance was conducted under higher inoculum pressure 2006 (WA) and identified several high yielding and broadly adapted lines (e.g. S2: 02-146-5 and 02-279-1, S3: 96-286-*1-11). These lines showed relatively lower disease incidence in the canopy by podding stage. The breeding line identified in 2004/05 with improved blackspot resistance (WAPEA2211) was included in S3 trials in 2006. It has later flowering and maturity than Kaspa and was unable to capitalise in the short, dry season experienced.

Table 1. Leaf-type, flower colour, seed type and seed yield (as %Kaspa at each site and mean across sites) of some field pea varieties and breeding lines in S3 yield evaluation trials 2006 (sowing date in parentheses)

Line/variety	Leaf type[1]	Flower colour[2]	Seed type[3]	Pingrup (27 June)	Scaddan (14 June)	Merredin (8 June)	Mean (%Kaspa)
Bundi	SL	W	W	107	115	78	100
Dunwa	C	P	D	101	97	107	102
Excel	SL	W	B	80	55	65	66
Helena	C	P	D	96	94	88	92
Kaspa	SL	Pi	D	100	100	100	100
Moonlight	SL	W	W	87	79	79	82
Parafield	C	P	D	90	93	104	95
Snowpeak	SL	W	W	83	73	74	76
Sturt	C	P	W	99	100	104	101
Yarrum	SL	P	D	84	94	93	90
OZP0601 (01-230-5)	SL	Pi	D	110	114	101	108
OZP0602 (01-256-10)	SL	Pi	D	99	120	104	107
OZP0603 (01-228-2)	SL	P/Pi	D	99	96	106	100
OZP0604 (01-269-6)	SL	Pi	D	96	97	103	98
OZP0605 (01-284-2)	SL	Pi	D	86	92	128	102
OZP0606 (97-031-6-6)	SL	P	D	99	103	94	99
97-031-6-10	SL	P	D	93	103	113	103
01-032-8	SL	P	D	99	104	106	103
97-031-6-3	SL	P	D	100	113	95	103
96-286*1-16	SL	P	D	98	115	90	101
01-136-3	SL	Pi	D	92	101	107	100
97-031-6-M-Pi	SL	Pi	D	89	105	105	100
01-227-5	SL	P/Pi	D	81	104	113	99
01-478-2	SL	P	D	102	113	81	99
96P403-2	SL	Pi	D	93	87	116	99
01-230-27	SL	Pi	D	85	113	97	98
97-033-1-6	SL	Pi	D	91	109	94	98
01-511-7	SL	Pi	D	84	102	107	98
97-031-6-M-P	SL	P	D	95	103	95	98
01-309-6	SL	P/Pi	D	89	93	111	97
01-230-14	SL	W	W	93	108	91	97
96-286*1-9	SL	P/Pi	D	93	101	98	97
01-246-13	SL	P	D	85	104	102	97
01-255-5	SL	P	D	86	91	114	97
01-019-6	SL	P	D	96	98	94	96
01-227-20	SL	W	W	95	95	98	96
01-255-7	SL	P/W	D	102	88	95	95
01-253-13	SL	Pi	D	83	107	95	95
97-015*2-8	SL	P	D	78	98	105	94
97-015*2-5	SL	Pi	D	92	98	88	93
WAPEA2211 (00P040-2)	SL	Pi	D	79	83	94	85
99-228*12	SL	P	D	84	63	94	80
Kaspa yield (kg/ha)				1747	1328	1414	
Site mean (kg/ha)				1563	1225	1304	
lsd 5%				303	223	323	
CV%				10	9	13	

[1] Leaf type: C = conventional trailing type; SL = semi leafless.
[2] Flower colour: P = purple; W = white; Pi = pink.
[3] Seed type: D = dun; W = white and B = blue.

Screening for resistance to viral diseases in 2006 has identified advanced lines with improved resistance to Bean Leaf Roll Virus (BLRV) in the field (NSW) and resistant genotypes within segregating populations for resistance to Pea Seed Borne Mosaic Virus (PSbMV) in the glasshouse (NSW). Superior resistance to bacterial blight (most likely pv syringae) has also been identified in field screening conducted in 2006 (Victoria and NSW). Production of breeder's seed of the most promising lines has commenced over summer 2006/07 to fast track the release of superior varieties for areas prone to this disease. One of these has also proven to be well adapted to WA (96-286*-1-16).

Glasshouse screening (VIC) has identified desirable variation for boron tolerance and superior tolerance to salinity in unadapted germplasm. A broadly adapted S2 breeding line with both high tolerance to boron and salt was also identified in 2006 (02-099-2) and will be evaluated further in 2007.

High yielding trailing type lines with superior pod shatter resistance at maturity will be promoted for further evaluation in 2007.

KEY WORDS

field pea, Australian Field Pea Improvement Program (AFPIP), Pulse Breeding Australia (PBA)

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Field pea germplasm enhancement for black spot resistance

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KEY MESSAGES

- Incremental progress is being achieved in enhancement of field pea for black spot resistance in agronomically desirable lines.
- More adapted resistant lines identified in this module will be incorporated in the National Breeding Program.
- Release of a variety with enhanced black spot resistance is now a possibility in five to eight years.

BACKGROUND

Black spot, caused by *Mycosphaerella pinodes*, is the most important disease of field pea across southern Australia. Attempts to develop resistant germplasm have been frustrated by both, the low level of resistance naturally available in the germplasm collections and the reliability of screening methods. However, more than a decade of work in Western Australia has now given a glimmer of hope that a useful measure of resistance, in adapted varieties, is possible through a focussed program. As a result the National Pea Breeding Program has based a black spot breeding module in WA.

AIMS

- To identify sources of resistance and develop parental lines for crossing.
- To develop germplasm combining desirable agronomic characteristics with black spot resistance.
- To contribute lines with good yield potential and resistance to black spot for trials by the National Program.

METHODS

Crosses are made in WA between agronomically suitable lines and sources of black spot resistance. Crossed populations are fast tracked to F4-F5 before selection under black spot epidemic. Genetically stable lines are screened for resistance and agronomic desirability over two years before being advanced to yield trials. This paper reports results from an advanced breeding trial of selected lines conducted at Bolgart, Dalwallinu, Pingrup and Merredin during 2006. Black spot reactions from 2005 and/or 2006 disease nurseries at Medina are also presented. Trials were sown as follows, Bolgart 29 June, Dalwallinu 31 May, Pingrup 27 June, Merredin 2 June. Each trial had three replications and plot size was 1.2 m x 10 m. As coefficient of variation (CV) for yield at Dalwallinu was unacceptably high (39%) these data were not used in the combined analysis. The yields results from three sites, Bolgart (CV 21%), Pingrup (CV 19%) and Merredin (CV 16%), were used in the combined analysis.

RESULTS

The 2005 and 2006 disease nursery results show that all breeding lines had at least marginally more resistance than control varieties. Breeding lines also showed desirable agronomic characteristics, with the exception of 99P916-1 and WAPEA2189. Most lines were semi-leafless and eight lines showed better standing ability at maturity than Kaspa. WAPEA2211 continued to show good yield potential and resistance, although its future is in doubt due to its susceptibility to downy mildew. This line will continue in trials to assess its potential where downy mildew is unlikely to be a problem. Apart from WAPEA2211 and 00P040-5, sugar pod characteristic has not been identified in any of the breeding lines.

CONCLUSIONS

Although, at this stage, it is not possible to predict if any of this material will ever be released as a variety, some lines show potential for date of sowing trials to see if the degree of improvement in resistance achieved so far will allow earlier sowing of field pea.

KEY WORDS

pea, black spot, resistance, downy mildew, yield

ACKNOWLEDGEMENTS

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Table 1. **Flower colour (Fc, w white, p purple, pk pink), leaf type (Lt, S semi-leafless, N normal), development score (Dv, 0-9, 0 no flowering, 3 flowering, 4 pod initiation, 9 fully developed seed), maturity score (Ms, 1-9, 1 earliest maturing), agronomic desirability (Agr, 0-3, 3 most desirable), standing ability (Sta, 1-9, 1 totally lodged and 9 all plants upright), mean of yield in kg per ha across Bolgart, Pingrup and Merredin (Overall), 100 seed weight in grams at Bolgart (100 SW), seed type, black spot reaction in 2005 (Bs05) at Medina and black spot reaction in 2006 (Bs06) at Medina in selected breeding lines and controls**

Line/variety	Fc	Lt	Ds	Ms	Agr	Sta	Overall yield	100 SW	Seed type	Bs05	Bs06
00P021-1	w	S	2	7	3	6	1699	17.6	blue		
00P021-5	p	S	0	7	2.5	6	1539	20.5	dun	5.0	5.8
00P021-9	p	S	0	9	3	6	1529	17.9	dun	7.0	5.8
00P024-7	w	S	1.5	9	2.5	3	1335	17.9	blue/white		5.5
00P029-3	p	S	0	6	2.5	4	1486	18.3	speckled dun	6.0	5.5
00P040-4	pk	S	0		3	5	592	19.8	speckled dun	4.5	
00P040-5	pk	S	0	6	3	6	1432	22.8	dun	6.0	5.0
00P040-6	w	N	0	0	2	2.5	651	13.9	white	4.0	
00P115-1	w	S	2	5	2.5	6.5	1062	18.6	white		5.5
00P116-1	w	S	3	5	3	5.5	1372	19.0	blue/white		5.8
97P719-25	w	N	0	9	2	2.5	1565	13.8	white	4.0	6.0
98P795-4	p	S	0	7	2	5	1429	20.2	speckled dun	4.0	5.5
99P916-1	w	S	0	6	0.5	2	1376	13.1	blue/white	5.0	5.0
WAPEA2189	w	S	2	5	1.5	4	1515	19.7	blue	6.0	6.0
WAPEA2211	pk	S	0	7	2	5.5	1683	21.3	dun	5.0	4.8
Dundale	p	N	3.5	6	2	2	1506	19.9	dun	7.0	7-7.5
Dunwa	p	N	2.5	7	2	2.5	1662	20.3	dun	7.0	7-7.5
Helena	p	N	3	6	2	2	1635	16.4	dun	7.0	7-7.5
Kaspa	pk	S	0	6	2	4.5	1641	19.1	dun	6.0	7.0
Parafield	p	N	2.5	7	2	2	1601	19.5	dun	7.5	7.5

Validation of Blackspot spore release model and testing of moderately resistant field pea line

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KEY MESSAGES

- Bundi appears to be better suited to delayed sowing (late June sowing) in low rainfall areas than Kaspa.
- In the absence of frost there appears to be no advantage in mixing semi-leafless and trailing varieties.

AIMS

- To validate the Blackspot spore release model throughout WA.
- To determine the level of resistance of 00PA40-2A to Blackspot.
- To determine if delayed sowing and an early flowering version of Kaspa provides similar yields to sowing 00PA40-2A early, or Kaspa at the recommended sowing time.
- To assess the use of mixes to extend the flowering period.

METHOD

Split plot design with 3 replicates.

Whole Plots: 3 times of sowing – Before model says its safe, After model says its safe and 2-4 weeks after model says its safe to sow; randomised within replicate blocks.

Sub Plots: 10 varieties – Kaspa, Kaspa-RBSEL1, 00PA40-2A, Bundi, Moonlight, 50% mix of Sturt and Kaspa, Sturt, 50% mix of Kaspa-RBSEL1 and Kaspa, 89-036-3-6 and Dundale; randomised within time of sowing whole plots.

RESULTS AND DISCUSSION

In 2006 five time of sowing trials were planned to validate the 'Blackspot Manager' disease model. The trials were scheduled to take place at Mullewa, Merredin, Newdegate, Mt Barker and Scaddan. Due to seasonal conditions three trial sites were abandoned. Newdegate was not sown due to the very delayed start to the season. Mullewa was sown but emerged and grew very poorly due to the dry seasonal conditions with the plots unable to be mechanically harvested. Visual observations and hand harvest indicate Bundi yielded 0.2 to 0.5 t/ha and the rest less than 0.2 t/ha. Mt Barker was overrun with wild radish late in the season and was sprayed off. This left Scaddan and Merredin. At all sites treatments which included the variety Sturt had very poor establishment. This another example of poor crop establishment with white peas. Thus Sturt were removed from the analysis.

In 2006 the Scaddan area had received good consistent summer rainfall with the frequency of rain sufficient to release Blackspot spores prior to the season commencing in May. The 'Blackspot Model' suggested that the risk of serious yield loss due to blackspot was low with 99% of spores released by 6 May. Despite a lower risk of blackspot than in most years, it was evident throughout the season that the first time of sowing (10 May) was of no advantage in terms of dry matter production and subsequent seed yield. Early sowing increased the level of blackspot but this did not translate into yield differences. Overall at Scaddan there were no differences between varieties except for Dundale and Yarrum being lower yielding than other lines or mixes. There were no significant interactions between time of sowing and variety at Scaddan.

At Merredin the first sowing date was sown on 22 May when the closest model run indicated 68% of blackspot spores had been released. The 'Blackspot Manager' model uses 50% spore release as the critical value, after which it is considered safe to sow field pea. At Merredin in 2006 there were low levels of blackspot up until mid-late spring at which time the early sown plots did have higher levels of

blackspot than later sown plots. Despite higher blackspot levels the early sown plots out yielded later sown plots. Similarly higher or lower levels of blackspot on individual pea lines did not translate into corresponding lower or higher yields. For example WAPEA2211, a late flowering Kaspa like line derived by crossing Kaspa to New Zealand material had consistently lower levels of blackspot compared to other lines, but this did not translate into higher yields. At many sites in 2006 it was observed WAPEA2211 was more susceptible to downy mildew, which will limit the advancement of this line.

Bundi a white seeded semi-leafless variety which flowers around 10 days earlier than Kaspa was the only line at Merredin to be ranked equal top yielder at all times of sowing. Kaspa and WAPEA2211 a late flowering line performed well at the first time of sowing but lost close to 1.0 t/ha of yield when sown a month later. Conversely the early flowering Kaspa reselection WAPEA2213, is probably too early flowering for mid May sowing in most parts of WA and appears better suited to being sown at the end of May and well into June.

Mix treatments of early (WAPEA2213) and late flowering (Kaspa) semi-leafless lines were added to the experiment primarily as a potential frost effect reduction strategy. Neither Scaddan nor Merredin suffered from any appreciable frost. In 2006 at Merredin using mixes rather than selecting the best adapted line for each sowing time (e.g. Kaspa for 22 May, WAPEA2213 for June and July sowings) reduced yield.

KEY WORDS

field pea, blackspot, sowing date

ACKNOWLEDGMENTS

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Paper reviewed by: Ian Pritchard

Table 1. Grain yield (kg/ha) response to time of sowing of seven field pea lines and one mix at Scaddan and Merredin in 2006. Values underlined are equal to maximum yield

Line	Scaddan				Merredin			
	10 May	26 May	12 June	Mean	22 May	28 June	17 July	Mean
Kaspa	1375	1565	1004	1315	1936	1029	623	1075
WAPEA2213	1361	1556	972	1296	1209	1390	775	1092
WAPEA2211	1443	1324	1194	1320	1709	799	499	880
Bundi	1387	1648	1194	1410	1782	1398	773	1244
Yarrum	1222	1472	980	1225	1791	1114	890	1211
Mix of WAPEA2213 and Kaspa	1463	1463	1315	1414	1514	1161	695	1069
89-036-3-6	1500	1630	1083	1404	1505	987	780	1050
Dundale	1166	1419	738	1108	1668	909	686	1013
Mean	1365	1510	1060	1314	1625	1080	706	1074
	P	lsd			P	lsd#		
TOS	0.039	316			< 0.001			
Line	0.016	178			< 0.002			
TOS.Line	0.439	379	308		< 0.003			
			same TOS					

\# lsd not shown as data has been log transformed.

Table 2. Blackspot rating (0 = no Blackspot, 9 = all leaf area affected) in response to time of sowing of seven field pea lines and one mix at Scaddan and Merredin in 2006

Line	Scaddan 4 October								Merredin 27 September		
	Severity				Incidence				Rating		
	10 May	26 May	12 June	Mean	10 May	26 May	12 June	Mean	22 May	28 June	17 July
Kaspa	6	5	4	5	9	9	6	8	8	2	2
WAPEA2213	7	7	5	6	9	9	8	9	9	2	2
WAPEA2211	6	4	4	5	9	8	6	8	6	2	2
Bundi	7	6	6	6	9	9	7	8	8	2	2
Yarrum	7	6	5	6	9	9	7	8	8	2	2
Mix of WAPEA2213 and Kaspa	6	5	5	6	9	9	7	8	8	2	2
89-036-3-6	6	6	4	5	9	9	5	8	7	2	2
Dundale	8	6	5	6	9	9	7	8	6	2	2
Mean	7	6	5	6	9	9	7	8	8	2	2
	P	lsd			P	lsd			P	lsd	
TOS	0.018	1			0.006	1			< 0.001	1	
Line	< 0.001	1			< 0.00	10.5			0.018	1	
TOS.Line	0.35	1	1		< 0.001	1	1		1	1	1
			same TOS				same TOS				same TOS

Yield losses from sowing field pea seed infected with Pea Seed-borne Mosaic Virus

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KEY MESSAGES

- In a large scale field experiment in 2006, plots sown with 8% PSbMV-infected seed had final virus incidence of 35% and yield losses of 13%.
- Seed harvested from plots with > 50% PSbMV final incidence had 10% seed-borne infection in seedlings.
- Field pea seed should be tested for PSbMV before sowing. Only sow seed with < 0.5% infection.

BACKGROUND

Pea Seed-borne Mosaic Virus (PSbMV) causes a seed-borne and aphid-borne disease which reduces both yield and seed quality of field pea. PSbMV symptoms in field pea are often mild and growers frequently confuse the symptoms caused by PSbMV with those of nutrient deficiency or herbicide damage, consequently the economic impact of the disease is under-estimate. Previous surveys of field pea in WA, found commercial seed stocks to be infected with PSbMV (e.g. in 2005 PSbMV levels in cv. Kaspa were 0.3-23%). The seed-infected plants act as within-crop sources of PSbMV and is spread by a number of species of aphid to healthy plants. Field experiments in 2005 showed that sowing PSbMV-infected seed of field pea can result in considerable loss in seed yield (up to 25% from sowing 6.5% infected seed). Yield losses occurred with initial PSbMV seed infection of > 1% but not with < 1%. Further yield loss data, from sowing PSbMV-infected seed, are required to determine seed infection thresholds to minimise risk under different locations .

AIM

To determine the yield losses in field pea caused by sowing PSbMV-infected seed.

METHOD

In 2006, a large-scale field experiment with PSbMV infected field pea, cv. Kaspa, was established at Avondale Research Station to provide further yield loss information. Plots were sown with seed stocks with 0.1%, 0.25%, 0.5%, 1%, 2%, 4% or 8% PSbMV infection. Seed with no PSbMV infection was not available so the control treatment was sown with 0.1% infected seed and sprayed with insecticide (Fastac® + Confidor®) at emergence, 3, 7, 11 and 15 weeks to minimise aphid vectors transmitting the virus.

In addition, 2 smaller field demonstration trials were established at Scaddan and Katanning (GSARI) Research Stations to determine whether regular application of insecticide is effective in controlling the spread of PSbMV. Plots were sown with 0.5% or 5% PSbMV-infected seed, and were either sprayed with insecticide (Fastac® + Confidor®) at emergence, 3, 7, 11 and 15 weeks or left unsprayed.

For each trial, random leaf samples were taken from each plot either fortnightly (Avondale) or monthly (Scaddan and Katanning) to determine PSbMV incidence. All samples were tested by ELISA using PSbMV-specific antiserum. All plots were harvested and seed yield assessed. Seed harvested from each treatment was germinated and seedlings tested for PSbMV to obtain seed transmission rates.

RESULTS

At Avondale, the dry start to the season and consequent late June sowing, resulted in late aphid arrival and delayed PSbMV spread within plots until mid-September. Final PSbMV incidence increased with the amount of initial seed-borne infection from the seed sown. In plots sown with 8% infected seed, final PSbMV incidence reached 36% compared with 27-28% of plants infected in plots sown with 2% or 4% PSbMV-infected seed. Plots sown with <1 to 1% infected seed had final PSbMV levels of 4-15%. The late virus spread resulted in very mild symptoms, including stunting and general pallor of plants. Although spread only reached 36% in plots sown with 8% infected seed, the yield loss was 13% (Figure 1).

For the field demonstration trials, final PSbMV incidence differed greatly depending on the location. At Scaddan sowing was in late May and the initial virus spread was recorded in early August, prior to flowering. While at Katanning the late start to the season delayed planting until end of June, virus spread within plots started after flowering (mid September) due to late aphid arrival. Virus symptoms included plant stunting, early senescence of older leaves and plant pallor. At both sites, plots sown with 5% PSbMV-infected seed had higher final virus levels than those sown with 0.5% infected seed (e.g. at Katanning, in plots sown with 5% infected seed, PSbMV infection reached 41% compared with 9% of plants in plots sown with 0.5% infected seed giving yield loss of 33%). Plots with insecticide application had lower final PSbMV infection compared with unsprayed ones (e.g. at Scaddan plots sown with 0.5% infected seed reached final PSbMV incidence of 86% compared with 54% of plants in sprayed plots, the yield loss was 17%), except at Katanning where plots with 0.5% infected seed showed no difference in final PSbMV levels.

Seed transmission of 3% was found in seed harvested at Avondale from plots with final PSBMV incidence of 36% (8% seed infection sown), no seed transmission was found in seed harvested from plots initially sown with < 4% PSbMV seed infection. Seed from plots at Scaddan with final PSbMV incidence of 54-89% had seed transmission rate of 9-10%. At Katanning, final crop infection levels were 9-12% and seed transmission rates were 1-1.5%, while those plots with 17-41% final incidence resulted in 5-8% of seed producing infected seedlings.

CONCLUSION

This work supports previous experiments to show that sowing PSbMV-infected seed of field pea can result in considerable yield losses. The extent of those losses depends on a number of factors including the initial PSbMV infection level in seed sown, autumn and winter climatic conditions which affect when aphids arrive, both of which affect virus spread within the crop. The application of insecticides to control aphids and virus spread may be useful in reducing yield losses under certain conditions. Final PSbMV infection levels affect seed transmission levels in the harvested seed and continue perpetuation of the virus in subsequent seasons. It is advisable to get a sample of seed tested before sowing so as to avoid the yield losses that arise from using seed with > 0.5% PSbMV infection.

KEY WORDS

field pea, virus, disease, incidence, yield losses

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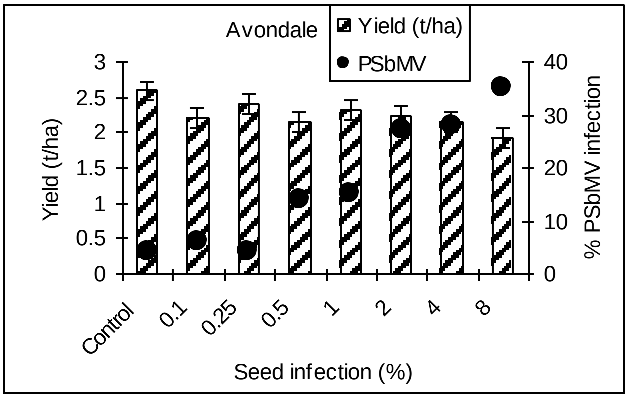

Figure 1. Effect of sowing PSbMV-infected seed on yield of field pea cv. Kaspa, Avondale.
Control =; 0.1% seed infection + Fastac® and Confidor® spray at emergence, 3, 7, and 11 weeks; Bars = lsd.

Faba bean in 2006

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About five thousand hectares of faba beans were sown in WA in 2006 with most being sown in the medium to high rainfall areas of the southern agricultural region. Early rains provided an opportunity for southern growers to sow their beans in April and May, but many growers in the northern wheatbelt either did not sow their beans or the crops struggled to emerge.

Dry conditions in spring reduced disease pressure in southern areas, but also reduced seed filling of crops. Yields were generally average to below average.

Many trials planned as part of the National Faba bean Improvement Program (NFBIP) in WA were not sown due to dry conditions at sowing. Those that were sown did quite well in a tough year, but there was very little disease to look for differences between lines. DAFWA moved the Stage 2 bulkup from Bindoon to Medina which was a resounding success in terms of multiplication rate and logistics.

In 2006 the technical officer working full time for NFBIP in WA, Tim Pope (CLIMA) resigned to take up a position in DAFWA. Terri Jasper was employed by DAFWA to fill this role and she worked closely with Ian Pritchard at DAFWA's Northam office and Mike Baker at South Perth to ensure the NFBIP trial program ran smoothly in 2006.

Germplasm evaluation – faba bean

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BACKGROUND

The total area cropped to faba bean in WA expanded rapidly in the early 1990s reaching a peak of about 40,000 ha in 1997. Disease (chocolate spot) epidemics and a series of dry seasons subsequently caused the area to fall to less than 10,000 ha. The release of Fiesta, a variety with improved chocolate spot resistance, and better disease management strategies has since seen a modest recovery in the faba bean industry. Nevertheless, at its current level the industry is well below its medium term potential of over 100,000 ha in WA.

There are two centres for breeding faba bean in Australia: Adelaide, SA and Narrabri, NSW. Germplasm from both these centres is evaluated in WA. The aim is to develop varieties with resistance to chocolate spot, ascochyta and rust, the three main faba bean diseases, as well as increased yield and yield stability. Fiesta is now the most widely grown faba variety in WA and has become the standard against which improvements in disease resistance and yield are measured. However, Fiord will produce higher yields than Fiesta in WA in disease free situations.

Germplasm was evaluated in Stage 2 (S2), Stage 3 (S3) and Stage 4 (S4) trials at several locations. The S2 trial was situated at Medina research station and involved 216 lines; mainly crossbreds obtained directly from the breeding centres in Adelaide and Narrabri. Stage 2 trials are mainly used for seed multiplication and results are not presented here. Stage 3 trials were planned for Dongara, Pingrup, Kojonup and Scaddan, but Dongara was not sown due to dry conditions. About 195 lines were evaluated at each site. Inclusion of lines in trials was dependant on the availability of seed. All lines were evaluated for a range of plant characteristics but only data on seed yield are presented here.

Stage 4 trials were planned for Mingenew (not sown – too dry), Moora, Corrigin (not sown – too dry), Gibson, Katanning (sown late and in dry conditions very low yields – data not shown), Mt Barker (weedy – sprayed off), Narrogin (not sown –too dry), and Muresk (not sown – too dry). Five current varieties plus eight lines that produced high yields in S2 and S3 trials over recent years were included.

KEY MESSAGES FROM STAGE 4 TRIALS

- No line out yielded Fiesta.
- 1270*278/10 remains in the mix to be the next line released to growers.

KEY MESSAGES FROM STAGE 3 TRIALS

- Five lines were ranked No. 1 at the three southern sites – AF02042, AF02002, AF02020, IX30/2-52 and 735*683/15
- 735*683/15 also performed well in 2005 S3 trials.
- 974*611*974/42 which performed well in 2005 also did well at Kojonup in 2006.
- AF02042, AF02002, AF02020 also performed creditably in 2005, ranked equal third across all sites.
- In individual trials there were up to 80 lines ranked equal No. 1 in 2006.

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RESULTS

Table 1. Grain yield (t/ha) and ranking of faba bean varieties in Stage 4 trials at Moora and Gibson (EDRS) in 2006

	Moora	EDRS
Sown	25 May	12 May
Harvested	7 November	8 November
Line		
1269*483/6	1.3	2.6
1270*278/10	1.3	3.3
483/5	1.4	2.8
974*(611*974)/42	1.0	3.0
Cairo	1.3	2.6
Farah	1.4	2.8
Fiesta	1.6	3.0
FiestaAR*(Ic*As)/2/DAW02-13	1.2	3.2
Fiord	1.3	2.8
IX30/1-09	1.5	3.0
IX30/2-20	1.3	3.0
Nura	1.2	2.9
SP98002	1.5	2.6
P	< 0.001	0.074
lsd 95%	0.2	0.6
lsd 90%		0.5

Table 2. Grain yield of faba bean lines in Stage 3 trials throughout Western Australia in 2006

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	t/ha	% of Fiesta	t/ha	% of Fiesta	t/ha	% of Fiesta
(IC*AS)*FIESTAAR/4	1.0	100	1.7	114	1.8	115
1038*286/32/DAW04-8	1.0	100	*	*	2.3	143
1103/3	1.4	148	*	*	1.6	98
1108/2	1.1	109	1.7	118	1.6	101
1149/4	1.0	107	1.7	114	1.5	96
1229/2/DAW03-4	0.9	90	1.2	80	1.6	99
1269*483/20	0.7	73	1.4	96	1.8	117
1269*483/6	0.9	97	1.5	103	1.6	99
1270*278/10	0.9	98	1.8	122	2.1	134
1270*483/20	1.0	106	1.2	82	1.9	117
1288/1/DAW43	1.0	105	1.7	116	2.0	126
1445/4	0.8	87	*	*	0.9	59
1447/1	1.1	117	1.4	95	1.1	69
1477/4	1.2	123	1.3	88	1.8	112
1505/1	0.9	92	1.6	105	1.7	107
1551	1.1	109	1.5	102	1.6	103
1554/DAW03-3	0.9	90	*	*	1.3	81
1555/1	0.8	88	1.6	106	1.3	85
1593	1.2	128	1.4	95	2.1	135
1783	0.5	48	1.0	66	0.9	59
1788	0.9	93	1.3	88	1.6	101
1841	0.6	65	0.9	64	0.9	56
227/2	0.7	69	1.5	100	1.0	62
278*1270/40	1.3	131	1.8	121	1.6	103
318/1	0.6	63	1.4	94	1.5	97
483*1270/25	1.0	105	1.8	120	2.0	125
AF02067	1.1	109	1.4	96	1.5	95
AF03001	0.9	91	1.5	100	1.7	110
AF03003	1.2	121	*	*	1.3	82
AF03017	1.1	116	1.1	76	1.5	93
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	t/ha	% of Fiesta	t/ha	% of Fiesta	t/ha	% of Fiesta
483/1/DAW03-1	0.7	76	1.5	100	2.0	124
483/5	1.3	130	1.7	117	1.2	78
611*722/3	1.0	105	1.4	95	1.9	119
683*834/18	1.1	119	1.4	94	1.7	105
735*683/15	1.1	112	1.7	118	1.9	121
974*611*974/2	0.8	85	1.4	93	1.8	113
974*611*974/2/DAW04-6	1.4	141	*	*	1.7	111
974*611*974/26	1.1	112	1.4	94	2.2	137
974*611*974/26/DAW04-5	0.9	91	1.4	93	1.7	107
974*611*974/32/DAW03-6	1.0	105	*	*	1.2	75
974*611*974/42	1.0	108	1.4	98	2.3	148
974*974*722/13	0.9	92	1.2	79	1.3	80
A-16/DAW04/3	1.0	100	1.3	88	1.4	87
AF02002	1.3	132	1.6	109	2.1	131
AF02007	0.8	80	1.4	96	1.8	114
AF02009	1.1	118	1.5	104	1.8	113
AF02010	1.2	122	1.8	123	1.6	103
AF02018	1.1	116	1.6	108	1.8	116
AF02020	1.1	111	1.6	108	2.0	128
AF02020/DAW04-4	1.0	103	1.8	123	1.9	121
AF02021	1.2	125	1.5	105	1.8	116
AF02042	1.2	123	1.5	102	2.1	133
AF02043	1.2	124	1.4	95	1.3	81
AF02044	1.2	127	1.7	112	1.7	109
AF02058	1.1	111	*	*	1.9	120
AF02061	1.0	107	1.5	105	1.5	93
AF03080	1.1	113	1.5	104	1.9	117
AF03081	1.0	108	1.5	103	1.8	117
AF03092	1.0	99	1.2	83	2.0	128
B-10/DAW04-2	1.0	102	1.4	95	1.4	89
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

Table 2 continued …

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
AF03018	1.1	114	1.3	85	1.8	117
AF03019	1.1	111	1.3	89	1.9	118
AF03023	0.8	85	1.3	91	1.5	96
AF03024	0.9	89	1.4	94	1.7	107
AF03025	1.0	104	1.4	94	1.8	117
AF03026	1.0	107	1.4	98	1.8	112
AF03027	1.0	105	1.5	105	1.6	100
AF03028	1.2	122	1.4	97	1.7	108
AF03030	1.3	132	1.4	93	1.9	117
AF03033	0.9	98	1.5	103	1.6	102
AF03034	0.9	88	*	*	1.7	111
AF03037	1.3	130	1.3	91	1.6	103
AF03039	0.8	84	1.5	99	1.9	122
AF03040	1.0	105	1.5	100	1.8	113
AF03041	0.8	85	1.5	104	1.3	83
AF03042	1.1	113	1.5	103	1.3	85
AF03043	1.1	109	1.3	90	1.8	112
AF03046	0.9	90	1.4	95	1.5	92
AF03048	0.9	88	*	*	2.0	125
AF03049	1.0	107	1.5	101	1.9	124
AF03054	0.6	58	1.3	89	1.7	111
AF03057	1.0	107	1.6	108	2.0	129
AF03059	1.0	104	1.5	99	1.7	108
AF03062	0.9	89	1.2	81	1.7	108
AF03063	0.8	87	1.1	78	1.8	111
AF03067	0.8	83	1.3	91	1.9	121
AF03068	0.8	80	0.5	37	1.5	96
AF03073	1.0	103	1.3	85	1.9	117
AF03075	1.1	109	1.5	103	1.9	118
AF03077	0.9	96	1.9	127	1.8	114
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
Cairo	1.1	115	1.9	127	1.8	114
D14/DAW03-10	0.6	66	1.7	115	1.6	102
D42/DAW03-9	0.8	83	*	*	1.4	91
Farah	1.0	107	1.4	94	1.9	119
FIESTA	1.0	100	1.5	100	1.6	100
FIESTA/MUT/DAW03-21	0.9	88	1.4	98	1.5	95
FIESTAAR*IC*AS/2DAW02-13	1.2	122	1.7	115	1.6	102
FIESTAAR*IC*AS/3	1.0	108	1.5	100	2.1	131
FIORD	1.1	114	1.5	100	1.4	87
HOMER/12	0.7	71	1.0	66	1.4	91
HOMER/9	0.9	90	1.4	94	1.5	96
IC*AS7/2	1.0	103	1.5	102	1.7	106
IX101/1-04	1.0	100	1.5	101	1.7	105
IX101/1-11	0.7	77	1.2	78	1.2	77
IX101/1-62	0.8	83	1.2	84	1.5	95
IX101/1-63	0.9	92	1.4	95	1.2	75
IX104/2-42	0.8	80	1.4	97	1.3	82
IX108/1-55	0.9	91	1.4	93	1.8	111
IX108/2-14	0.7	77	1.3	91	1.1	71
IX108/2-43	0.9	90	1.3	91	1.1	70
IX108/3-49	0.9	96	1.6	111	1.4	88
IX112/2-13	1.1	110	1.4	98	1.2	79
IX112/2-16	0.7	75	1.3	86	1.0	64
IX112/3-10	0.9	90	1.3	85	1.2	79
IX112/3-30	1.3	132	1.6	107	1.6	99
IX112/3-46	0.9	96	1.5	104	1.3	81
IX129/1-03	1.3	131	1.4	94	1.5	94
IX133/1-10	0.7	75	1.5	104	1.1	69
IX133/1-11	0.8	79	1.4	93	1.4	87
IX25/2-11	1.2	121	1.9	130	1.8	111
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

Table 2 continued …

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
AF03079	0.9	89	1.6	108	1.8	116
IX29/1-32	1.1	109	1.5	104	1.8	115
IX29/2-06	1.4	144	1.7	113	1.5	95
IX30/1-09	1.1	110	1.5	99	1.4	90
IX30/1-16	1.1	109	*	*	1.5	97
IX30/2-03	1.1	118	1.6	110	1.5	98
IX30/2-19	1.4	143	1.5	105	1.7	105
IX30/2-20	1.1	108	1.6	111	1.4	91
IX30/2-31	1.0	100	1.7	116	1.3	85
IX30/2-40	1.0	107	1.7	118	1.7	110
IX30/2-42	1.1	109	1.4	95	1.7	106
IX30/2-52	1.2	128	1.7	116	2.0	126
IX32/1-04	1.0	107	1.9	126	1.3	85
IX49/2-43	0.9	98	1.0	68	0.9	55
IX53/3-25	0.7	76	1.2	82	1.1	69
IX58/1-15	0.9	89	1.2	80	1.6	104
IX58/1-20	0.7	70	1.2	82	1.4	90
IX58/1-21	1.0	106	1.3	86	1.5	94
IX58/2-31	0.8	86	1.4	98	1.4	89
IX60/1-84	1.0	108	1.2	79	1.3	85
IX61/1-97	0.8	83	1.3	90	1.6	104
IX63/2-41	0.6	66	0.9	59	1.0	62
IX64/3-35	0.9	92	1.3	86	1.6	102
IX64/4-20	0.9	89	1.4	93	1.4	88
IX65-109	0.8	87	1.3	92	1.6	104
IX66/1-33	0.7	71	1.6	111	1.3	80
IX66/1-49	1.1	114	1.1	78	1.3	83
IX66/2-8	1.0	99	*	*	1.3	85
IX71-39	0.8	86	1.6	109	1.4	87
IX73/2-01	1.0	100	*	*	1.4	87
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
IX25/2-15	1.3	131	1.4	96	1.8	116
IX89/3-45	1.2	120	1.2	84	1.5	95
IX90/1-32	0.8	81	1.1	74	1.4	89
IX90/2-41	0.7	76	1.3	87	1.3	80
IX93/3-30	1.0	101	1.2	81	1.2	74
MANAFEST	1.1	112	1.6	105	1.7	108
NARBON BEAN	0.9	93	0.9	62	0.7	47
NURA	1.0	98	1.5	100	1.7	108
S95003/4/DAW03-5	1.1	115	1.9	128	1.6	102
SP01040	0.8	80	1.4	97	1.3	84
SP01041	1.1	115	1.3	86	1.4	91
SP01045	1.2	127	1.3	89	1.7	106
SP01092	1.3	135	1.4	95	1.5	93
SP01105	1.1	109	1.4	97	1.7	108
SP01118	1.0	107	1.4	94	1.6	99
SP01131	1.2	121	*	*	1.4	89
SP01143	0.8	87	1.4	93	1.2	75
SP01155	0.9	90	1.5	103	1.2	73
SP02043	0.8	87	1.4	92	1.7	107
SP02070	1.5	150	1.6	108	1.7	107
SP02074	1.1	118	1.4	97	1.6	100
SP02090	0.9	96	1.4	92	1.3	81
SP95054/DAW02-07	1.1	117	1.6	106	1.6	103
SP98002	0.9	97	1.4	92	1.3	83
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

Table 2 continued …

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
IX73/2-11	1.1	112	1.3	90	1.4	89
IX75/1-10	1.1	109	1.2	84	1.3	86
IX85/1-37	1.1	112	*	*	1.5	98
IX87/2-22	0.7	75	1.3	89	1.2	76
IX87/3-14	0.6	62	1.2	84	1.6	98
IX89/3-31	0.8	81	1.7	116	1.2	78
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

	Pingrup Sown 9 May Harvest 15 Nov.		Scaddan Sown 11 May Harvested 2 Nov.		Kojonup Sown 30 May Harvested 12 Dec.	
Line	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**	**t/ha**	**% of Fiesta**
P	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Average lsd	0.4	39	0.5	33	0.5	29

Breeding highlights of the Coordinated Improvement Program for Australian Lentils (CIPAL)

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KEY MESSAGES

- Two new lentil varieties, Nipper (red) and Boomer (green), with improved disease resistance (ascochyta blight and botrytis grey mould) will be available to growers in 2008.
- Boomer will offer a good alternative to growers wanting to produce green lentils, but Nipper is unlikely to provide any improvement over Digger and Cassab in Western Australia (WA).
- A number of breeding lines have performed well in 2005 and 2006 in WA, and are showing potential for commercial release in the future. These include 99-088L*02H037, 99-088L*02HO51, 97-030L*02H025, CIPAL411, CIPAL413, CIPAL415, CIPAL501, CIPAL609, CIPAL610 and CIPAL611.
- Evaluating germplasm at an early breeding stage in WA assists to identify adapted lentil lines suitable for the western region and other low rainfall environments across Australia that can be progressed towards commercial release.

BACKGROUND

The Coordinated Improvement Program for Australian Lentils (CIPAL) carries out lentil breeding and evaluation through the GRDC funded national pulse breeding program, Pulse Breeding Australia (PBA). CIPAL is based in Victoria (VIC) with collaborators in South Australia (SA), New South Wales, Tasmania and WA. The major objective of CIPAL is to develop superior red and green lentil varieties that will increase lentil production and profitability in Australia through greater productivity, reliability of yield and quality, reduced inputs and new market access. To achieve this, the breeding effort is focussed on developing breeding lines with appropriate phenology, improved disease resistance (ascochyta blight and botrytis grey mould), harvestability and seed quality (size, colour and milling), tolerance to soil limitations (boron and salinity) and common broadleaf herbicides, and resistance to exotic diseases (anthracnose, fusarium and rust). Evaluation of lentils in WA involves initial screening of early generation material (S1) in single rows at one site and two stages (S2 and S3) of replicated field trials at two sites.

AIMS

- To develop superior red and green lentil varieties with potential for Australia.
- To identify breeding lines with improved and stable yield, improved harvestability, vigorous early growth, early flowering, disease resistance and drought tolerance in WA.

METHOD

Trials were located at Merredin (S1, S2 and S3) and Coorow (S3) in 2006. The S1 trial comprised of 420 breeding lines and control varieties sown in unreplicated 2 m single rows. The breeding lines were visually evaluated for phenology (flowering and maturity), early vigour, disease resistance (ascochyta blight and/or botrytis grey mould if present), biomass production, podding intensity, grain loss (pod drop/shattering) and lodging. The S2 and S3 trials were sown in replicated plots (1.2 m wide x 10 m long) including 138 and 66 breeding lines and varieties, respectively. These trials were visually evaluated for characteristics similar to the S1 trial, and machine harvested for seed yield and mean seed weight.

RESULTS AND DISCUSSION

At Merredin and Coorow, seasonal rainfall (May-October) was well below average and the trial at Coorow was not harvested. Seed yield at Merredin was limited by pre-flowering moisture stress, particularly during June, July and August however rain in September provided enough moisture for crops to recover, but crop growth was variable across plots. There were no diseases observed in the trials. In general, weed control was good at Merredin and the trials were treated with insecticide after flowering to minimise the risk of aphid infestation.

Based on the observations made at Merredin and interstate S1 trials, 235 breeding lines were identified with promising adaptation. Of particular note at Merredin were 02-429L*04HS012, 02-190*04HS001, 02-623L*04HS004 and 01-Unknown*04H013. Due to drought across Australia in 2006, seed production in VIC and SA was severely limited, therefore selected lines were harvested at Merredin and seed production is in progress over summer under irrigation at Manjimup, WA. The results the 2006 S1 trials and screening nurseries (e.g. disease) will be used to select appropriate breeding lines for progression to S2 trials in 2007.

Mean seed yield of the S2 trial was 476 kg/ha (Table 1). A number of breeding lines out-ranked the commercial varieties for yield. Three lines (00-011L*03H003, 02-232*03HS019 and 99-078L*00HS008-03H038) showing promise in the WA S1 trial in 2005 also performed well in this trial with early maturity, good vigour, and final yield rankings of 2, 14 and 17, respectively. Three of the highest ranked S2 breeding lines in trials across Australia in 2006 (02-311*03HS021, 02-372*03HS012 and 02-139*03HS014) also ranked in the top 10 in this trial.

Table 1. Maturity score (MAT), mean seed weight (MSW, g/100 seeds), seed yield (SY, kg/ha and % Digger) and yield ranking (rank) of the highest yielding S2 lentil breeding lines and varieties at Merredin 2006 (sown 1 June)

Line/variety	MAT[1]	MSW	SY[2]	SY %Digger	Rank
Cumra	3.0	4.01	463	88	75
Digger	5.0	4.04	525	100	48
Northfield	6.0	3.11	368	70	117
02-098*03HS012	5.0	3.43	757	144	1
00-011L*03H003	4.0	3.67	754	144	2
02-222*03HS023	4.0	3.82	707	135	3
02-212*03HS021	5.0	3.94	703	134	4
02-311*03HS021	3.5	4.15	682	130	5
02-173*03HS025	5.0	3.20	677	129	6
02-139*03HS014	5.0	3.33	674	129	7
02-372*03HS012	4.5	4.06	667	127	8
01-419L*1-03HS023	5.0	3.29	666	127	9
02-218*03HS009	5.0	3.38	647	123	10
02-312*03HS010	5.0	3.43	635	121	11
02-321*03HS010	6.0	3.84	626	119	12
99-067L*03H003	4.5	3.44	621	118	13
02-232*03HS019	4.5	4.38	619	118	14
02-196*03HS035	5.0	4.05	601	115	15
02-022*03HS002	4.5	2.75	601	115	16
99-078L*00HS008-03H038	3.5	4.49	601	115	17
02-173*03HS030	5.0	3.78	599	114	18
02-161*03HS019	5.0	3.77	594	113	19
02-196*03HS030	5.5	4.49	593	113	20
Mean	5.2	3.59	476		
lsd 5%	-	-	190		

1 Maturity score where 1 = very early to 9 = very late.
2 Seed yield analysed using REML statistical methods.

The stage 3 evaluation trial at Merredin included a selection of mainly red lentil varieties and lines (Table 2). Mean seed yield was 615 kg/ha. Similar to the S2 trial, this trial was quite variable due to the high level of moisture stress. A number of breeding lines exhibited significantly greater yields than current commercial varieties. The lines 99-088L*02H051, CIPAL501, CIPAL609 and CIPAL611 produced the greatest seed yields, and two of these lines (99-088L*02H051 and CIPAL611) also performed well at Merredin in 2005. The line CIPAL610 was not outstanding in this trial in 2006, but was identified in S1 trials at Merredin in 2004, performed well in WA in 2005 and has produced the greatest mean yield across Australia in 2006.

Table 2. Yield ranking[1] in S2 trial in WA 2005, Maturity score (MAT), mean seed weight (MSW, g/100 seeds), seed yield (SY, kg/ha and % Digger) and yield ranking (rank) of the highest yielding S3 lentil breeding lines and varieties at Merredin 2006 (sown 2 June)

Breeding line/variety	Rank S2 WA 2005	MAT[2]	MSW	SY[3]	SY %Digger	Rank
Aldinga	-	6.0	4.42	697	126	12
Boomer (CIPAL402)[4]	-	5.3	5.82	610	110	32
Cassab	7	6.0	3.96	452	82	65
Cumra	-	3.0	4.28	598	108	35
Digger	16	5.0	3.60	554	100	48
Nipper (CIPAL203)	-	5.7	3.56	500	90	60
Northfield	-	5.7	2.80	679	123	16
Nugget	-	6.3	3.65	694	125	13
CIPAL405	-	5.0	3.80	643	116	27
CIPAL411	-	3.7	4.02	545	98	51
CIPAL413	-	5.3	4.48	744	134	7
CIPAL415	-	4.7	3.12	568	103	41
CIPAL501	-	5.0	4.06	830	150	2
CIPAL502	-	5.0	2.60	553	100	49
CIPAL504	-	3.7	4.42	664	120	20
CIPAL601(94-003L*98H039)		5.7	4.88	481	87	62
CIPAL602 (96-024L*00H058)	-	5.3	3.72	582	105	37
CIPAL603 (97-031L*01H013)	-	3.0	3.55	668	121	18
CIPAL604 (97-049L*00H020)	-	4.3	4.91	661	119	21
CIPAL605 (97-050L*01H043)	-	5.3	3.93	616	111	30
CIPAL606 (98-009L*01H046)	-	6.0	3.40	530	96	55
CIPAL607 (98-009L*01H060)	-	5.7	3.22	692	125	14
CIPAL608 (98-009L*01H061)	-	5.7	3.16	615	111	31
CIPAL609 (98-035L*01R014)	-	3.7	4.14	800	144	3
CIPAL610 (99-070L*02H036)	8	2.0	5.20	554	100	47
CIPAL611 (99-088L*02H003)	1	5.7	4.35	788	142	4
99-088L*02H051	13	3.3	4.60	834	151	1
98-043L*01H008	-	4.7	3.76	779	141	5
97-039L*98S172-99HS001	-	5.0	4.00	771	139	6
97-039L*99R098	-	4.7	4.08	743	134	8
99-088L*02H037	2	4.3	4.22	718	130	9
97-030L*02H025	20	6.3	4.18	708	128	10
Mean	-	5.3	3.81	615	-	-
lsd 5%	-	-	-	152	-	-

1 Yield ranking if in top 25 lines 2005.
2 Maturity score where 1 = very early to 9 = very late.
3 Seed yield analysed using REML statistical methods.
4 Indicates green lentils.

Two new varieties were commercialised in 2005, but problems with seed production have seen release to growers delayed until 2008. Nipper, tested as CIPAL203, is the first red lentil released in Australia with disease resistance to both ascochyta blight and botrytis grey mould. In most other characteristics it is similar to Northfield, including seed shape and size, but is more suited to the longer season environments of eastern Australia where Northfield is well-adapted. Boomer, which has replaced the green lentil variety, Matilda, was the only green lentil included in the trial and performed similarly to Digger and Cassab for seed yield (Table 2). Both new varieties have improved disease resistance (ascochyta blight and botrytis grey mould) compared to current varieties. In general, Nipper is unlikely to provide any improvement over Digger and Cassab in WA, but Boomer may offer a good alternative to growers providing they want to produce green lentils.

The results from the S1, S2 and S3 trials in WA and similar trials across Australia will be used to identify which lines/varieties offer the best potential and where they should be targeted for production. Since the introduction of S1 evaluation in WA (2004), key lines with adaptation to WA have been identified. These lines are now being evaluated in National Variety Testing (NVT) trials and demonstrate the value of regional testing at an early stage in the breeding program. Given the dry conditions experienced across Australia in 2006, further evaluation in breeding trials and NVT trials will be necessary in 2007 to provide reliable information and validate the potential of the most advanced breeding lines.

KEY WORDS

lentil, Coordinated Improvement Program for Australian Lentils (CIPAL), Pulse Breeding Australia (PBA)

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Screening pulse germplasm for tolerance to alternate herbicides

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INTRODUCTION

The control of broad-leaf weeds in pulse crops, particular wild radish, has become a critical issue not only for the profitability of pulse crops but also for the general management of broad-leaf weeds in cropping rotations. Wild radish is the major broad-leafed weed in Western Australia. This is due primarily to the evolution of multiple herbicide resistance in this weed which is now a common occurrence in wild radish populations occurring across the WA wheatbelt. The increasing difficulty in controlling this weed is reducing the profitability of pulse crops in particular as well as cropping systems in general.

Herbicides with alternate modes of action are required and isoxaflutole (Group F), isoxaben (Group K) and carfentrazone-ethyl (Group G) are candidate herbicides being evaluated in this project. There is limited knowledge of the tolerance of lupin, chickpea, lentil, faba bean and field pea to these herbicides. Earlier work (Si *et al*. 2006) has shown that narrow-leafed lupin germplasm has higher tolerance to isoxaflutole and carfentrazone than canola. Identification of tolerant germplasm would be valuable to plant breeders and potentially enable the utilisation of these chemistries in pulse crops.

AIMS

To screen a broad cross section of pulse cultivars and germplasm of the major Australian pulses species for tolerance to isoxaflutole, isoxaben and carfentrazone-ethyl.

METHOD

The number of germplasm accessions screened was: 100 each of lupin, chickpea and field pea and 50 each of lentil and faba bean. Two wild radish populations were included as control. The accessions of each species were obtained from germplasm centres and breeding programs across Australia and consisted of wild types, land races and cultivars in the world.

Screening took place from July to October in 2005 and 2006 at UWA Crawley campus. Thirty plants of each accession were grown in a rectangular tray containing potting mix at an outdoor area. Plants were watered and fertilised when necessary. Carfentrazone-ethyl (Group G) and isoxaben (Group K) were applied to uniform seedlings at 4-leaf stage using a cabinet sprayer fitted with two flat fan nozzles with a delivery rate of 110 L/ha. Isoxaflutole (Group F) was applied 1 day after sowing. Herbicide rates used in the screening were 250-300 g/ha for isoxaflutole, 250 g/ha for isoxaben and 80 g/ha for carfentrazone-ethyl. These rates gave the largest differentials between pulses and wild radish, according to preliminary dose response experiments comparing two cultivars and wild radish. Visual damage was recorded at 2-3 weeks after spraying for individual plants using a scale from 0 to 5 where 0 = no symptom and 5 = plant dead.

RESULTS

Isoxaflutole

Chickpea cultivars and germplasm had no visual damage symptoms to isoxaflutole at three weeks after herbicide application (Table 1). Field pea cultivars Excell and Helena showed no damage whilst Kaspa had mild symptoms at 300 g/ha (Table 2). Across 100 accessions of the field pea germplasm, most had none or mild symptom. Lentil germplasm appeared to be susceptible. Faba bean cultivars were variable, with Nura having little symptom and Farah severely damaged. Faba bean germplasm showed similar range of variation in tolerance to commercial cultivars (Table 2).

Isoxaben

Lupin and chickpea germplasm collections and cultivars showed complete tolerance to isoxaben at 250 g/ha when screened in 2005 whilst wild radish was severely damaged (Table 1). In 2006, lentil was the most tolerant among other pulses screened although variation ranging from little to moderate damage was observed in the germplasm (Table 2). Field pea and faba bean were clearly more tolerant than wild radish.

Carfentrazone-ethyl

All grain legumes species had moderate damage by carfentrazone-ethyl at two weeks after spray, but the damage to wild radish was more severe (Tables 1 and 2).

DISCUSSION

The high rate of herbicides used in the screening trials allows us to differentiate germplasm rapidly so that a large number of accessions can be assessed over a short period of time. Lines that show no or minimal visual symptoms at two to three weeks after spraying should be considered potentially tolerant. Ideally such accessions should be tested further in terms of biomass reduction compared to unsprayed controls.

Chickpea is the most tolerant species among the five pulses screened against isoxaflutole. Isoxaflutole is registered in chickpea. Field pea showed a relatively good level of tolerance.

We identified tolerance in faba bean although the level of tolerance is not quite as good as chickpea. This knowledge highlights the possibility to improve the tolerance in faba bean. The large differences in tolerance between cultivars Nura and Farah suggest that it would be effective to select for tolerance in the breeding program.

Post-emergent application of isoxaben caused no damage in lupin and chickpea at rates which damaged and retarded growth of wild radish. Damage in field pea, faba bean and lentil was mild. The comparative advantage of pulses over wild radish suggests that it would be worthwhile for further investigation.

Carfentrazone-ethyl caused significant visual damage in all pulses. However, in other experiments we have seen that they grow out of these symptoms but it is not known to what extent their growth under field conditions would have been compromised.

IMPORTANT NOTE

All herbicides mentioned in this paper are not currently registered or recommended on any pulse crop in Australia except isoxaflutole in chickpea.

KEY WORDS

isoxaflutole, isoxaben, carfentrazone-ethyl, wild radish, lupin, chickpea, field pea, lentil, faba bean

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Table 1. Comparison of lupin and chickpea with wild radish in response to isoxaflutole, isoxaben and carfentrazone-ethyl in 2005

Species	Germplasm	Cultivar	Visual damage score[A]		
			Isoxaflutole @ 250 g/ha	Isoxaben @ 250 g/ha	Carfentrazone-ethyl @ 80 g/ha
Narrow-leafed lupin	Mean[B]		-	0	4.3
	Range		-	0	2.8-5.0
		Belara	1.5	0	3.7
		Mandelup	1.5	0	3.9
		Tanjil	2.5	0	3.8
Chickpea	Mean[B]		0	0	2.3
	Range		0	0	0.6-4.0
		Genesis 509	0	0	3.0
		Kimberly Large	0	0	1.6
		Sonali	0	0	2.7
Wild radish		WARR 7	5.0	2.7	4.8
		WARR 5[C]	4.4	3.4	4.9

[A] Score scales: 0 = no symptoms and 5 = plant dead.
[B] Mean of 100 accessions for each species and each accession consisting of 30 plants.
[C] Wild radish population resistant to Group C herbicides.

Table 2. Comparison of field pea, faba bean and lentil with wild radish in response to isoxaflutole, isoxaben and carfentrazone-ethyl in 2006

Species	Germplasm	Cultivar	Visual damage score[A]		
			Isoxaflutole @ 300 g/ha	Isoxaben @ 250 g/ha	Carfentrazone-ethyl @ 80 g/a
Field pea	Mean[B]		0.6	1.5	3.2
	Range		0-3	0.3-3.5	1.3-4.6
		Excell	0	1.8	2.6
		Helena	0	1.5	2.9
		Kaspa	0.5	2.3	3.0
Faba bean	Mean[B]		2.0	1.0	2.7
	Range		0.5-4.5	0-2.5	1.7-4.0
		Farah	4.5	1.5	3.9
		Fiord	1.5	1.5	3.2
		Nura	0.5	2.5	3.7
Lentil	Mean[B]		3.4	0.7	4.7
	Range		1.0-5.0	0.1-1.3	1.2-5.0
		Boomer	2.5	0.8	4.6
		Digger	4.0	0.8	4.9
		Nipper	4.5	0.8	5.0
Wild radish		WARR 7	5.0	3.3	3.5
		WARR 20[C]	4.5	4.8	3.0

[A] Score scales: 0 = no symptoms and 5 = plant dead.
[B] Mean of 100 accessions for field pea and 50 accessions for either faba bean or lentil, and each accession consisting of 30 plants.
[C] Resistant to Group B and C herbicides.

Genomic synteny in legumes: Application to crop breeding

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AIMS AND BACKGROUND

Orthologous markers transferable between distantly related legume species allow for the rapid generation of genetic maps in species where there is little pre-existing genomic or EST information. We are using the model legume *Medicago truncatula* (Mt) to develop such markers in legumes of importance to Australian agriculture. This will enable the construction of comparative genetic maps, help to determine patterns of chromosomal evolution in the legume family, and characterise syntenic relationships between *M. truncatula* and cultivated legumes. This information can then be used to identify markers tightly linked to the genes of interest, candidate gene/s for a trait, and expedite the isolation of such genes.

MARKER DEVELOPMENT

Among the Papilionoideae, we compared ESTs from the phylogenetically distant Mt, *Lupinus albus*, and Glycine max species to produce 500 intron-targeted amplified polymorphic markers (ITAPs). In addition to 126 Mt cross-species markers from Department of Plant Pathology, University of California (USA), these markers were used to generate comparative genetic maps of lentil (*Lens culinaris*), white lupin (*Lupinus albus*) and faba bean (*Vicia faba*).

MARKER GENERATION AND GENETIC MAPPING

Our results showed that ninety per cent of the ITAPs markers amplified genomic DNA in Mt, eighty per cent in *L. albus*, and seventy per cent in *L. culinaris*. The comparative map of *L. culinaris* was constructed based on 79 ITAP markers. The *L. albus* comparative map was developed using 105 gene-based markers together with 223 AFLP markers. Although a direct and simple syntenic relationship was observed between Mt and *L. culinaris* genomes, there is evidence of moderate chromosomal rearrangement. This can account for the different chromosome numbers in the two species (Figure 1). A more complicated pattern among homologous blocks was apparent between the *L. albus* and Mt genomes (Figure 2).

A similar approach using published Mt SSR markers successfully generated sets of orthologous Mt markers that are polymorphic within Australian lucerne breeding lines. These identified markers were used to assign lucerne disease resistance maps to fully sequenced Mt chromosomes. This information would greatly assist to identify more closely linked markers to the mapped disease resistance genes/QTL. In addition, all these orthologous markers are being used for comparative mapping in faba bean.

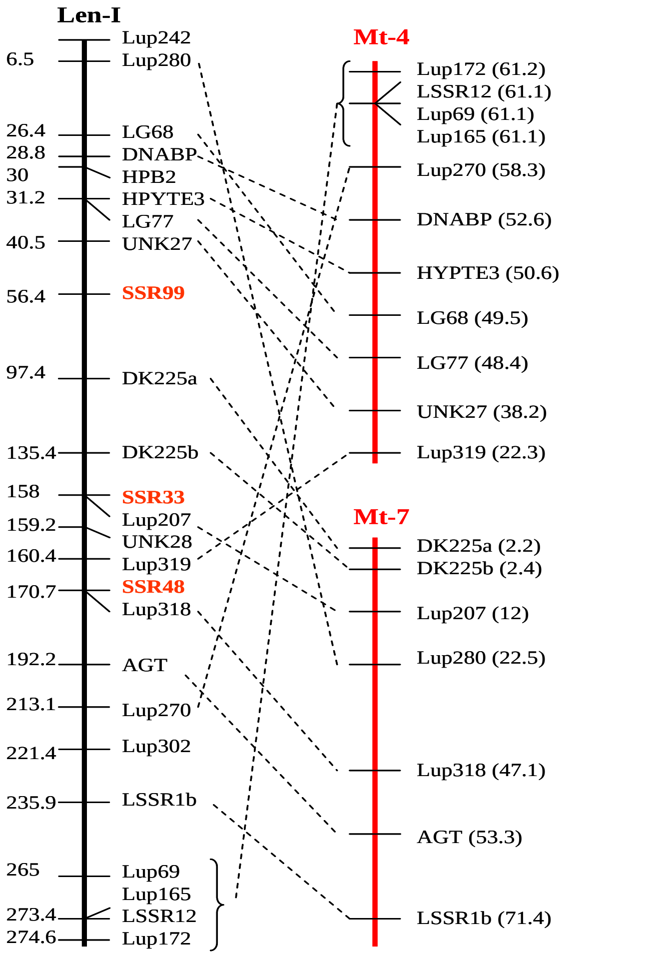

Figure 1. **An example of macrosynteny between *Medicago truncatula* LG4 and 7 and lentil LG1.**

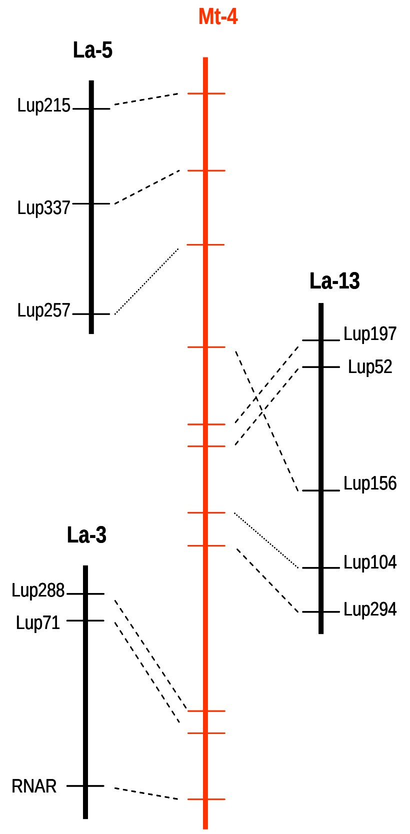

Figure 2. **An example of macrosynteny between *Medicago truncatula* LG4 and *L. albus.***

ACKNOWLEDGEMENTS

We thank Dr Hua'an Yang and Dr Bevan Buirchell for providing *L. albus* seeds for the mapping population. This research was supported by ARC Linkage project LP0454871 and NSW Department of Primary Industries.

Tolerance of lupins, chickpeas and canola to Balance® (Isoxaflutole) and Gallery® (Isoxaben)

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BACKGROUND

Balance® is a group F herbicide, which is registered for post sowing/pre emergence application in Chickpeas and is generally not incorporated in the soil. It is used for the control of wild radish and cape weed. Gallery® is a group K herbicide used to control the wild radish and cape weed but in soybean crops and orchards. It is not registered for use on pulse crops.

AIMS

- Determine species sensitivity to Balance®.
- Determine species sensitivity to Gallery®.
- Determine a sensitivity rate for future testing.

METHOD

Two pot experiments were conducted concurrently in the glasshouse at the Department of Agriculture and Food, South Perth. Both trials used the same seed source and two replications. Pots contained 2.75 kg of red sandy loam soil and were sealed at the bottom to prevent drainage. Full basal nutrients were applied in solution to the surface of the soil. Balance® (75% isoxaflutole ai) or Gallery® (75% isoxaben ai) were applied to the surface of the soil as a suspension in water. Once dry, nutrients and herbicide were mixed throughout the soil. Ten seeds per pot were sown. The water content of the soil was maintained at field water capacity for the duration of the trial.

Experiment 1 was a factorial combination of eight rates of isoxaflutole (0.01, 0.02, 0.04, 0.08, 0.16, 0.32, 0.64, and 1.28 µg isoxaflutole/g soil) and four species (*L. angustifolius* (narrow-leafed lupin) cv. Mandelup; *L. luteus* (yellow lupin), cv. Pootallong; *Brassica napus* (canola), cv. Boomer; and *Cicre arietinum* (chickpea), cv. Howzat).

The number of seedlings that emerged was counted at 11 and 14 days after sowing (DAS). Plants were thinned to four plants per pot 14 DAS. At 14 DAS plants were also scored for the severity of leaf scorching using a 1 to 5 scale where 1 = healthy plants and 5 = severely scorched leaves with the plant dead or dying. Shoots were harvested 28 DAS.

Experiment 2 was a factorial combination of eight rates of Gallery (0.02, 0.04, 0.08, 0.16, 0.32, 0.64, 1.28 and 2.56 µg isoxaben/g soil) and four species (same as experiment 1). The number of seedlings that emerged was counted at 11, 14, 23 and 28 DAS. At 14 DAS plants were also scored for the severity of leaf scorching using a 5 step scale where 1 = healthy plants; 5 = severely scorched leaves with the plant dead or dying. Shoots were harvested 28 DAS.

RESULTS

Experiment 1

Eleven days after seeding (DAS), more ($P < 0.001$) canola seedlings had emerged than chickpea seedlings. This trend was the same for all rates of isoxaflutole. By 14 DAS, however, all species had the same number of plants emerged.

At 14 DAS Boomer showed more scorching than other species at all levels of isoxaflutole (Figure 1). At the lowest three rates of isoxaflutole Mandelup had a lower score for scorching than Howzat (Figure 1). From the fourth rate (0.08 µg/g soil) the score for Mandelup was higher than for Howzat. All other species scored the same or worst than Howzat.

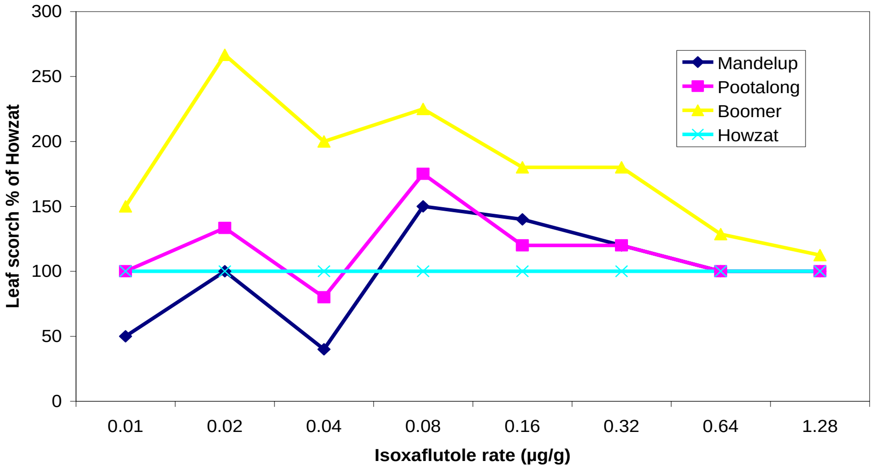

Figure 1. **The effect of increasing rate of isoxaflutole, on scorching of leaves in narrow-leafed lupin (Mandelup), yellow lupin (Pootallong), canola (Boomer) and chickpea (Howzat). Plants were rated at 14 DAS on a 1 to 5 scale: 1 = no scorching; 5 = severely scorched leaves with the plant dead or dying. Scores are presented as a percentage of Howzat.**

Application of isoxaflutole substantially reduced ($P < 0.01$) the dry weight of shoots of all species (Figure 2). Boomer grew very poorly and produced less than 0.1 g per pot at all rates of isoxaflutole so we have not presented data on the dry weight of shoots of Boomer. The dry weight of shoots of Pootallong was the same as Howzat at all rates of isoxaflutole. Overall average of Mandelup produced about 120% greater ($P < 0.001$) dry weight of shoots than Howzat or Pootallong at the first four rates of isoxaflutole and then the same dry weight of shoots at rates of isoxaflutole higher than 0.08 µg/g.

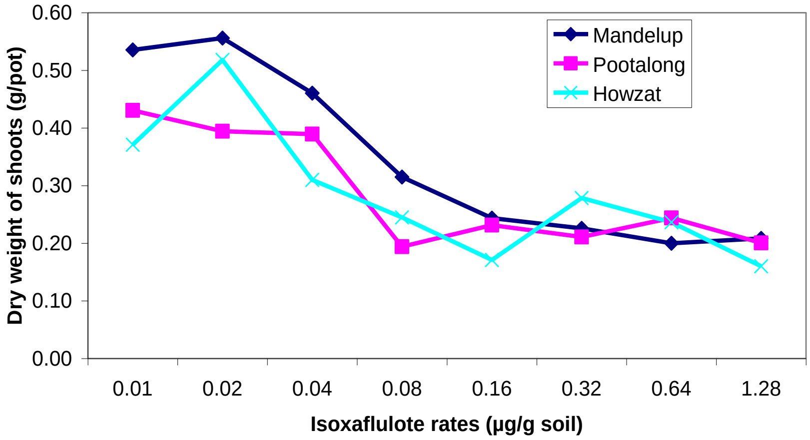

Figure 2. **The effect of increasing rate of isoxaflutole, on dry weight of shoots (g/pot) at 28 DAS for narrow-leafed lupin (Mandelup), yellow lupin (Pootallong), canola (Boomer) and chickpea (Howzat). Species by chemical rates significant P = 0.025.**

Experiment 2

Mandelup showed no reduction in emergence for the first three rates (0.02, 0.04 and 0.08 µg/g soil) of isoxaben at 11 DAS. For rates 0.16 to 2.56 µg/g soil, there was a reduction of 15% to 95% in emergence. Pootallong had a emergence reduction from 25% to 100% (lowest to highest rate). From 0.32 µg/g soil of isoxaben on wards there was no emergence. Howzat also had a emergence reduction of 40% to 95%. The surviving plants showed signs of malformation or distortion of the leaves with the increase rate of chemical. Boomer also had germination reduction similar to Howzat, but by the 14 DAS they had nearly total seedling death for all rates except 0.01 µg.

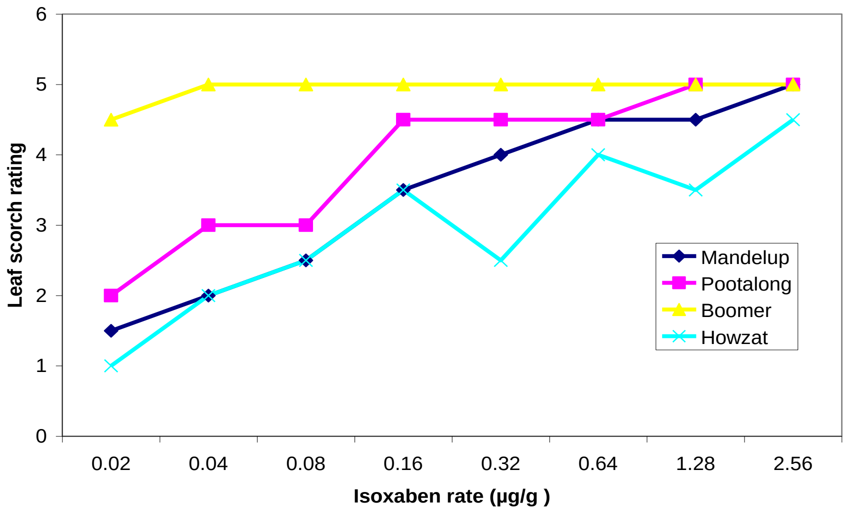

Figure 3. The effect of increasing rate of isoxaben, on scorching of leaves in narrow-leafed lupin (Mandelup), yellow lupin (Pootallong), canola (Boomer) and chickpea (Howzat). Plants were rated at 14 DAS on a 0 to 5 scale: 1 = no scorching; 5 = severely scorched leaves with the plant dead or dying.

The Figure 3 shows the comparison of the scoring for all species. As indicated the isoxaben wiped out the Boomer plants. Although all species were badly affected by isoxaben even at the lower rates, Howzat seems to be less affected followed by Mandelup. Species by Chemical rate P = 0.012.

DISCUSSION

At low rates of application (< 0.04 µg/g) seedlings of Mandelup and Pootallong in this trial appeared to be as tolerant to isoxaflutole as Howzat. These low rates of application marginally affected the growth of Howzat but severely reduced the growth of Boomer, so they may be equivalent to effective rates used for radish control in chickpea production. Mandelup however, may be more sensitive than Howzat or Pootallong to higher rates of isoxaflutole because its dry weight shoots declined a proportionally greater amount when plants were grown at rates higher than 0.16 µg/g compared with rates lower than 0.08 µg/g).

Given the poor plant emergence and leaf scorch ratings for isoxaben for all species used in this trial, it seems unlikely that isoxaben would be safe to use as a pre-sowing or pre-emergence in pulse crops. Although the data suggest that Howzat might have a little more tolerance to the herbicide. However, (Dhammu and Nicholson 2006) has shown in field trials that lupins have good tolerance to isoxaben when applied at the 2-4 leaf stage.

Further trials for both in the glasshouse and field would be advantage to find the recommended rates, application and timing of isoxaflulote or isoxaben that could be applied for maximum effect on the weeds with little effect on the lupins.

KEY WORDS

ixoaflutole, isoxaben, canola, chick pea, Narrow Leaf Lupin (NLL) *L. lutues* (Yellow Lupins), germination counts, dry matter weights

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CANOLA AND OILSEEDS

The performance of TT Canola varieties in the National Variety Test (NVT), WA, 2006

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KEY MESSAGES

- The seasonal conditions for the second year of the NVT program were in complete contrast to those of 2005. Canola variety performance across WA in 2006 was evaluated under below average rainfall with a short hot finish to the season compared to the 2005 season which had above average rainfall and a cool finish.
- The dry conditions at sowing, during plant establishment and early growth influenced days to 50% flower in northern and central regions. Varieties took longer to reach 50% flower compared to 2005. The days to 50% flower in southern regions were similar to 2005.
- There was less flowering differential between varieties in 2005 compared to 2004.
- With the exception of cooler coastal and southern sites, short season maturity varieties dominated the rankings in 2006. The season tested the ability of varieties to take advantage of limited moisture and complete flowering and pod fill under harsh growing conditions.
- Stubby, Boomer and Tanami were consistent performers across a range of sites with Cobbler and Rottnest both showing some consistency after one year of NVT evaluation. The dry seasonal conditions suited short season varieties which are notorious for being determinant in nature and lacking in ability to take advantage of an extended growing season. Tanami and Cobbler both show potential to take advantage of a range of seasons, with yields ranging from 0.80 t/ha-2.61 t/ha in 2006. These varieties also have the potential to provide a late May sowing option that will compete with wheat for profitability.
- Of the mid season varieties, Bravo and Thunder show yield consistency across a range of sites over two years. These varieties perform particularly well in cooler, longer growing season environments, show some degree of adaptability to sowing time and season length and are suited to most regions. These varieties perform well with an early break and longer growing season.
- Management decisions on variety selection should not solely be based on one season's data. The 2005 and 2006 results can be accessed on the database website www.nvtonline.com.au.

AIMS

To independently evaluate canola variety performance in the 2006 growing season across rainfall zones and soil types in the WA wheatbelt as part of the National Variety Testing (NVT) program.

To compare canola variety performances in the 2006 growing season to the 2005 growing season.

METHOD

Twenty-one triazine tolerant, main season and early season canola varieties were evaluated across 20 sites within the six Agzones in WA. The soil type was predominantly sandy gravel, the exception being Scaddan which was shallow sand over clay duplex. All canola trials were sown at a single time of sowing, 5-27 May, the exception being Williams sown on 8 June. Trials were designed with three replications across six ranges as complete block randomisations as per Australian Crop Accreditation System (ACAS) protocols. Canola vigour, blackleg, relative flowering, grain yield and quality were evaluated. National Statistics Program Biometricians are contracted by the GRDC to analyse the data.

RESULTS

Table 1. Flowering comparison to ATR-stubby (relative days after sowing to 50% flowering)

Variety	Avg 2005	Avg 2006	North 2005	North 2006	Central 2005	Central 2006	South 2005	South 2006
	91 das	98 das	77 das	96 das	91 das	100 das	98 das	99 das
ATR Banjo	8	2	9	3	7	2	9	2
ATR Barra		5		5		6		3
ATR Beacon	15	5	16	5	13	4	16	5
ATR Cobbler		-1		-2		-2		0
ATR Grace	19		18		18		19	
ATR Hyden		6		7		6		6
ATR Marlin		4		4		3		5
ATR Signal		1		1		0		2
ATR Stubby	0	0	0	0	0	0	0	0
ATR Summitt	16	6	17	6	16	6	17	6
BravoTT	12	2	16	1	9	2	11	3
CB Boomer	-3	-2	3	-2	-6	-2	-4	-2
CB Trigold	-4		-7		-1		-4	
Flinders TTC		6		5		5		6
Rottnest TTC		0		-1		-1		0
Surpass 501 TT	11	0	18	-1	11	0	14	0
CB Tanami		-2		-2		-3		-2
ThunderTT	13	5	17	6	9	4	13	6
TornadoTT	8	2	13	2	5	0	8	2
Trilogy	-10		-11		-10		-10	

Table 2. TT Canola Grain Yield (t/ha) and Oil Content (%) for Central and Northern Regions in 2006 WA NVT Trials

Location		Eneabba (sown 5/5/06)				Calingiri (sown 27/5/06)				Cunderdin (sown 11/5/06)				Merredin (sown 12/5/06)			
Agzone		2				2				2				4			
Rainfall zone		H2				H3				M3				L3			
		Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)
Early	**ATR Banjo**	2.31	45.3	13	3	1.55	44.1	21	2	1.11	38.9	15	11	0.74	39.7	19	9
	ATR Cobbler (NMT040)	2.34	44.9	11		1.82	42.4	3		1.37	36.7	5		1.09	40.5	2	
	ATR Hyden	1.93	43.4	21		1.57	40.4	19		1.05	36.3	16		0.89	36.4	13	
	ATR Marlin (ATR423)	2.31	47.4	14		1.71	44.0	10		1.17	40.4	13		0.97	39.8	6	
	ATR Signal (NMT052)	2.31	42.9	15		1.64	40.2	14		0.86	36.0	21		0.69	37.9	21	
	ATR Stubby	2.41	43.5	8	2	1.57	41.2	20	3	1.38	36.3	4	3	0.78	37.2	17	6
	CB Boomer (CBTT-026)	2.27	44.6	17	11	1.67	42.7	12	7	1.42	37.0	3	5	1.16	39.4	1	2
	CB Tanami (CBTT-061)	2.5	43.6	4		1.78	41.2	4		1.72	38.3	1		0.99	38.4	5	
	CB Trigold	2.11	46.8	19	7	1.75	44.1	5	9	1.49	39.2	2	12	1.02	40.8	4	7
	Rottnest (ATR501)	2.41	43.0	9		1.91	41.5	1		1.24	38.1	10		1.09	38.1	3	
	Surpass 501TT	2.04	46.8	20	13	1.63	44.7	15	11	1.26	40.9	8	4	0.87	43.2	15	12
Main	**ATR Barra (TN4*207)**	2.59	46.0	1		1.6	43.1	17		0.94	39.2	19		0.9	39.7	12	
	ATR Beacon	2.43	43.6	6	8	1.72	41.4	8	10	1.02	37.6	17	9	0.87	39.3	14	4
	ATR Summitt	2.36	44.8	10	6	1.58	43.4	18	5	0.9	37.9	20	10	0.86	40.9	16	8
	BravoTT	2.58	45.2	2	1	1.62	42.1	16	1	1.24	37.5	9	6	0.97	39.6	7	1
	Flinders (ATR438)	2.44	45.6	5		1.75	42.8	6		1.2	39.3	12		0.75	39.8	18	
	ThunderTT	2.43	45.1	7	10	1.7	43.8	11	4	1.33	38.3	11	1	0.94	41.4	11	5
	TornadoTT	2.34	46.6	12	12	1.72	43.6	9	6	1.32	40.4	7	2	0.95	41.3	10	3
lsd t/ha (P < 0.05)		0.193				0.101				0.139				0.182			
CV%		5.05				3.5				6.48				11.3			

Northern Region

Due to the very dry start and drought conditions, Agzone 1 did not produce any viable trials. The Nabawa and Mingenew sites were in the ground for 54 days prior to receiving a germinating rainfall event.

Eneabba received excellent break of season rainfall with follow up growing season rain. The best performing varieties at this site were the mid season lines Barra and Bravo. Bravo was also the best performer in 2005.

Of the short season varieties, Tanami, Rottnest and Stubby yielded similar to Barra and Bravo. In 2005 Stubby ranked second.

Central Region

The central sites of Calingiri, Cunderdin and Merredin were generally very dry and suffered a hot dry finish. Cunderdin and Merredin received some fortuitous rainfall events during the season that many surrounding areas missed out on. This provided us the opportunity to get the trials established and growing. Tanami, Cobbler and Trigold performed consistently in all locations with Rottnest and Boomer ranked highly at two of the three sites. Boomer performed well in 2004 and 2005. The central and eastern environments are particularly suited to the short season varieties in most seasons. The mid season varieties; Thunder, Tornado and Bravo are more suited to the Calingiri region in most growing seasons as opposed to the early season varieties. The mid season varieties may be considered in eastern regions on a sandy based soil with an early break and good subsoil moisture.

Southern Region

The Williams site was sown 8/6/2007 into non wetting forest gravel. This trial was slow to establish, received low growing season rainfall and yet still managed to produce yields in excess of 2.7 t/ha. This region is generally suited to the mid season varieties. The excellent performance of Tanami at this site is a further indication that the variety is not limited by determinacy and has the ability utilise an extended growing season. The mid season varieties, Flinders, Bravo and Thunder also showed seasonal adaptability and yielded in excess of 2 t/ha.

The highest yielding plot at the Tunney/Kojonup site in 2005 was in excess of 5 t/ha with all early maturing varieties yielding less than 2 t/ha. The 2006 season has seen a complete reversal of the trend with the yields dominated by short season varieties Cobbler (1.75 t/ha) and Tanami (1.69 t/ha). The nearest mid season variety Bravo was 230 kg/ha behind. Late sowing, non wetting forest gravel and low growing season rainfall has meant this site has performed similarly to a low rainfall site.

Short season varieties were the best performers at the lower yielding sites of Katanning, Nyabing, Lake Grace and Holt Rock. Cobbler and Tanami were again the most consistent with Stubby performing well over the two years.

South Coast

The south coast environment is generally cooler during flowering and pod fill and produces a longer growing season. The sites suffered in terms of a sharp finish to the season similar to the rest of the state, however, they received reasonable growing season rainfall, the exception being Jerramungup and Scaddan. This region is most suited to the mid season varieties. Thunder and Bravo have shown consistency over a couple of seasons at the south coast sites.

The Scaddan site showed similar disease levels and lodging to the 2005 Tunney site, hence the poor performance of some of the short season varieties at this site in 2006.

Table 3. TT Canola Grain Yield (t/ha) and Oil Content (%) for South West Region in 2006 WA NVT Trials

Location		Williams (sown 8/6/06)				Tunney/Kojonup (sown 26/5/06)				Katanning (sown 25/5/06)				Nyabing (sown 27/5/06)			
Agzone		3				3				2				3			
Rainfall zone		H4				H5W				M5W				M5W			
		Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)
Early	ATR Banjo	1.98	42.7	17	6	1.5	42.5	5	7	0.61	39.0	13	7	1.15	42.5	4	9
	ATR Cobbler (NMT040)	2.17	43.9	9		1.75	43.5	1		0.86	38.0	2		1.28	40.5	2	
	ATR Hyden	2.04	39.4	14		0.79	39.1	21		0.46	34.8	19		0.97	38.9	12	
	ATR Marlin (ATR423)	2.14	45.2	10		1.48	43.6	6		0.42	40.1	20		0.88	43.7	19	
	ATR Signal (NMT052)	1.84	40.5	21		1.45	40.0	9		0.69	36.3	7		0.99	39.4	10	
	ATR Stubby	1.86	42.0	19	11	1.42	41.5	10	11	0.89	37.0	1	11	1.17	37.8	3	12
	CB Boomer (CBTT-026)	2.46	42.2	2	13	1.16	41.0	18	9	0.67	35.8	8	9	0.96	40.4	14	4
	CB Tanami (CBTT-061)	2.71	40.5	1		1.69	41.3	2		0.85	36.0	3		1.36	39.3	1	
	CB Trigold	2.11	45.0	12	12	1.07	44.2	20	12	0.69	37.5	6	12	0.97	41.5	13	14
	Rottnest (ATR501)	2.04	40.0	13		1.58	41.1	3		0.71	36.7	5		1.06	39.2	8	
	Surpass 501TT	1.84	44.4	20	5	1.12	43.9	19	14	0.55	41.0	16		0.71	44.2	21	11
Main	ATR Barra (TN4*207)	2.2	42.4	7		1.25	42.2	17		0.46	37.8	18		0.98	41.3	11	
	ATR Beacon	1.98	41.1	16	8	1.39	40.9	12	5	0.59	36.1	14	6	0.93	37.9	15	6
	ATR Summitt	1.96	40.7	18	4	1.38	40.8	14	3	0.64	36.2	9	5	0.89	39.3	18	5
	BravoTT	2.29	40.8	4	2	1.47	41.2	7	2	0.64	36.8	10	3	1.11	39.1	6	3
	Flinders (ATR438)	2.45	41.1	3		1.39	42.1	13		0.58	36.9	15		0.9	39.5	17	
	ThunderTT	2.21	41.9	6	3	1.4	42.2	11	1	0.41	37.0	21	2	0.80	41.7	20	1
	TornadoTT	2.01	42.8	15	10	1.3	43.4	16	4	0.51	39.2	17	1	1.04	42.6	9	2
lsd t/ha (P < 0.05)		0.384				0.263				0.141				0.202			
CV%		10.9				11.25				13.3				12.1			

Table 4. TT Canola Grain Yield (t/ha) and Oil Content (%) for South East Region in 2006 WA NVT Trials

Location		Lake Grace (sown 24/5/06)				Holt Rock (19/5/06)			
Agzone		5				5			
Rainfall zone		L4				L4			
		Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)
Early	**ATR Banjo**	1.11	40.4	12		1.12	38.5	17	7
	ATR Cobbler (NMT040)	1.52	40.2	1		1.37	36.7	8	
	ATR Hyden	1.04	38.8	16		1.23	34.6	12	
	ATR Marlin (ATR423)	1.25	41.8	3		1.11	40.7	19	
	ATR Signal (NMT052)	1.15	40.0	10		1.04	37.4	21	
	ATR Stubby	1.21	39.6	8		1.62	36.8	3	1
	CB Boomer (CBTT-026)	1.19	38.0	9		1.67	38.8	2	2
	CB Tanami (CBTT-061)	1.44	38.8	2		1.71	38.2	1	
	CB Trigold	1.24	40.2	5		1.52	39.1	5	3
	Rottnest (ATR501)	1.22	39.4	7		1.31	37.8	9	
	Surpass 501TT	1.14	42.1	11		1.53	41.2	4	8
Main	**ATR Barra (TN4*207)**	1.02	40.9	17		1.11	38.8	18	
	ATR Beacon	1.08	38.8	13		1.22	36.5	13	9
	ATR Summitt	0.84	37.1	21		1.07	37.6	20	11
	BravoTT	1.07	39.5	14		1.41	37.1	7	6
	Flinders (ATR438)	0.96	40.7	19		1.13	37.1	16	
	ThunderTT	1.02	41.3	18		1.18	37.4	15	4
	TornadoTT	1.05	42.4	15		1.27	39.4	11	5
lsd t/ha (P < 0.05)		0.202				0.181			
CV%		9.9				8.4			

Table 5. TT Canola Grain Yield (t/ha) and Oil Content (%) for South Coast Region in 2006 WA NVT Trials

Location		South Stirlings (sown 17/5/06)				Jerramungup (sown 29/5/06)				Scaddan (sown 10/5/06)				Munglinup (sown 9/5/06)			
Agzone		6				5				5				6			
Rainfall zone		H5C				M5C				M5E				M5E			
		Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)	Yield (t/ha)	Oil (%)	Rank (yield) 2006 (21)	Rank (yield) 2005 (14)
Early	ATR Banjo	1.91	45.0	12		0.64	41.9	21		1.51	42.1	16	12	1.89	42.3	16	5
	ATR Cobbler (NMT040)	2.05	44.1	7		1	40.3	1		1.68	40.8	11		2.36	41.6	6	
	ATR Hyden	1.74	43.4	19		0.78	40.1	15		1.52	38.4	16		2.01	40.8	15	
	ATR Marlin (ATR423)	2.35	46.4	1		0.83	41.9	13		1.83	42.9	7		2.37	44.1	5	
	ATR Signal (NMT052)	1.91	41.4	13		0.84	38.6	10		1.65	38.5	12		2.36	39.9	7	
	ATR Stubby	1.79	42.5	16		0.8	39.1	14		0.94	40.2	20	9	1.71	40.1	19	10
	CB Boomer (CBTT-026)	1.92	43.4	11		0.84	38.8	12		1.42	40.6	17	4	1.88	40.2	17	11
	CB Tanami (CBTT-061)	2.15	41.8	5		0.89	38.9	6		1.34	38.9	18		1.85	41.1	18	
	CB Trigold	1.76	44.7	18		0.72	39.6	18		1.12	41.3	19	3	1.31	42.4	20	13
	Rottnest (ATR501)	1.85	42.7	15		0.92	39.8	3		1.89	39.5	5		2.54	41.0	2	
	Surpass 501TT	1.53	47.1	21		0.71	40.6	19		0.91	41.1	21	14	1.21	44.2	21	12
Main	ATR Barra (TN4*207)	2.3	44.3	2		0.87	39.5	8		1.9	41.7	4		2.26	43.6	11	
	ATR Beacon	2.02	44.1	9		0.75	38.4	17		1.63	39.5	13	7	2.03	41.3	14	8
	ATR Summitt	2.05	44.8	8		0.7	41.0	20		1.8	40.1	9	6	2.1	41.7	13	7
	BravoTT	1.55	43.7	20		0.88	41.1	7		1.81	39.8	8	1	2.14	41.7	12	2
	Flinders (ATR438)	2.27	44.5	3		0.9	41.1	4		1.56	39.4	14		2.36	42.5	8	
	ThunderTT	2.08	44.4	6		0.76	41.3	16		1.97	42.3	2	2	2.56	43.5	1	3
	TornadoTT	1.78	45.2	17		0.9	40.6	5		2	41.8	1	5	2.32	44.0	9	1
lsd t/ha (P < 0.05)		0.364				0.162				0.182				0.384			
CV%		11.4				11.8				7				10.8			

CONCLUSION

The seasonal conditions for the second year of the NVT program were in complete contrast to the seasonal conditions of 2005. Canola variety performance across WA in 2006 was evaluated under below average rainfall with a short hot finish to the season compared to the 2005 season which had above average rainfall and a cool finish.

The dry conditions at sowing during plant establishment and early growth influenced days to 50% flower in northern and central regions. Varieties took longer to reach 50% flower compared to 2005. The days to 50% flower in southern regions were similar to 2005.

There was less flowering differential between varieties in 2006 compared to 2005.

With the exception of cooler coastal and southern sites, short season varieties dominated the rankings in 2006. The season tested the ability of varieties to take advantage of limited moisture and complete flowering and pod fill under harsh growing conditions.

KEY WORDS

NVT, canola, trials, ACAS, Agzone

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Evaluation of Brassica crops for biodiesel in Western Australia

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ABSTRACT

Twenty Brassica cultivars were field tested to find improvement in the economic potential of biodiesel production in the short season environment of the central and eastern wheatbelt of Western Australia. The WA selections RT008-04M3 (*B. napus*), 86N077-860871 (*B. juncea*) and ATC94011-01W2 (*B. carinata*) produced the highest seed yield, 1.73 t/ha, 1.39 t/ha and 1.17 t/ha respectively, within each of the three Brassica species tested. The control variety Stubby yielded 1.13 t/ha. The germplasm exhibited considerable variation in plant characteristics and yield, potentially useful to identify high oil yield suited to a short, dry season environment of Western Australia.

AIM

To identify potentially high oil yielding and agronomically stable Brassica varieties for biodiesel production in Western Australia.

METHOD

Six *B. napus* lines, 12 *B. juncea* lines and two *B. carinata* lines were sown in replicated plots at Wongan Hills Research Station on 1 June 2006. Six control varieties including four triazine tolerant varieties (Stubby, Tranby, Boomer and Tanami) and two conventional varieties (Opal and Spectrum) were sown. Sown plots were 5 rows (1 m width) and 8 m length, sown on 1.8 m plot centres. The plots were sown in six sections, two sections per replication. Weed control was obtained through the pre-seeding application of 1.5 L/ha Sprayseed and 1.8 L/ha of Triflur X on 31 May. Agras fertiliser 100 kg/ha (16 kg N, 7.6 kg P and 14 kg S) was drilled with the seed. Lontrel was applied post seeding on 26 July. Select was applied at 250 mL/ha on 28 July. Ammonium sulphate was topdressed at 140 kg/ha (29 kg N and 34 kg S) on 14 August and Urea was topdressed at 44 kg/ha (20 kg N) on 23 August. The trial was sprayed to control aphid and diamondback moth in spring.

The plots were rated for emergence, disease symptoms and the dates of first and last flowering. Plots were harvested on 24 November. Seed samples were collected for oil and quality analyses.

RESULTS

Seasonal rainfall

Rainfall for the season (May-October) was below the long term average (150 vs 232 mm) on the trial site at Wongan Hills. The 2006 season began with high summer rainfall in January and February, but with little follow up rain until mid June. Consequently seeding was delayed from the most suitable timing of early May sowing at Wongan Hills. The seeding was into dry soil and the first rain after seeding was on 19 June. The spring rainfall was adequate for pod ripening.

Flowering window

A large variation in the start of flowering (F50) and finish of flowering (F90) between germplasm of *B. napus*, *B. juncea* and *B. carinata* were observed (Table 1). *B. juncea* germplasm was earliest in start of flowering at 212 days, having 38 to 47 days to end of flowering (F90). *B. napus* germplasm was one week later in start of flowering at 220 days, having 30-37 days to end of flowering (F90). Two lines of *B. carinata* flowered differently, the WA selection from AgVic (ATC94011-01W2) was the earliest flowering 212 days (having 44 days to finish flowering). In contrast the UWA selection (UWA-0694024-2) flowered late at 237 days and finished early in only 24 days.

Seed yield

There were significant differences in mean yield between germplasm (Table 1), the highest yield was *B. napus* (WA selection from AgVic – RT008-04M3) with 1.73 t/ha, ranging down to 0.80 t/ha for *B. juncea* (UWA line -UWA-06-4J21). Tanami, the new canola variety from CBWA yielded 1.38 t/ha compared to Stubby 1.13 t/ha.

Similarly *B. carinata* line (WA selection from AgVic – ATC94011-01W2) yielded 1.17 t/ha compared to UWA line (UWA-0694024-2) 0.85 t/ha. *B. juncea* germplasm from India also yielded high – 1.36 t/ha (RH-819) and 1.18 t/ha (PBR-91).

Oil yield and meal quality data were not available at the time of reporting.

Table 1. Mean seed yield, flowering and plant height data for Brassica germplasm for biodiesel production

Species name	Yield, t/ha	Flowering 50%	Flowering 90%	Flowing days	Height (cm)	Species	Source
RT008-04M3	1.73	218*	253*	35	92.1	*napus*	AgVic
86N077-860871	1.39	216	257	41	103.2	*juncea*	WADA
TANAMI	1.38	220	255	36	91.3	*napus*	CBWA
BLN3189-04M9	1.37	220	254	34	93.1	*napus*	NSWA
RH-819	1.36	213	255	41	107.7	*juncea*	India
JR049	1.23	213	255	42	105.0	*juncea*	AgVic
PBR-91	1.18	213	256	43	109.8	*juncea*	India
ATC94011-01W2	1.17	212	255	43	101.4	*carinata*	AgVic-ATFC
BST7-210	1.16	221	257	36	86.6	*napus*	WADA
82N022-102	1.15	212	255	43	106.3	*juncea*	WADA
BLN3356TT-04M3	1.14	222	256	34	83.3	*napus*	NSWA
ATR-STUBBY	1.13	225	260	35	89.9	*napus*	Ag-Seed
RLM-619	1.12	213	256	43	101.6	*juncea*	India
82N022-98	1.11	213	258	44	109.0	*juncea*	WADA
AG-SPECTRUM	1.09	232	262	30	97.8	*napus*	Ag-Seed
AV-OPAL	1.08	227	259	31	92.7	*napus*	AgVic
BST7-205	1.08	222	258	36	87.1	*napus*	WADA
TRANBY	1.07	223	257	35	85.5	*napus*	WADA
82N022-67	1.01	213	256	43	113.1	*juncea*	WADA
86N078-860874	1.01	212	259	47	105.5	*juncea*	WADA
BOOMER	1.00	220	254	34	90.1	*napus*	CBWA
BJ42-04SB	0.92	214	254	39	83.1	*juncea*	WADA
BLN3355TT-04W8	0.88	224	260	37	94.4	*napus*	NSWA
UWA-06-94024-2	0.85	237	262	24	105.5	*carinata*	UWA
UWA-06-SEL21	0.85	226	261	34	129.1	*juncea*	UWA
UWA-06-4J21	0.80	217	255	38	95.0	*juncea*	UWA
lsd (0.05)	0.11						

* Julian Days.

CONCLUSION

Although the seasonal conditions in 2006 were not conducive to high yields, the trial produced useful seed yields and data on plant characteristics. There are 3 *B. napus* and 2 *B. juncea* germplasm that yielded significantly better than Stubby. One line of *B carinata* yielded similar to Stubby. In general the Brassica germplasm exhibited considerable variation in plant characteristics and yield that is useful to identify high oil yield (biodiesel lines) suited to a short, dry season environment of Western Australia. Further testing of the promising germplasm for biodiesel production will be carried out in the 2007 season.

KEY WORDS

canola, mustard, biodiesel

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Production risk of canola in different rainfall zones in Western Australia

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KEY MESSAGES

- Long-term simulations with the APSIM-Canola model can be used as a practical tool to establish the latest possible dates to sow profitable canola in different locations in Western Australia, for different soil types, canola prices and growing costs.

AIMS

Growers in WA currently perceive canola (*Brassica napus* L.) as a risky crop. Between 1990 and 1999 growers responded to the introduction of disease resistant cultivars, improved agronomy, favourable seasons and favourable prices by increasing the area sown from close to nil to 900,000 ha. Since 2000, the area of canola sown has gradually declined to 400,000 ha in 2005. In the period 2000 to 2004 the high occurrence of poor seasons with late sowing opportunities, due to late starts to the rainy season after a dry summer, and volatility of canola prices created the perception of risk of growing canola among growers. Due to the short history of canola production in WA, there is little information on yield expectations in relation to rainfall, location and soil type. The aims of this paper are 1, to assess the effect of location, rainfall, soil type, and soil water at sowing on canola yield and 2, to determine cut-off sowing dates for profitable canola production.

METHOD

The APSIM-Canola model was used with the long-term climate record in order to examine the effects of seasonal variability, location, soil type, sowing date and plant available water at sowing, on grain yield. The model simulates crop development (phenology), growth, yield, water uptake and nitrogen accumulation in response to temperature, radiation, daylength, soil water and nitrogen supply. The model uses a daily time-step and is driven by daily weather inputs. It calculates the potential yield, that is, the yield not limited by weeds, pests, and diseases, but limited only by temperature, solar radiation, water, and nitrogen supply. In our analysis the impact of waterlogging was not accounted for.

Long-term simulations using the climate record for 1900-2004 were run for three representative locations of the high (Kojonup; 33.84°S, 117.15°E), medium (Lake Grace; 33.10°S, 118.46°E) and low (Merredin; 31.50°S, 118.22°E) rainfall zones of the wheatbelt of Western Australia. Simulations were run for three typical soil types of the area, a sandy soil, a duplex soil and a clay soil, with 59, 86 and 116 mm plant-available water, respectively. Cultivar Karoo, representative of an early-medium maturity triazine tolerant type, was sown to establish 80 plants/m^2. Fertiliser applications were set to ensure that N did not limit canola yields.

Two simulation experiments were run, to address some practical questions.

1) What is the impact of starting soil water levels on yield expectations?

The soil water profile was initialised (reset) each year in the following ways: 1) reset on 1 January to the lower limit of plant-available water, to represent maximum water use from previous crop; 2) reset on the date of sowing with 0, 20 or 40 mm of plant-available soil water in the surface layers of the profile, to represent varying degrees of plant-available water at sowing due to summer rainfall or/and incomplete water use from a previous crop. Sowing time varied each year according to a sowing rule set between 1 May and 15 June. Sowing occurred when at least 20 mm of rainfall had accumulated within 5 days.

2) What is the impact of sowing date on yield expectations?

The soil water profile was initialised (reset) each year on 1 January to the lower limit of plant-available water. Every year the canola crop was sown on five fixed sowing dates 20 days apart: 5 April, 25 April, 15 May, 4 June and 24 June.

RESULTS

Variation in yield due to rainfall zone and soil type

Cumulative distribution functions (CDFs) depict the probability of achieving at least a given yield (Figure 1). CDFs for simulated yields obtained with a sowing rule are presented for the three locations and three soil types studied. The results demonstrate the large variability in yields generated by climate variability in the region. Among locations, average yields were highest at the high rainfall location Kojonup and lowest at the low rainfall location Merredin. Average yields were highest on the duplex soil and lowest on the sandy soil. Maximum yields varied from 1,900 kg/ha on the sandy soil at Merredin to 3,500 kg/ha on the clay soil at Kojonup. Minimum yields varied from zero at Lake Grace and Merredin in a clay soil to 200 kg/ha at Kojonup in a clay soil. At Kojonup the median yield ranged from 2,100 kg/ha on the sandy soil to 2,700 kg/ha on the duplex soil. At Lake Grace the median yield varied from 1,000 kg/ha on the sandy soil to 1,300 kg/ha on the duplex soil. At Merredin the median yields were lowest on sandy and clay soils (550 kg/ha) and highest on the duplex soil (800 kg/ha). The results indicate the importance of rainfall, location and soil type in determining the overall level of production.

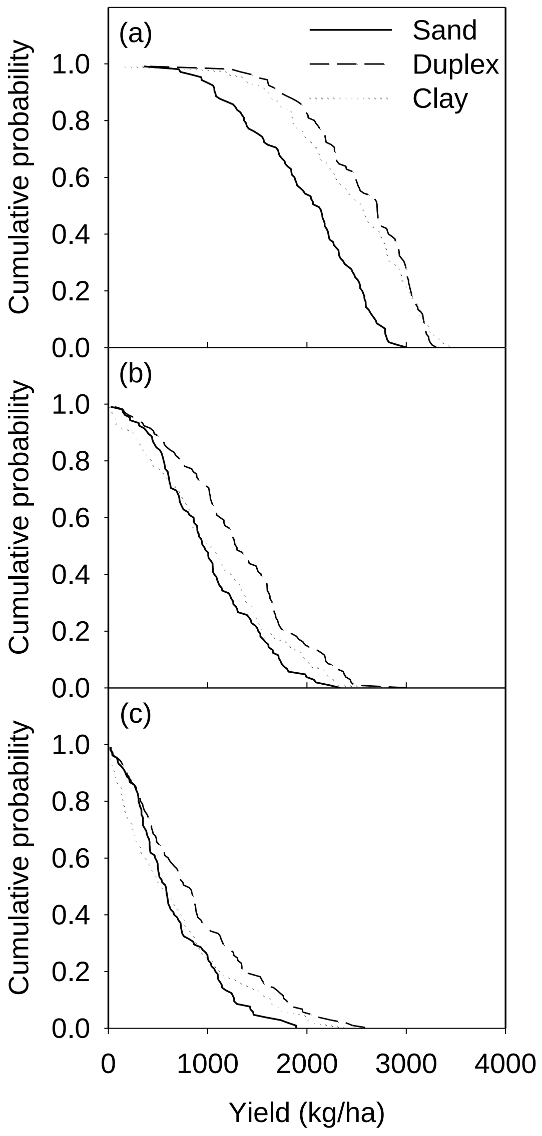

Figure 1. Simulated cumulative distribution functions of simulated grain yield for (a) Kojonup, (b) Lake Grace and (c) Merredin for three soil types. Each curve is composed of 105 seasons.

Importance of sowing date

The simulations with fixed sowing dates showed that locations had different responses of grain yield to sowing date. In general all locations showed a decline in yield with delayed sowing. For Kojonup there was no yield decline between the first two sowing dates (beginning and end of April) and a linear decline thereafter. The linear decline in grain yield ranged from 141 kg/ha/week in Kojonup to 71 kg/ha/week in Merredin (Table 1). Expressing the yield decline as a percentage of the maximum yield, it varied between 5.8% per week on a sandy soil in Lake Grace and 4.2% per week on a clay soil in Kojonup (Table 1). As a consequence, yields for different seasons tended to converge with delayed sowing. Among soil types, yield reductions with delayed sowing were highest on sandy soil and lowest on clay soil (Table 1). On sandy soils, yield reductions as a percentage were similar in all three locations. Whereas on duplex and clay soils, percentage yield reductions were smaller at Kojonup.

Table 1. Simulated response of grain yield to sowing date in terms of kg/ha decline per week's delay in sowing date and yield reduction (%) expressed as a per cent of the maximum yield. Yield declines are average of 105 seasons

Location	Soil	kg/ha.week	% Yield/week
Kojonup	Sand	141	5.6
	Duplex	140	4.3
	Clay	131	4.2
Lake Grace	Sand	108	5.8
	Duplex	116	5.0
	Clay	100	5.0
Merredin	Sand	80	5.6
	Duplex	94	5.5
	Clay	71	4.5

Importance of starting soil water

Starting soil water, defined as plant available water at sowing, produced a yield advantage over sowing on a dry soil in all three locations and soil types (Figure 2). The yield advantage due to starting soil water was greater on the duplex soil than on the sandy soil, due to the lower plant available water capacity of the sandy soil. Starting soil water produced a yield advantage in every year in the low and medium rainfall locations. However, in the high rainfall location produced a yield penalty of 15 to 40 kg/ha in about 5% of the years, due to increased losses of nitrogen by leaching. Starting soil water of 20 mm provided a yield advantage in all locations. Starting soil water of 40 mm provided additional yield advantage in Lake Grace and Merredin, but not in Kojonup. In Kojonup, starting soil water gave a median yield advantage of 22 to 66 kg/ha across soil types, representing a median yield increase of 1 to 2% compared to a dry soil profile. In Lake Grace the median yield advantage from initial soil water ranged from 217 to 475 kg/ha, representing a median yield increase of 36 to 71%. In Merredin the median yield advantage from starting soil water ranged from 142 to 368 kg/ha, representing a 47 to 97% increase in yield. The results indicated the importance of starting soil water in determining overall level of production, especially in the low and medium rainfall locations.

Break even yields for different canola prices and growing costs

Growing costs or variable costs of canola are higher than wheat. Growing costs for canola production in the three shires studies ranged from 230 $/ha in Merredin to 290 $/ha in Kojonup in 2005 according to the 'Gross margins guide 2005 WA' prepared by regional economists of the Department of Agriculture and Food, Western Australia. Variation between regions is mainly a function of fertiliser inputs. In comparison, growing costs for wheat production in the same shires ranged from 180 to 220 $/ha.

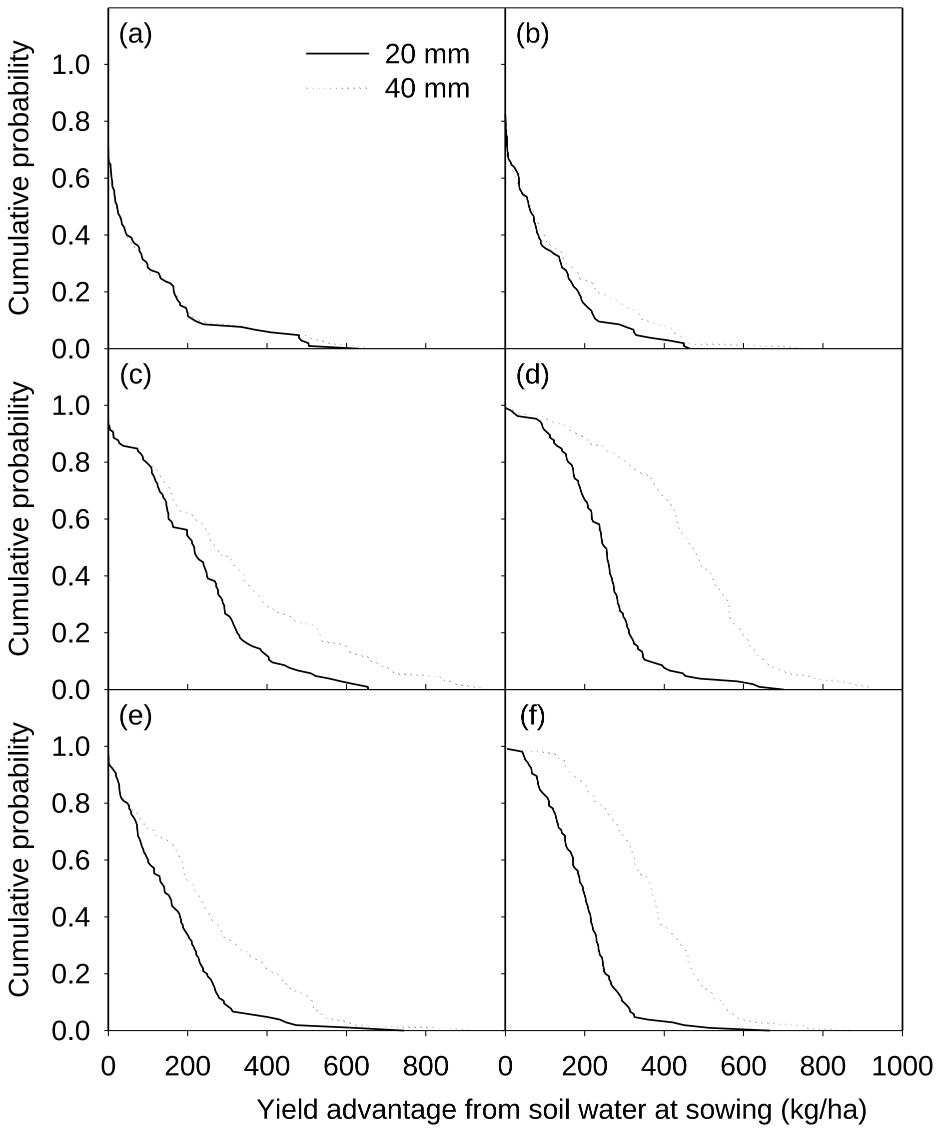

Figure 2. Cumulative distribution functions of simulated yield advantage of 20 mm and 40 mm of plant available water at sowing compared to lower limit at sowing for (a, b) Kojonup, (c, d) Lake Grace and (e, f) Merredin on a sandy soil (a, c, e) and on a duplex soil (b, d, f). Each curve is composed of 105 seasons.

Canola price has been variable in the last few years. The latest (2006) estimate of net price on-farm for canola is around $400/ha. Growing costs and the price of canola determine the minimum yield required to cover costs (the 'break even' yield). Table 2 shows minimum yields required to break even for combinations of different canola prices and growing costs. In this calculation, canola price did not account for oil content.

If we consider an average canola price for the last few years of about 300 $/t and growing costs of 250 to 300 $/ha depending on yield expectations, the break even yield is 800 to 1000 kg/ha. The probability of achieving this 'break even' yield depends on location, soil type and sowing date (Figure 3). For example, in Kojonup 1000 kg/ha can be achieved in more than 80% of years in a sandy soil if sown before the end of May and in more than 95% of years in a duplex soil for any sowing date within the sowing window. In Lake Grace, 1000 kg/ha can be achieved in 80% of years on a sandy soil if sown before the end of April and on a duplex soil if sown before the middle of May. In contrast, in Merredin on a sandy soil, 1000 kg/ha can be achieved in 50% of years if sown before the end of April and in less than 10% of years if sown before the end of May. In Merredin on a duplex soil, 1000 kg/ha can be achieved 70% of years if sown before the end of April and in 30% of years if sown before the end of May.

Table 2. Break-even yield (kg/ha) for combinations of different canola prices and growing costs

Canola price ($/tonne)	Growing costs ($/ha)					
	200	225	250	275	300	325
250	800	900	1000	1100	1200	1300
300	670	750	830	920	1000	1080
350	570	640	710	790	860	930
400	500	560	630	690	750	810
450	440	500	560	610	670	720
500	400	450	500	550	600	650

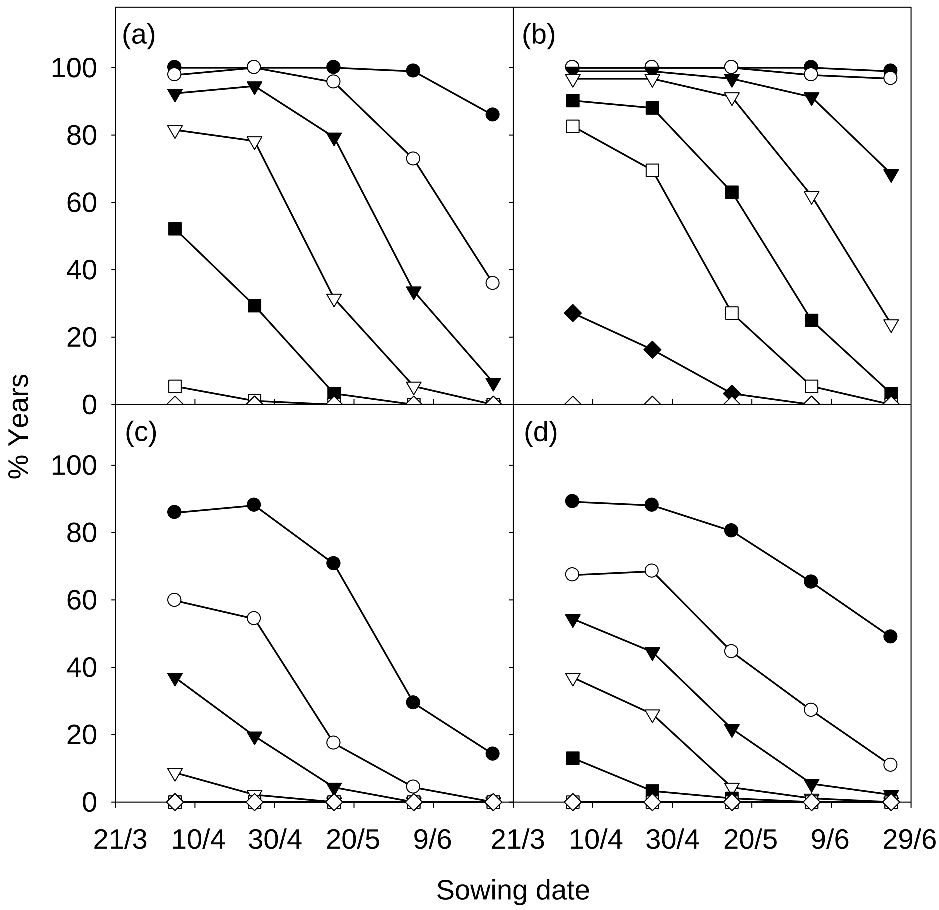

Figure 3. Proportion of years (%) with simulated grain yield greater than 500 (●), 1000 (○), 1500 (▼), 2000 (▽), 2500 (■), 3000 (□), 3500 (◊) and 4000 (△) kg/ha versus sowing date for (a, b) Kojonup and (c, d) Merredin on a sandy (a, c) and duplex (b, d) soils.

Figure 3 shows that with sowing at the end of May, in Kojonup there is a 50% chance of achieving at least 1500 kg/ha on the sandy soil and 2500 kg/ha on the duplex soil. In Merredin, with sowing at the end of May, there is a 50% chance of achieving less than 500 kg/ha on the sandy soil and less than 1000 kg/ha on the duplex soil.

The latest possible sowing date to achieve profitability in canola production will depend on the canola price and growing costs for the season, which will determine the break even yield for that year. For example if we assume a break even yield of 1000 kg/ha, with the soil types and the cultivar used in the simulations the latest possible sowing date to achieve a yield of 1000 kg/ha in 50% of the years in Kojonup is mid June in the sandy soil and end of June in the duplex soil. In Merredin the latest

possible sowing date to achieve a yield of 1000 kg/ha in 50% of the years is end of April in the sandy soil and mid June in the duplex soil. If we assume a year with high canola price and/or low growing costs so that the break even yield was 500 kg/ha, the latest possible sowing dates to achieve a yield of 500 kg/ha in 50% of the years in Merredin would be end of May in the sandy soil and end of June in the duplex soil (Figure 3).

CONCLUSION

The reliability of canola production varies widely between the different rainfall zones in the WA wheatbelt. In the high rainfall zone, there is a better than 80% chance that canola will be profitable in this zone for a wide range of canola prices and growing costs. In the medium and low rainfall zones proposition in most seasons, particularly with late sowing opportunities. In the medium and low rainfall profitability of canola is highly sensitive to changes in costs and prices and is currently a risky zones of the WA wheatbelt optimal management (i.e. early sowing, high prices, low growing costs) can go some way towards mitigating the risks of profitable canola production. Timing of the opening rains or sowing (before end of May in medium rainfall and before end of April in low rainfall locations) and level of stored soil water at sowing (more than 20 mm) are indicators that could be used to trigger the sowing of canola on an opportunistic basis in the low and medium rainfall zones. Such strategies will be necessary to avoid the possibility of canola disappearing as a permanent feature of cereal dominated cropping systems in WA and the attendant of negative consequences such as increase of weeds and diseases.

KEY WORDS

crop model, yield, profitability, probability

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Future directions of blackleg management – dynamics of blackleg susceptibility in canola varieties

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KEY MESSAGES

- Crown canker severity arising from exposure to stubble borne ascospores was significantly reduced in 6 leaf or older plants compared to cotyledonary to 4-leaf plants.
- The susceptibility period may vary in regions and seasons depending on sowing times.
- Avoidance of peak ascospore shower activity in young canola through manipulation of sowing date can reduce risk of severe blackleg.

AIMS

The primary aim of this research was to improve blackleg management strategies through enhancing our understanding of blackleg x environment interactions. Experiments were conducted to determine the dynamics of crown canker susceptibility of canola to blackleg.

The ascospores of blackleg infect leaves of canola plants to cause lesions, and the fungus grows from these lesions systemically down petioles to infect the stem bases and causes crown cankers in late spring. The initial understanding of age related resistance was that early seedling infections lead to the development of crown cankers whereas infection of adult plants does not lead to development of crown cankers as resistance in older plants prevents systemic invasion of the leaf petioles. However, the precise susceptibility window of current canola varieties is yet unknown. This information on the onset of age related resistance on the expression of crown cankers together with forecasting the onset and dynamics of blackleg spore showers would help in better quantifying the risk of blackleg and consequently better aligning management strategies with the risk of yield loss.

METHOD

Two canola varieties ATR Stubby and ATR Beacon (WA blackleg resistance rating of 4 and 6 respectively) were sown at South Perth. The varieties were sown in 2 metre rows, each at a range of dates in order to obtain different growth stages of plants for inoculation. The first time of sowing was 3 May 2006 followed by five sowings at two-weekly intervals. All plants in the six different growth stages viz., 1 (cotyledon), 2.3 (3-leaf), 2.4 (4-leaf), 2.6 (6-leaf), 4.1 (first flower open) and 4.3 (lower pods starting to fill) were simultaneously exposed to blackleg ascospore inoculum on 7 August 2007 by evenly distributing infected stubble between the rows. The number of plants showing blackleg leaf spotting was counted for each growth stage three weeks after inoculation. Per cent plant population with leaf spotting was calculated. The severity of crown cankers was assessed at the end of the season at growth stage 5.4 (seeds in lower pods brown) on a 0-5 rating scale (0: no disease, 1: -25% crown circumference girdled; 2: 26-50% crown circumference girdled, 3: 51-75% crown circumference girdled, 4: 75-100% crown circumference girdled, 5: plant lodged or broken at the crown). The per cent disease index (PDI) of crown cankers was calculated for each growth stage.

The experimental design was a randomised block with four replications. The data for per cent of plants with leaf spotting was subjected to square root transformation before analysis in order to stabilise variance. Treatment effects were compared after analysis of variance using Genstat Release 9.1.

RESULTS

There was no significant (P = 0.09) effect of growth stage on per cent plants with leaf spotting (Figure 1). This indicates that canola leaves at all growth stages are equally susceptible to blackleg. However, there was a significant effect of variety on per cent plants with leaf spotting, Beacon having a significantly higher incidence of leaf spotting than Stubby. There was no interaction between growth stage and variety.

Plants which were seedlings at the time of infection expressed more severe crown cankers at the end of the season than older plants ($P < 0.001$). However, there was no interaction between variety and growth stage. The average per cent disease severity (PDI) of crown cankers was significantly highest when plants were exposed to inoculum at cotyledon up to 6-leaf stages compared with the plants at flowering and podding stages (Figure 2). Interestingly mild to severe crown cankers were still produced in some plant populations when plants were exposed either at flowering or podding stage. Although Beacon is more resistant to expression of crown cankers, there were significantly more plants with leaf spotting in Beacon than in Stubby. However, the final severity of crown cankers was not significantly different in the two varieties. This indicates that the incidence of plants with leaf spotting is necessarily not an indicator of crown canker severity at the adult stage.

CONCLUSION

The three key elements in blackleg management remain the use of resistant varieties, reducing the risk of spore showers and application of fungicides. However, we have gained further insight into the disease x environmental interactions through the recent research on canola blackleg. The research highlighted that canola is more susceptible to blackleg up to 6-leaf stage, however, the length of this susceptibility window may vary in different regions and with different sowing times. For example a crop sown during end of May to mid June may remain susceptible for up to 10 weeks or more compared with crops sown during early to mid May period. Therefore, protection from blackleg in high disease pressure situations and particularly for the late sown crops may be required for longer periods for moderately susceptible to moderately resistant varieties.

Development of Blackleg Sporacle model has been a significant leap towards defining regional risk of blackleg through predicting the onset of blackleg spore showers. However, the effect of seasonal conditions on onset of ascospore maturity, ascospore discharge pattern and consequently yield loss, needs to be investigated. Future blackleg models forecasting on regional disease dynamics and its impact on yield, may help growers in better understanding the risk of blackleg and consequently applying appropriate cost-effective strategies in managing blackleg disease.

KEY WORDS

blackleg, canola, Blackleg Sporacle, disease management

ACKNOWLEDGMENTS

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Paper reviewed by: Robert Loughman

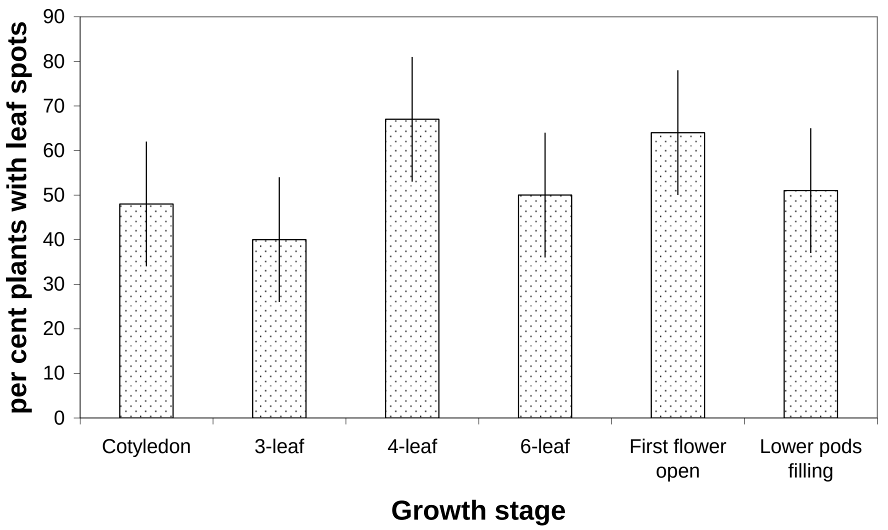

Figure 1. Per cent plants with leaf spotting observed three weeks after inoculation for canola plants exposed to blackleg ascospores at different growth stages. (Original data presented, the data was square root transformed to stabilise variance for analysis.)

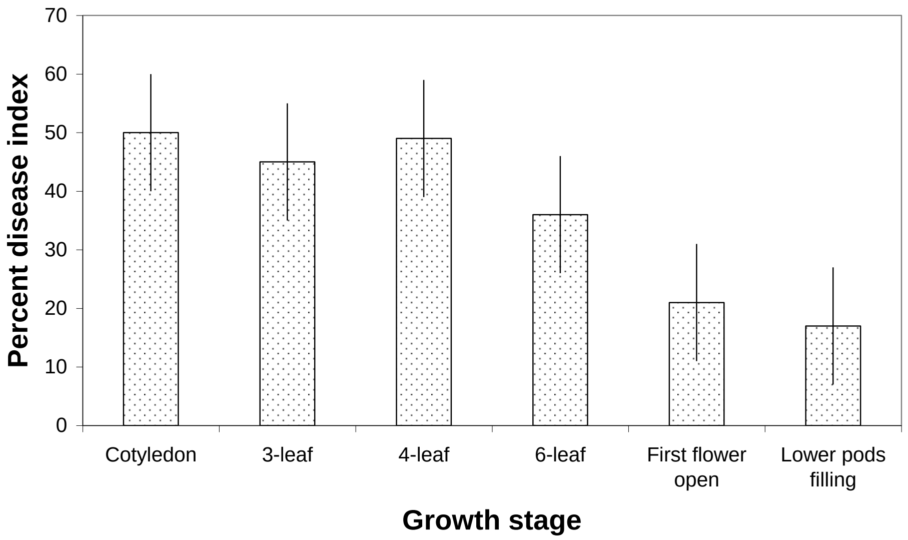

Figure 2. Per cent disease index of crown cankers when canola plants at different growth stages were exposed to blackleg ascospores.

Appendix 1: Contributors

Research reported here has been conducted by a wide range of people from several institutions in WA. The Grain Legume projects at DAFWA has taken the lead in developing and editing this book. Telephone numbers and e-mail addresses for principal authors of articles have been listed to encourage interested readers to contact the authors for further information. In some cases, the results presented in this book are only preliminary and will be analysed in more detail throughout the year.

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Note: Not all details of contributors were present at the time of printing. For further information please contact the editor, Wayne Parker.

Appendix 2: List of common acronyms

Acronym	Full name
AARI	Aegean Agricultural Research Institute
ACCIP	Australian Coordinated Chickpea Improvement Program
ACIAR	Australian Centre for International Agricultural Research
AFLP	Amplified Fragment length polymorphism
AFPIP	Australian Field Pea Improvement Program
ALC	Australian Lupin Collection
AMV	Alfalfa Mosaic Virus
ARC	Australian Research Council
ARWA	Agricultural Research Western Australia
ATFCC	Australian Temperate Field Crops Collection
BARI	Bangladesh Agricultural Research Institute
BGM	Botrytis grey mould
CAR	Central Agricultural Region
CBH	Cooperative Bulk Handling
CICA	Coordinated Improvement of Chickpeas Australia
CIPAL	Coordinated Improvement Program for Australian Lentils
CLIMA	Centre for Legumes in Mediterranean Agriculture
CMV	Cucumber Mosaic Virus
COGGO	Council of Grain Growers Organisation
GSARI	Great Southern Agricultural Research Institute
CVT	Cultivar Variety Testing
DAFWA	Department of Agriculture and Food, Western Australia
DPI	Department of Primary Industries
DSS	Decision Support System
ELISA	Enzyme-Linked Immunosorbent Assay
GPWA	The Grain Pool of Western Australia
GRDC	Grains Research and Development Corporation
GSPGA	Great Southern Pulse Grower Association
HI	Harvest Index
IARI	Indian Agricultural Research Institute
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Centre for Research in the Semi-Arid Tropics
ORIA	Ord River Irrigation Area
NAR	Northern Agricultural Region
NARC	Nepal Agricultural Research Council
NBS	National Bureau of Standards
NFBIP	National Faba Bean Improvement Program
NVT	National Variety Testing
PASE	Pulse Association of the South East
PBR	Plant Breeding Rights
POLA	Pulse, Oilseed and Lupin Association
PSbMV	Pea Seed-Borne Mosaic Virus
RIRDC	Rural Industries Research and Development Corporation
RLN	Root Lesion Nematode
RSU	Research Support Unit
RUE	Radiation Use Efficiency
SAR	Southern Agricultural Region

Acronym	Full name
SARDI	South Australian Research and Development Institute
SEPWA	South East Premium Wheat Association
SPIRIT	Strategic Partnerships with Industry Research and Training
USDA	United States Department of Agriculture
WAHRI	Western Australian Herbicide Resistance Initiative
WANTFA	Western Australian No-Tillage Farmers Association
WUE	Water Use Efficiency