Crop Updates 2002 - Lupins

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2002
LUPINS UPDATES
WESTERN AUSTRALIA

PRESENTED AT THE SHERATON HOTEL, PERTH
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Compiled and edited by Amelia McLarty

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# LUPINS UPDATES, 2002

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Lupin industry issues and research directions

After a very lack-lustre start to the 2001 season many lupin growers were pleasantly surprised at the yields achieved, particularly in districts that enjoyed a softer finish.

With better prices this season, returns from growing lupins for many have taken a welcome shift in the right direction. Lupin deliveries to CBH total 455,000 t, significantly up on the small crop the previous season. There is also a lot of production retained on-farm and traded domestically.

The dry start to the season meant that anthracnose did not get an early foothold but many crops were weedy, short and difficult to harvest. The feedback on new varieties is quite consistent - “we can see a big yield improvement". But herbicide tolerance concerns, mainly with Tanjil and Wonga, remains a big issue, particularly in the northern districts.

The advent of a protein premium marks the beginning of a new era in the marketing strategy for lupins. Unfortunately, protein levels were not as high across the board as were expected based on previous data. This highlights the urgency for breeders and agronomists to work towards providing growers with better varieties and tools to increase protein and lift potential returns.

Within the Department of Agriculture lupin R&D has been re-vitalised under a new team structure that provides closer coordination and integration of breeding, on-farm production technology, end-use and product development activities. Also of note is the resurgence of the Centre for Legumes in Mediterranean Agriculture (CLIMA) - a research alliance between the University of Western Australia, Department of Agriculture, CSIRO and Murdoch University. CLIMA provides additional opportunities for innovative and basic research into legumes and lupins are very much on the agenda. Lupin researchers at the Department of Agriculture and CLIMA continue to build strong connections to agribusiness, farmer groups and other research providers, particularly the Department of Fisheries, the Chemistry Centre of WA and private researcher companies.

Notable activities that will pay dividends in the future include:

- research which improves lupin establishment in dry seedbeds through moisture delving techniques;
- a collaborative Fusarium wilt project with Poland and Russia which sees progress towards breeding Australian varieties resistant to this serious exotic pathogen;
- WALAN 2141 is the highest yielding line in Stage 4 trials with the desirable characteristics of Belara together with increased vigour, anthracnose resistance and higher protein (commercial release potential - 2003);
- rapid development of an anthracnose resistant albus lupin (commercial release potential - 2004);
- a more sophisticated understanding of the potential for lupins in aquaculture is matched by increasing commercial interest by some sectors of this rapidly expanding industry (Department of Fisheries);
- new processing technology for high quality lupin protein isolates and nutraceuticals with the potential to grow a valuable new lupin processing industry (Biorex Health Ltd).

Much of this activity and other material presented at this year’s Crop Updates is funded by growers through the Grains Research and Development Corporation and their continuing support is gratefully acknowledged.

Mark Sweetingham
LEADER - GRAIN LEGUME RESEARCH & INDUSTRY DEVELOPMENT

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Department of Agriculture, Western Australia
Acknowledgments

I have found coordinating the lupin component of the 2002 Agribusiness Crop Updates to be very rewarding, but it needs to be acknowledged that compiling this book takes a considerable amount of cooperation and team effort by a number of people. I would like to take this opportunity to thank all the contributors and reviewers of this book for all their effort, particularly for meeting the tight deadlines required for publication. I would also like to thank Chiquita Butler for her efforts in the formatting of this book.

I would like to acknowledge my ‘reference group’. The task of deciding which papers should be presented over the two days is always difficult. To assist me with this task, I enlisted the help of a group of researchers, agronomists and consultants by asking them what research they thought was important for their respective regions. The feedback received from this reference group has been of great assistance. I would like to thank them all for taking the time to provide feedback.

Amelia McLarty
LUPIN CONVENOR
DEPARTMENT OF AGRICULTURE, WONGAN HILLS
Evaluation of *Lupinus mutabilis* in Western Australia

Bob French and Laurie Wahlsten, Senior Research Officer and Technical Officer, Department of Agriculture, Merredin

Martin Harries, Research Officer, Department of Agriculture, Geraldton

BACKGROUND AND AIMS

There are more than 500 species in the genus *Lupinus*, each with different characteristics that might suit them to specific ecological niches, or to specific market niches. *Lupinus mutabilis* is native to the Andean region of South America and has high seed protein and oil contents. Semi-domesticated lines of *L. mutabilis* are used in peasant agriculture, and are also widely grown in temperate climates as ornamentals. The high protein and oil contents of *L. mutabilis* are attractive from a grain quality point of view, and *L. mutabilis* could be a suitable species for further domestication work in Western Australia. The aim of this work was to test the potential productivity of several lines of *L. mutabilis* in relation to other species of *Lupinus* in Western Australian environments.

METHOD

The growth of four lines of *L. mutabilis* (one ornamental lupin ‘Adcock’, and 3 lines from the WA Lupin Collection) were compared with ‘Kiev Mutant’ *L. albus*, ‘Quilinock’ *L. angustifolius*, ‘Wodjil’ *L. luteus*, and a line of *L. atlanticus* at six locations in Western Australia in 2001. The locations were Mullewa, Mingenew, Wongan Hills, two at Merredin, and Frankland. All sites were on sandy soils, except one site at Merredin on a clay loam and the one at Frankland on a gravel. Seed was hand-sown in plots of three 1 m rows 18 cm apart. 10 seeds were sown in each row and each experiment was set out as a randomised block experiment with three replicates. Sowing dates ranged from 17 May at Merredin to 22 June at Frankland. Observations were made on the plots throughout the year, and the experiments at Mingenew and Frankland were harvested at maturity.

RESULTS

Observations

The experiment at Mullewa did not emerge properly owing to dry conditions, but all other experiments emerged and grew. *L. mutabilis* in the experiments at Mingenew, Wongan Hills and Merredin suffered from what appeared to be simazine damage: soon after emergence leaf bleaching occurred and plants were not thrifty. All *L. mutabilis* seedlings at Wongan Hills (which had received 1.4 kg/ha Simagranz a month before sowing) died within six weeks of emergence, but the others recovered to a certain extent. The trials at Merredin received 2.5 L/ha simazine in the week prior to planting, and were too uneven to be worth harvesting. The trial at Mingenew, which received 2 L/ha simazine, recovered sufficiently to be worth harvesting. The trial at Frankland did not receive any simazine, but was treated with 200 mL/ha Spinnaker before sowing. It showed none of the leaf bleaching symptoms observed at the other sites.

Establishment and early growth

All *L. mutabilis* lines established rapidly at Merredin: two days earlier than *L. angustifolius* and four days earlier than *L. albus* on the sand; but two days later than *L. angustifolius* and four days earlier than *L. albus* on the clay soil. At all sites *L. mutabilis* seedlings appeared very robust and vigorous until symptoms of simazine damage began to appear. The robustness may have increased their attractiveness to locusts at Merredin, but they appeared to have similar tolerance of red-legged earthmite to the lupin species other than *L. luteus*, which is more susceptible, at Wongan Hills.

Maturity

Three *L. mutabilis* lines were later flowering and maturing than the other species, but there was one (P26961) that appeared to flower and begin setting pods at about the same time as *L. luteus* cv. Wodjill. Observations at Frankland suggested it reached maturity at about the same time as Quilinock, or a little later. The other *L. mutabilis* lines still had green stems and some green leaves a month later at Frankland, but they had mature pods.
**Growth and yield**

The later maturing *L. mutabilis* lines at Frankland showed symptoms of greater budworm damage than earlier maturing lines and species, so the yields of these lines are underestimated. *L. mutabilis* yields were only about a quarter of *L. angustifolius* yields at Mingenew, but this may be due to the herbicide damage.

**Biomass at maturity, grain yield, and harvest index of different lupin species at Frankland 2001**

<table>
<thead>
<tr>
<th>Species, cv.</th>
<th>Biomass (g/m²)</th>
<th>Grain yield (g/m²)</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. angustifolius</em> cv. Quillinock</td>
<td>1336</td>
<td>495</td>
<td>0.299</td>
</tr>
<tr>
<td><em>L. mutabilis</em> P26961</td>
<td>1346</td>
<td>418</td>
<td>0.244</td>
</tr>
<tr>
<td><em>L. mutabilis</em> P25956</td>
<td>1305</td>
<td>272</td>
<td>0.168</td>
</tr>
<tr>
<td><em>L. mutabilis</em> P26956</td>
<td>1206</td>
<td>281</td>
<td>0.184</td>
</tr>
<tr>
<td><em>L. mutabilis</em> 'Adcock'</td>
<td>1488</td>
<td>267</td>
<td>0.148</td>
</tr>
<tr>
<td><em>L. luteus</em> cv. Wodjil</td>
<td>1124</td>
<td>253</td>
<td>0.177</td>
</tr>
<tr>
<td><em>L. albus</em> cv. Kiev Mutant</td>
<td>597</td>
<td>136</td>
<td>0.207</td>
</tr>
<tr>
<td><em>L. atlanticus</em> Atlas</td>
<td>905</td>
<td>100</td>
<td>0.079</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>401</td>
<td>101</td>
<td>0.087</td>
</tr>
</tbody>
</table>

**CONCLUSION**

*Lupinus mutabilis* has sufficient vigour and yield potential to be worth pursuing as a potential crop in Western Australia. The late maturity of the lines examined would be most suitable in long growing season environments, such as the Great Southern. However, only a very limited set of genotypes has been examined at this stage and earlier flowering lines are available which could increase its adaptation to shorter season environments. It appears more sensitive to simazine than other lupin species. This would have to be rectified, or other weed control strategies developed, before a commercial industry could be successful.

**KEYWORDS**

*Lupinus mutabilis*, lupin species, alternative crops

**GRDC Project No.:** CF

**Paper reviewed by:** Mark Sweetingham
Adaptation of restricted-branching lupins in short-growing season environments

Bob French and Laurie Wahlsten, Senior Research Officer and Technical Officer, Department of Agriculture, Merredin

KEY MESSAGE
Restricted-branching lupin cultivars have no better yield potential in short-growing season environments than conventional branching cultivars with similar maturity. The conventional cultivar Belara has similar maturity to the restricted-branching breeding line WALAN 2053 and responded to growing conditions in a similar fashion, but it has higher yield potential.

BACKGROUND AND AIMS
Restricted-branching in lupins has been suggested as a useful trait to improve adaptation to high rainfall environments where vegetative growth is sometimes excessive; and in low rainfall environments where the length of the reproductive period is curtailed. Several trials in high rainfall environments, reported on in the 2001 Crop Updates, suggested that the improved pod retention of modern conventional branching lupin cultivars has reduced the likelihood of excessive vegetative growth in high rainfall environments. In addition, these trials showed that restricted-branching reduces the ability of lupin cultivars to respond to high yield potential conditions. However, in the drier than normal 2000 growing season restricted-branching cultivars yielded better relative to conventional branching cultivars than in most years, adding weight to the argument that they are well suited to short growing seasons. The aim of this work was to test the growth and yield of the best available restricted-branching lines against well-adapted conventional branching material.

METHODS
Two restricted-branching lupin lines (Tallerack and WALAN 2053) were compared with two well-adapted conventional branching cultivars (Belara and Kalya) at Mullewa and Merredin in 2001. Two irrigation treatments were imposed at each site: nil and irrigated weekly following pod set on the main stem until after the cessation of flowering. Irrigation was applied using t-tape, and irrigated treatments received an extra 80 mm of water at Merredin and an extra 100 mm at Mullewa. The experiments were laid out as randomised block designs with four replicates.

RESULTS
If restricted-branching confers specific adaptation to stressful reproductive periods, we would expect it to reduce the grain yield response to irrigation. However, the restricted-branching character was not related to the irrigation response at either site (Table 1). At Merredin the earlier maturing lines (Belara and WALAN 2053) responded more to irrigation, and at Mullewa they responded less, than the later maturing Kalya and Tallerack. In addition, at both sites the highest yielding cultivar was conventional branching in the non-irrigated treatment: Kalya at Merredin, and Belara Mullewa.

Yield component data (Table 2) shows that responses to irrigation at the two sites were different. Most of the yield response at Merredin came from increased pod number per plant, and the greatest increases in pod number were in Belara and WALAN 2053. In these cultivars seed size was reduced by irrigation at Merredin. At Mullewa there were large irrigation responses in both pod number and seed size. Here, the greatest pod number increases occurred in Kalya and Tallerack, and the greatest seed size response in Belara. So the most obvious contrast between genotypes is between two groups, one containing Belara and WALAN 2053, and the other containing Kalya and Tallerack. This grouping is not related to branching type, but to maturity. Data from Merredin, not shown here, shows that Belara and WALAN 2053 reached physiological maturity 5-6 days earlier than Kalya and Tallerack in the control treatment.
Table 1. Effect of irrigation and branching type on lupin grain yield (t/ha) at Mullewa and Merredin in 2001

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Merredin</th>
<th>Mullewa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Irrigated</td>
</tr>
<tr>
<td>Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belara</td>
<td>2.38</td>
<td>3.19</td>
</tr>
<tr>
<td>Kalya</td>
<td>2.48</td>
<td>2.97</td>
</tr>
<tr>
<td>Restricted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tallerack</td>
<td>2.31</td>
<td>2.85</td>
</tr>
<tr>
<td>WALAN 2053</td>
<td>2.21</td>
<td>2.93</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>0.12</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table 2. Effect of irrigation and branching type on lupin yield components at Mullewa and Merredin in 2001

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Irrigation</th>
<th>Merredin</th>
<th>Mullewa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pods/plant</td>
<td>Seeds/pod</td>
<td>Seed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>weight (g)</td>
</tr>
<tr>
<td>Belara</td>
<td>Nil</td>
<td>11.9</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>15.4</td>
<td>3.8</td>
</tr>
<tr>
<td>Kalya</td>
<td>Nil</td>
<td>11.0</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>12.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Tallerack</td>
<td>Nil</td>
<td>12.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>14.4</td>
<td>3.7</td>
</tr>
<tr>
<td>WALAN 2053</td>
<td>Nil</td>
<td>9.1</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Irrigated</td>
<td>14.5</td>
<td>3.3</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>3.6</td>
<td>0.22</td>
<td>0.0068</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Suitability for short-growing seasons is determined by maturity rather than the presence or absence of the restricted-branching character. An early maturing conventional branching cultivar such as Belara will yield as well as a restricted-branching cultivar with similar maturity in a short-growing season environment. The conventional cultivar has the advantage of being able to respond more to good seasonal conditions if they occur.

KEYWORDS

Lupins, restricted-branching, short-growing seasons

GRDC Project No.: DAW 583

Paper reviewed by: Greg Shea
Moisture delving for better lupin establishment

Dr Paul Blackwell, Department of Agriculture, Geraldton District Office

KEY MESSAGE

Wet soil delving through a 50 mm dry layer can provide 80% of the lupin establishment from sowing fully wet sand. This can be 50% better than double disc seeding in equivalent conditions.

BACKGROUND

Lupin growers on the northern sandplains are faced with many occasions when summer or early autumn rain has resulted in a wet sub-surface and a shallow dry surface. From a long term study of the meteorological record Abrecht (1994) showed there is a 25% chance of getting at least 18 dry days after a wet sowing before 5 May. This shows that in at least 1 in 4 cases, surface soil will easily dry after summer or early autumn rain. When there is a shallow dry surface (40-100 mm deep) many current designs of soil openers will result in the seed being placed in a mixture of wet and dry sand. This results in poor crop establishment and early vigour. Current strategies for better weed control also encourage the opportunity to use knockdown herbicides and avoid fully dry sowing for better weed management in lupins. This results in waiting till after an early rain for a germination of weeds, by which time the surface soil has dried again. In 2000 the Williamson family, of Pine Ridge Farms Yuna, developed a ‘V’ shaped closer which reduced the mixing of wet and dry sand when sowing through a dry layer (Blackwell et al. 2000). This proved successful in farm use and enabled the lower, wetter sand to be placed near the seed, using a process of ‘delving’ where the wet soil is lifted closer to the surface as it slides up the point and the shank of the tine. Delving is a method devised in the UK for mixing clay with peat in fen soils, the clay being lifted from depths of up to 1 m. The same principles have been used to lift and mix clay with water repellent sand (Blackwell et al. 1994). Wet sand delving is on a much smaller scale (up to about 0.3 m). The idea has also been tried in the early ‘90s by Lindsay Olman of Pindar, who used a vertical plate welded to the underside of a ducksfoot point to bring moist soil to the surface through a dry layer. The potential value of such shallow delving methods encouraged further investigation and quantification of the concept.

METHODS

Three different moisture conditions at seeding were created by irrigating dry soil and protection from natural rain with a rainfall shelter; fully wet (WET), a 50 mm dry layer over wet soil (50 mm DRY) and a 75 mm dry layer over wet soil (75 mm DRY). Belara lupins were sown on 4 May with three different delving methods; deep wide delving (DWD), shallow wide delving (SWD) and shallow narrow delving (SND). Deep delving dug to 250 mm, shallow delving to 125 mm. Wide delving used a 50 mm wide point, narrow delving used a 12 mm wide point. The control comparison (nil) was double disc openers, which give very little vertical soil movement. All points were on a ‘C’ shaped spring tine and were followed by a ‘V’ shaped closer a trailing sprung boot and a 50 mm wide press wheel. The crop had no natural rain till 17 days after seeding. Crop establishment and growth stage were measured regularly, as well as grain yield and simazine damage; further technical details are in the full paper. The physical dimensions of the delving systems and the soil moisture conditions are summarised in Figure 1.

RESULTS

The establishment 17 days after seeding, Figure 2, showed that for an early May seeding into sand with 50 mm of dry soil over moisture, deep wide delving (50 mm point working at 250 mm depth) could result in about 80% of the establishment in wet conditions by the same equipment. The DWD treatment was also 50% better than soil opening systems with no delving. Delving showed no establishment penalties in wet sand, nor did it work well when the dry layer was 75 mm deep.
Figure 1. Physical dimensions of the soil openers and moisture conditions.

Figure 2. Plant establishment for the four different soil openers and three different depths of moist soil at seeding. The least significant difference between openers at 95% probability is shown by the bar.

CONCLUSIONS
Wet soil delving through a 50 mm dry layer can provide 80% of the establishment from sowing fully wet sand. This can be 50% better than double disc seeding in equivalent conditions. Delving success seems very sensitive to the depth of dry sand.

REFERENCES

KEY WORDS
Establishment, dry soil, wet delving

GRDC Project No.: GLP
Paper reviewed by: Bob French

NB: There is an extended version of this paper on the Crop Update 2002 CD.
Lupins, tramlines, 600 mm rows, rolling and shield spraying ... a good result in a dry season!

Paul Blackwell and Mike Collins, Department of Agriculture

KEY MESSAGE
This tramline system, with wide rows, post-emergence rolling and shield spraying gave a break-even gross margin and about $60/ha better returns than normal row spacings in a growing season with about half the average annual rainfall. Harvesting was also easier than with narrower rows, due to higher pods and better feed onto the harvester table.

AIM
To compare the productivity and profitability of a tramline-based lupin system with post-emergence rolling and shield spraying with methods not using tramlines or wider rows.

METHODS AND RESULTS
The crop was sown at the research station near Mullewa on yellow sand and red loamy sand. Seeding was on 7 May with 110 kg/ha Belara and 65 kg/ha compound fertiliser banded with knife points and press wheels digging to 125 mm. The plots were sown with a 7.5 m wide airseeder. Each plot was 22.5 m wide and 350 m long, there were three replicates of the three cropping systems (Table 1). With only half the average annual rainfall at Mullewa (156 mm) we harvested almost 40% more lupin grain from 600 mm row spacings than from 300 mm rows: 620 kg/ha compared to 433 kg/ha (Table 1). The wider rows allowed better access to moisture, less drought stress and the wide row crop stayed greener longer.

Table 1. Lupin yields and pod ground clearance of the three different systems
The yields on the wide rows have been corrected for the extra width of the 900 mm wide tramlines and to the equivalent for a 12 m wide seeder; there was no compensatory yield from the rows at the edge of the tramlines.

<table>
<thead>
<tr>
<th>System</th>
<th>Yield, kg/ha</th>
<th>Height of lowest pod, mm</th>
<th>Height of ridge, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 300 mm rows, no tramline</td>
<td>433</td>
<td>202</td>
<td>50</td>
</tr>
<tr>
<td>(2) 300 mm rows, no tramline, double seed rate</td>
<td>416</td>
<td>188</td>
<td>50</td>
</tr>
<tr>
<td>(3) 600 mm rows, 900 mm tramlines, rolling and shield spraying</td>
<td>620</td>
<td>229</td>
<td>0</td>
</tr>
<tr>
<td>600 mm rows, 900 mm tramlines, rolling and shield spraying and equivalent to a 12 m wide seeder</td>
<td>604 (Corrected by the equivalent of one missing one 300 mm row per seeder width.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The lupins in the wider rows (system 3) grew taller with the lowest pod about 25 mm higher than lupins in system 1 or 2. When combined with flattened ridges from post emergence rolling in system 3, there was another 50 mm better ground clearance from the lowest pod. Thus the 600 mm rows were easier to harvest than the normal 300 mm spaced rows; the crop also fed better into the header front.

Shield spraying
Two 900 mm wide tramlines allowed tractor access for shield spraying between the wide rows on 1 August when the lupins were flowering. This reduced herbicide costs by 50% (see Table 2), because less selective herbicide was used. The shields used 80% of normal broadacre rate of knockdown (Roundup®) between the rows and only about 20% of normal broadacre grass selective within the rows. The tramline system also did not use Brodal®, most radish was killed by the shield spraying. There was a 40% better radish kill with the shield system than with the poor kill rate with Brodal® in dry conditions (applied 14 June).
Current lupin prices, over $200/t, less herbicide cost and better yields resulted in a break-even gross margin for the tramline-based system when all costs were accounted for (Table 2).

Table 2. Gross margin analysis for the normal or tramline farming lupins

<table>
<thead>
<tr>
<th>System (yield)</th>
<th>Normal system (433 kg/ha)</th>
<th>Tramline system (604 kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop value on farm, $/t</td>
<td>192</td>
<td>192</td>
</tr>
<tr>
<td>Dockage for radish, $/t</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Price paid, $/t</td>
<td>189</td>
<td>192</td>
</tr>
<tr>
<td>Gross receipts, $/ha</td>
<td>83</td>
<td>116</td>
</tr>
<tr>
<td>Seed and fertiliser, $/ha</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Herbicides, $/ha</td>
<td>59</td>
<td>28</td>
</tr>
<tr>
<td>Machinery and labour, $/ha</td>
<td>30</td>
<td>33*</td>
</tr>
<tr>
<td>Insurance and interest, $/ha</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Total variable costs $/ha</td>
<td>140</td>
<td>110</td>
</tr>
<tr>
<td>GROSS MARGIN $/ha</td>
<td>-58</td>
<td>6</td>
</tr>
</tbody>
</table>

* Similar costs assumed. We assume that the cost of shield spraying by a contractor will be double the normal broadacre rate, thus the cost of shield spraying is equivalent to the cost of the two broadacre sprayings it replaced and the total machinery costs for each system are similar.

We also compared another system where the seed rate was doubled, to help compete with weeds better. Half the seed (110 kg/ha) was topdressed before seeding and the other half (110 kg/ha) sown in the rows. This gave a yield like the normal sowing (416 kg/ha) but greater grain loss at harvest, due to the large number of small plants. In the normal system and tramline system there was about 50 kg/ha on the ground after harvest, but in the double seed rate system there was 112 kg/ha on the ground. The extra seed cost of the system and smaller yield gave a gross margin of -$80/ha and no difference in weed population was found. Related trials at Wongan Hills showed significant yield improvement from early in-row Kerb® (2 kg/ha band sprayed at seeding) and early between row knock downs.

CONCLUSIONS

The wider rows allowed better access to moisture and less drought stress and set more pods to yield better. Post-emergence rolling provided another 50 mm better lowest pod ground clearance for easier harvesting. Shield spraying killed many radish plants, including some in-row, and reduced herbicide costs by 50%. The tramline system with 600 mm row spacing, post emergence rolling and shield spraying had a break-even gross margin and about $60/ha better returns than 300 mm row spacings.

KEY WORDS

Wide rows, shield spraying, tramlines

GRDC Project No.: DAW 718

Paper reviewed by: Abul Hashem

NB: The detailed trial record is in the Trials and Demo report of the NAR for 2002 and there is an extended version of this paper on the Crop Update 2002 CD.
Lupin wider row spacing data and observations

Bill Crabtree\textsuperscript{A}, Geoff Fosbery\textsuperscript{B}, Angie Roe\textsuperscript{B}, Mike Collins\textsuperscript{C} and Matt Beckett\textsuperscript{A}

\textsuperscript{A}WANTFA, \textsuperscript{B}Farm Focus Consultants and \textsuperscript{C}Department of Agriculture Northam

KEY MESSAGE

Doubling lupin row spacing often gave slight grain yield increases. The best responses came from sites that gave the least grain yield. One-metre wide lupins yielded 1.9 t/ha at Meckering when sown early at the high seeding rate. Lupin pod height was generally higher than with narrow rows - this has implications for ease of harvest. Wide rows give less soil disturbance and easier stubble management, which is likely to stimulate fewer weeds. Wide rows also assist in controlled traffic, enable cheaper knockdown herbicide application in the inter-row, and allow selective and more expensive pesticides to be banded in the crop row. Wide row pulse crops have been adopted in NSW and Victoria.

AIMS

1. To determine if wide or paired rows penalise lupin grain yields.
2. To determine if lupins, sown on 100 cm row spacings, can perform optimally at low seeding rates.
3. To determine whether lupins sown on wide rows benefit from precise seed placement.

METHOD

Two field trials were conducted at the WANTFA Meckering R&D site in 2001 and eight farmer weigh trailer strip trials were conducted during 2000 and 2001. Two data points are included from Mike Collins on similar trials (in graph of farmer strip trials) and one from Dr Paul Blackwell, Department of Agriculture (square in graph).

\textit{Meckering trial one:} A randomised complete block trial compared six row spacings or configurations (normal spacing at 21, 42 and 84 cm and paired row spacing - where the pair is 21 cm apart and the inter-row gap is 42, 63 or 84 cm) by three replicates. Tanjil lupins were sown in 2.2 m wide by 20 m long plots at 100 kg/ha into ungrazed wheat stubble on 13 June with a DBS knife opener. Super was placed with the seed at 120 kg/ha for the normal 21 cm row spacing and was banded 10 cm to the side of the seeding row with the other spacings. Potash was topdressed at 50 kg/ha on 4 September. Conventional pesticides were applied before and after seeding. Measurements included: plant counts, DM cuts, grain yield and grain analyses (by CBH). The average, lowest main-stem pod height, and lowest actual pod height, was recorded from each treatment.

\textit{Meckering trial two:} A factorial trial compared lupins sown with two seeders (precision disc and knife point) on 100 cm row spacings at three sowing rates (17.5, 35 and 70 kg/ha) by three replicates. The trial was sown into grazed wheat stubble. Super at 88 kg/ha was placed 75 mm (disc) and 100 mm (knife) to the side of the seed row to avoid fertiliser toxicity with a second opener. Conventional pesticides were applied before and after seeding. Tanjil lupins were in 6 m wide by 20 m long plots, on 25 May with a DBS or John Deere Precision disc opener. Measurements included: two plant counts, two DM cuts, grain yield and grain analyses (by CBH). Lowest lupin pod height was taken at random from six one-metre lengths along each plot of the best treatment - the lowest height of any pod in this metre was recorded on each side of the E-W sown rows.

\textit{Farmer strip trials:} Eight farmers throughout the central and northern wheatbelt conducted normal (18-25 cm wide) and twice normal row spacing strips under the guidance of Farm Focus Consultants during the years 2000 and 2001. Fertiliser and pesticide application were consistent with good agronomic practice. For the wide rows the farmers put two hoses down the same opener for at least one strip down the paddock adjacent to the normal row spacing seeder run. A weigh trailer was used to collect three replicates of the grain yield from normal and double row spacings.

RESULTS

\textit{Meckering trial one:} Increasing the width of lupin rows did not penalise lupin grain yield with the single skip spacing or the 42 cm wide solid row spacing. However, at the double and triple skip, and very wide (84 cm) row spacings, grain yields were reduced. The late sowing (13 June), is likely to have contributed to this reduction in yield on the wider row spacing. Pod height from the lowest main-stem pods increased with increasing row spacing, by 10 to 18%. Increasing row spacing decreased lupin plant numbers. There were no protein or screening differences between treatments.
Lupin grain yield response from 2000-01 to doubling row spacings

\[ y = 1.78e^{-0.03x} \]

\[ R^2 = 0.82 \]

Table 1. Meckering lupin row spacing trial (01W08)

<table>
<thead>
<tr>
<th>Trt #</th>
<th>Row spacing type</th>
<th>Average spacing (cm)</th>
<th>Emergence at 17 July (p/m²)</th>
<th>Dry matter 10 October (t/ha)</th>
<th>Grain yield (t/ha)</th>
<th>Lowest pod height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solid</td>
<td>21.0</td>
<td>60</td>
<td>5.5</td>
<td>2.19</td>
<td>37.9</td>
</tr>
<tr>
<td>2</td>
<td>Solid</td>
<td>42.0</td>
<td>54</td>
<td>4.2</td>
<td>2.07</td>
<td>41.8</td>
</tr>
<tr>
<td>3</td>
<td>Solid</td>
<td>84.0</td>
<td>38</td>
<td>3.1</td>
<td>1.47</td>
<td>42.7</td>
</tr>
<tr>
<td>4</td>
<td>Single skipA</td>
<td>31.5</td>
<td>52</td>
<td>4.5</td>
<td>2.07</td>
<td>39.0</td>
</tr>
<tr>
<td>5</td>
<td>Double skip</td>
<td>42.0</td>
<td>48</td>
<td>4.3</td>
<td>1.92</td>
<td>42.2</td>
</tr>
<tr>
<td>6</td>
<td>Triple skip</td>
<td>52.5</td>
<td>53</td>
<td>4.0</td>
<td>1.83</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5% LSD = 8</td>
<td>0.13</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

\[ p-value = 0.00 \]

\[ 0.00 \]

\[ 0.05 \]

\[ 0.12 \]

\[ MS^{a} = \text{Main stem of the lupin plant.} \]

**SkipA** = Two rows of crop and then missing a single row (single skip), missing 2 rows (double skip), etc.

**Meckering trial two**: The knife opener increased emergence, mid-DM, late-DM and grain yield by 94, 40, 16 and 50% over the disc opener (Table 2). The best grain yield was 1.9 t/ha with the knife opener at the highest seeding rate. The disc opener gave poor emergence due to the high level of hair-pinning from the heavily grazed wheat stubble. This was despite 26 mm of rain falling 6-8 days after sowing. Increasing the seeding rates increased emergence, DM and grain yield.

Table 2. Lupin emergence, DM and grain yield with different openers and seeding rates

<table>
<thead>
<tr>
<th>Trt</th>
<th>Opener used</th>
<th>Seed rate (kg/ha)</th>
<th>Plant counts (plants/m²)</th>
<th>Dry matter - 24 October (t/ha)</th>
<th>Grain yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>29 June 4 Oct</td>
<td>All</td>
<td>Rate</td>
<td>Opener</td>
</tr>
<tr>
<td>1</td>
<td>Knife</td>
<td>17.5</td>
<td>11</td>
<td>9</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>Knife</td>
<td>35</td>
<td>19</td>
<td>19</td>
<td>4.7</td>
</tr>
<tr>
<td>3</td>
<td>Knife</td>
<td>70</td>
<td>36</td>
<td>37</td>
<td>6.4</td>
</tr>
<tr>
<td>4</td>
<td>Disc</td>
<td>17.5</td>
<td>5</td>
<td>4</td>
<td>2.3</td>
</tr>
<tr>
<td>5</td>
<td>Disc</td>
<td>35</td>
<td>9</td>
<td>10</td>
<td>4.7</td>
</tr>
<tr>
<td>6</td>
<td>Disc</td>
<td>70</td>
<td>20</td>
<td>22</td>
<td>6.0</td>
</tr>
</tbody>
</table>

\[ 5\% \ LSD = \]

\[ 0.02 \]

\[ 0.07 \]

\[ 0.08 \]

\[ 0.03 \]

\[ 0.00 \]

\[ 0.00 \]

**Pod height**: The lowest lupin pod-heights, were on average, twice as high on the south side of the plant than on the north side (rows running east-west), 20 and 10 cm respectively (5% LSD of 3.5 cm).

**Grain quality**: Grain proteins, screenings, and hectolitre weights showed no differences between treatments.

**Canopy closure**: The lupins gave large growth rates towards the end of the season. DM increase was from 3.0 to 4.7 t/ha from 10 to 24 October (10 October data not shown). The canopy fully closed by the end of October on the high seeding-rate with the knife openers, when there was only 50% closure observed on 18 September (see photo on page 463 of WANTFA Farming Systems, November 2001).

**Precision issue**: The high level of seedling mortality occurring with the precision opener at the highest seeding rate, rendered the hypothesis (wide-row lupins will benefit from precise seed placement) untested.

**Farmer strip trials**: These sites usually gave higher grain yields with doubling the row spacings (see graph right). The square points are from Crabtree, Collins and Blackwell (from top-left to bottom right).

**CONCLUSIONS**

Farmers can be confidently encouraged to try wide lupin row spacings. The extra pod height has good implications for farmers who often struggle to harvest low lupin crops.

**ACKNOWLEDGMENTS**

Funding is from BEELINE technology, GRDC, CSBP Futurefarm and Elders. Agritech Crop Research conducted the Meckering trials, Bowden and Lance took plant and soil samples and Farm Focus clients.

GRDC Project No.: WAN6, WAN3, DAW617

Paper reviewed by: Dr Bill Bowden
Lupin genotypes respond differently to potash

Bob French and Laurie Wahlsten, Senior Research Officer and Technical Officer, Department of Agriculture, Merredin

KEY MESSAGE

A grain yield response to potash (K) fertiliser was observed on soils with less than 30 mg/kg extractable K, but the response was not consistent at levels between 30 and 40 mg/kg. Modern, high yield potential, lupin cultivars seem more responsive to K than older cultivars. In order to get greatest benefit from these cultivars, attention should therefore be given to K nutrition in situations where there might be a deficiency.

BACKGROUND AND AIMS

Crops remove considerable amounts of K from the soil that, in Western Australian farming systems, have traditionally not been replaced. Consequently, natural levels of K in WA agricultural soils are becoming depleted, and K fertiliser is now often necessary to maintain high levels of productivity. Sandy soils, on which lupins are usually grown, typically have lower natural levels of K than loamy and clay soils, but little is known about the K requirements of lupins. Such knowledge will become increasingly important as farming systems become more productive and natural K levels become further depleted. The aims of the research described here were to:

- Find how low soil K levels can be before lupin grain yield will respond to applied K fertiliser
- Find whether lupin cultivars differ in their sensitivity to K nutrition

METHODS

Four randomised block experiments compared seven lupin cultivars at 3 rates of potash. Plots were 20 m × 8 rows. These experiments were on sites chosen to differ in soil K, but there was reason to believe that all would be responsive. Two sites were at Eneabba, on soils with naturally low K levels, a third was at Wongan Hills and the fourth at Kellerberrin. The latter two sites had a long history of cropping and the initially reasonable K levels had become depleted over this time. K was applied as muriate of potash topdressed in front of the cone-seeder, and incorporated by the sowing operation.

RESULTS

Soil description

<table>
<thead>
<tr>
<th>Eneabba Site 1</th>
<th>Eneabba Site 2</th>
<th>Wongan Hills</th>
<th>Kellerberrin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep grey sand</td>
<td>Deep grey sand</td>
<td>Deep yellow sand</td>
<td>Gritty sand over clay</td>
</tr>
<tr>
<td>pH 5.4 at 0-10 cm and 5.0 at 15-25 cm</td>
<td>pH 5.8 at 0-10 cm and 4.8 at 15-25 cm</td>
<td>pH 5.4 at 0-10 cm, 4.0 at 15-25 cm and 5.2 at 40-50 cm</td>
<td>pH 4.7 at 0-10 cm, 5.1 at 15-25 cm and 5.0 at 40-50 cm</td>
</tr>
<tr>
<td>bicarbonate 35 mg/kg K at 0-10 cm and 17 mg/kg at 15-25 cm</td>
<td>bicarbonate 15 mg/kg K at 0-10 cm and &lt; 10 mg/kg at 15-25 cm</td>
<td>bicarbonate K 37 mg/kg at 0-10 cm, 31 mg/kg at 15-25 cm and 23 mg/kg at 40-50 cm</td>
<td>bicarbonate K 52 mg/kg at 0-10 cm, 56 mg/kg at 15-25 cm and 64 mg/kg at 40-50 cm</td>
</tr>
<tr>
<td>This site had had K fertiliser applied in the past</td>
<td>This site had no history of K application</td>
<td>This site had no history of K application</td>
<td>This site had no history of K application</td>
</tr>
</tbody>
</table>
Grain yields (t/ha)

<table>
<thead>
<tr>
<th></th>
<th>Eneabba Site 1</th>
<th>Eneabba Site 2</th>
<th>Wongan Hills</th>
<th>Kellerberrin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>120</td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>Belara</td>
<td>1.47</td>
<td>1.61</td>
<td>1.30</td>
<td>2.18</td>
</tr>
<tr>
<td>Kalya</td>
<td>1.65</td>
<td>1.48</td>
<td>1.50</td>
<td>2.13</td>
</tr>
<tr>
<td>Merrit</td>
<td>1.44</td>
<td>1.41</td>
<td>1.85</td>
<td>2.39</td>
</tr>
<tr>
<td>Myallie</td>
<td>1.36</td>
<td>1.31</td>
<td>1.97</td>
<td>2.31</td>
</tr>
<tr>
<td>Quilinock</td>
<td>1.48</td>
<td>1.59</td>
<td>1.57</td>
<td>2.08</td>
</tr>
<tr>
<td>Tallerack</td>
<td>1.44</td>
<td>1.39</td>
<td>1.28</td>
<td>1.95</td>
</tr>
<tr>
<td>Tanjil</td>
<td>1.39</td>
<td>1.58</td>
<td>1.76</td>
<td>2.19</td>
</tr>
<tr>
<td>LSD (P = 0.05)</td>
<td>0.16</td>
<td>0.44</td>
<td>0.52</td>
<td>0.12</td>
</tr>
</tbody>
</table>

**CONCLUSION**

There were large differences between sites in the grain yield responses to potash. The lowest K site was clearly most responsive. Small responses were observed when soil K levels were between 30 and 40 mg/kg, but these were not consistent between cultivars. Very little response was observed when soil K exceeded 50 mg/kg, although the site at Kellerberrin also had very low yield potential, due to the dry growing season, which may also have limited responsiveness.

There were differences between cultivars in their response to K. Belara was among the most responsive cultivars at all sites except Kellerberrin, and Myallie was consistently unresponsive. The recent cultivars Quilinock and Tanjil also showed signs of being fairly responsive. This suggests that high yield potential lupin cultivars may have larger K requirements than older varieties, and that attention will have to be given to K nutrition on marginal soils to get the best out of these new varieties.

**KEY WORDS**

Potash, nutrition, cultivars, lupins

GRDC Project No.: DAW 583

Paper reviewed by: Greg Shea
Consequence of radish competition on lupin nutrients in a wheat-lupin rotation

Abul Hashem, Department of Agriculture, Northam and Nerys Wilkins, Department of Agriculture, Merredin

KEY MESSAGES

- Competition from radish plants in a long-term wheat-lupin rotation substantially reduced lupin seed size, total nutrient uptake and protein percentage of lupin seed.
- Lupin seed protein percentage decreased with the decreases in seed size due to competition.

BACKGROUND

Competition from radish may reduce lupin yield by 28-92%. Radish competition not only reduces lupin yield, but may also alter lupin seed quality such as seed size and protein percentage. Little information is available on the effect of long term radish competition on the nutrient uptake and quality of lupin seed.

AIMS

The aims of this trial were to examine the effect of long-term competition from radish on the lupin seed size, protein percentage and nutrient uptake by seed in a wheat-lupin rotation.

METHODS

A long-term wheat-lupin rotation was established in 1997 at the Merredin Research Station to examine the effect of chemical and non-chemical weed control options on the competitiveness of wild radish. During wheat phase in 1997, autumn tickling, wheat seed rates, and low and high level of herbicides from various groups, were combined to achieve eight treatments including an untreated control and a treatment for total prevention of radish seed production.

The herbicides used in wheat were rotated with herbicides with different modes of action in subsequent crops: lupin (1998), wheat (1999), lupin (2000) and wheat (2001). In the 1998 and 2000 lupin crops, simazine 2.0 L/ha was used uniformly on all plots before seeding (PS). In 2000, after four years of competition, seed samples of lupin were collected and analysed for N, P and K. Lupin seed size (g/1000 seeds) was also measured on these samples. Data were analysed by ANOVA and simple linear regression analysis.

RESULTS

Competition from radish significantly reduced total uptake of N, P and K by lupin seed (Figure 1). Uptake of nutrients was the highest where less than 1 radish plant/m² was present at 3 weeks after emergence (WAE) of crop. Presence of 10 radish plants/m² at 3 WAE reduced N, P, and K uptake by 72, 71 and 69% respectively although concentrations of these nutrients were not significantly affected by radish density. The reduction in nutrient uptake by lupin seed could be attributed to a reduction in lupin seed yield due to competition from radish.
Regression analyses indicate that seed size of lupin was reduced with the increases in radish density in lupin at 3 WAE (Figure 2). However, lupin seed protein percentage increased linearly with increases in seed size of lupin. These results suggest that competition from radish can reduce lupin protein mainly due to a reduction in lupin seed size. Lupin seed coat contains less protein than seed kernel (Bill Bowden, personal communication). Seed coat makes up a greater proportion of small seed, and seed kernel a smaller a proportion, than in large seed. This is a possible explanation why small seed tends to have lower protein contents than large seed.

CONCLUSION

Competition from radish plants reduced, uptake of nutrients by lupin seed, seed size and seed protein percentage in a long-term wheat-lupin rotation in Merredin.

KEY WORDS

Competition, seed size, nutrient uptake, protein percentage

GRDC Project No.: DAW 535

Paper reviewed by: Dr Bob French and Dr Bill Bowden
Consequence of ryegrass competition on lupin nutrients in a wheat-lupin rotation

Abul Hashem, Department of Agriculture, Northam and Nerys Wilkins, Department of Agriculture, Merredin

KEY MESSAGE

• Long-term competition from ryegrass did not reduce protein, phosphorus or potassium concentrations in lupin seed although competition reduced lupin seed yield.
• Competition between ryegrass and lupin plants occurred during early vegetative growth stages rather than during the seed filling stages.

BACKGROUND

Competition from ryegrass not only reduces yields of crops but also the quality of crops. Nutrient contents of seed, particularly protein, are a good indication of seed quality. Lupins sown at wide row spacings are considered to be poor competitors particularly where weeds such as ryegrass have developed resistance to herbicides. It is therefore important to determine if the seed quality is affected by long-term competition from ryegrass.

AIMS

One of the aims of this trial was to examine the effect of long-term competition from ryegrass on the nutrient contents of lupin seed in wheat-lupin rotation.

METHODS

This trial was established with wheat in 1997 on lupin stubble in a sandy loam soils at the Wongan Hills Research Station. The population of ryegrass was known to be resistant to Fops of Group A herbicides. Eight treatments including: (a) an untreated control; (b) a range of herbicides; and (c) non-chemical weed control options such as tickling, high seed rate and delayed seeding, were laid out in a randomised block design. These treatments provided a range of ryegrass control levels resulting in a range of ryegrass densities across treatments in wheat in 1997, lupin in 1998, wheat in 1999, lupin in 2000 and wheat in 2001. Lupin biomass was destructively collected 15 weeks after emergence (WAE) of lupin, dried at 70°C for 48 hours and dry weight recorded. Lupin seed samples were collected from two replications in 2000 and analysed for N, P and K after four years of competition from ryegrass. Data were subjected to linear regression analysis.

RESULTS

The linear regression has predicted that as the ryegrass density at 3 WAE increases by 1 plant/m², lupin yield is reduced by 0.53 kg/ha (Figure 1). This means that presence of 500 ryegrass plants/m² at 3 WAE reduced lupin yield by 18% and 1000 ryegrass plants/m² reduced lupin yields by 36% compared with 1387 kg/ha, the highest yield obtained in absence of any competition.

The linear relationship between concentrations of protein, P or K in lupin seed and ryegrass plants/m² at 3 WAE is very weak ($R^2 < 0.1$) indicating that N, P and K concentrations were not affected by ryegrass densities as recorded on 3 WAE in this trial (Figure 1). A strong positive linear relationship between dry biomass at early flowering stage of lupin and its seed yield means that lupin biomass was set by competition from ryegrass during vegetative growth stages and seed yield formation was proportional to its biomass at 15 WAE (Figure 2). These results on the constant concentrations of nutrients in lupin seed and relationship between biomass and seed yield of lupin suggest that competition between these two species occurred during early vegetative growth stages rather than during seed filling stages of lupin.
Figure 1. Concentrations of protein, phosphorous and potassium, and yield of lupin seeds in 2000 after four years of competition from ryegrass in wheat-lupin rotation at Wongan Hills Research Station.

Figure 2. Relationship between lupin dry biomass at early flowering stages of lupin plants and lupin seed yield in 2000, after four years of competition from ryegrass, in a wheat-lupin rotation at Wongan Hills Research Station.

CONCLUSIONS
Long-term competition from ryegrass did not reduce protein, phosphorus or potassium concentrations in lupin seed but it reduced lupin seed yield. Lupin seed yield was strongly related to lupin biomass at early flowering stage. As such, competition between ryegrass and lupin appears to have occurred during early vegetative stages of lupin.

KEY WORDS
Competition, lupin protein, seed nutrients

GRDC Project No.: DAW 535
Paper reviewed by: Dr Bill Bowden
Fungicide sprays for control of lupin anthracnose
Geoff Thomas and Ken Adcock, Department of Agriculture

KEY MESSAGE
- There are no fungicide sprays registered for use on lupins, this paper reports on experimental trials only and does not recommend the use of fungicide sprays for anthracnose control.
- Fungicide sprays reduced anthracnose infection, increased yield and reduced seed infection, four sprays during the flowering period (with or without two additional pre-flowering sprays) were most effective, however a single spray at flowering on 1st order branches was also effective.
- There were no differences in efficacy between the systemic and contact (non-systemic) fungicides used in these trials.
- These trials indicate there may be opportunities for the use of fungicide sprays to protect yield in high value or highly susceptible crops and to reduce seed infection for seed production schemes.
- Under most conditions it is likely that using appropriate resistant varieties will give better yields and economic returns than the use of fungicide sprays.

AIMS
These trials were established to determine the efficacy of fungicide sprays for reducing anthracnose infection of lupins, reducing yield losses and reducing infection of harvested seed.

METHODS
Two trials were conducted at Badgingarra Research Station, in different paddocks, to establish different levels of disease pressure. Spray treatments were applied using a boom spray mounted on a 4 wheel motorbike at a water volume of ~ 200 L/ha. Detailed assessment of infection levels were made on all plots at leaf drop (9/10 trial 1, 23/10 trial 2) and both trials were harvested on 22/11/01. Infection in harvested seed was determined by laboratory incubation of 500 seeds/plot.

Lupin variety: Belara (sown 7/5/01)
Plots: 25 m x 1.5 m, 3.5 m bare ground buffers between plots
Infection: Three transplanted infected plants per plot on 25/5/01 (~ 0.25% infection)
Design: Randomised block design, 4 replications
Seven spray timings:
- Nil
- Full control (every 3 weeks from 6 weeks, 14/6, 2/7, 20/7, 13/8, 31/8, 10/9)
- Pre-flowering control (every 3 weeks from 6 weeks until flowering, 14/6, 2/7)
- Main stem flowering (20/7)
- 1st branch flowering (13/8)
- 2nd branch flowering (31/8)
- Full flower protection (20/7, 13/8, 31/8, 10/9)
Products:
- Aggie mancozeb (800 g/kg mancozeb) @ 2 kg/ha
- Amistar (500g/kg azoxystrobin) @ 500 g/ha

RESULTS
Infected transplants were added 3 weeks after sowing (25 mm of rain 6 days later), the first spray was 3 weeks following this. As a result, infection was well established before the first spray occurred.

All fungicide applications were planned to be on approximately 3 week intervals, with exact timing to try and ensure that they occurred 3-4 days before significant rainfall (> 5 mm). The actual situation was; spray 4 (1st order branches flowering) and 6 had > 5 mm rainfall within 2 days after spraying, sprays 2, 3, 5 had > 5 mm 7-10 days after spraying and spray 1 had only 2 mm following application.

Azoxystrobin and mancozeb were equally effective, there were no interactions between fungicide and spray timing and so combined results for azoxystrobin and mancozeb have been presented (Table 1).

Disease levels were higher in trial 2, almost 100% of plants in untreated plots being infected compared to 75% in trial 1, this is reflected in both percentage of pods infected and yield. The multiple spray treatments and the spray at first order flowering significantly reduced infection on stems and pods in
both trials. These treatments also significantly increased yield in trial 1 (10-15%) and trial 2 (42-57%), in trial 2 a single spray at flowering on second order branches also significantly increased yield (21%).

No treatment was able to eradicate disease, however the multiple spray treatments reduced pod infection in both trials. At the time of writing seed infection levels were only available for some mancozeb treatments in Trial 1 and a single replicate of Trial 2. Multiple spray treatments had significantly reduced seed infection in both trials, a single spray had also reduced seed infection but to a lesser degree in Trial 1.

Table 1. Effect of foliar fungicides on yield (combined result for azoxystrobin and mancozeb) and infection of harvested seed (result for mancozeb only) of anthracnose infected Belara lupins in two trials at Badgingarra Research Station in 2001

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Trial 1</th>
<th></th>
<th>Trial 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield</td>
<td>% Seed</td>
<td>Yield</td>
<td>% Seed</td>
</tr>
<tr>
<td></td>
<td>(t/ha)</td>
<td>infectedA</td>
<td>(t/ha)</td>
<td>infectedA</td>
</tr>
<tr>
<td>Nil</td>
<td>2.10</td>
<td>2.5</td>
<td>1.14</td>
<td>2.6</td>
</tr>
<tr>
<td>Pre-flowering control (2 sprays)</td>
<td>2.22</td>
<td>.B</td>
<td>1.22</td>
<td>.B</td>
</tr>
<tr>
<td>Main stem flowering (1 spray)</td>
<td>2.11</td>
<td>2.8</td>
<td>1.24</td>
<td>2.0</td>
</tr>
<tr>
<td>1st branch flowering (1 spray)</td>
<td>2.37</td>
<td>1.9</td>
<td>1.62</td>
<td>0.2</td>
</tr>
<tr>
<td>2nd branch flowering (1 spray)</td>
<td>2.23</td>
<td>.B</td>
<td>1.39</td>
<td>1.8</td>
</tr>
<tr>
<td>Full flower protection (4 sprays)</td>
<td>2.31</td>
<td>1.2</td>
<td>1.78</td>
<td>0.4</td>
</tr>
<tr>
<td>Full control (6 sprays)</td>
<td>2.42</td>
<td>1.1</td>
<td>1.79</td>
<td>0.4</td>
</tr>
<tr>
<td>LSD</td>
<td>0.21</td>
<td>0.8</td>
<td>0.20</td>
<td>.C</td>
</tr>
</tbody>
</table>

A Preliminary data, results for Mancozeb only available at this time.
B Preliminary data, results not available at this time.
C Preliminary data, results for single replicate, no statistical analysis available at this time.

CONCLUSIONS

Early sprays did not reduce anthracnose infection, possibly due to the low rainfall around the time of these initial sprays and the continued influx of inoculum from other plots, these spray times are more likely to be effective when the only inoculum is seed borne. Similarly the comparatively low effect of the main stem flowering spray could be related to the long period, 10 days, between spraying and subsequent rain. As this spray was applied before flowers had fully opened, pods emerging after flowers opened would have had very little fungicide protection and been exposed to infection from the rain 10 days after spraying. This lack of longer term protection is understandable in the contact fungicide mancozeb but disappointing in the systemic fungicide azoxystrobin.

No treatment (including the multiple spray applications) was able to eradicate anthracnose from pods or harvested seed, however significant reductions of seed infection did occur indicating that with lower disease pressure fungicide sprays may be an additional tool for producing clean seed.

These trials were carried out in conditions highly conducive to the disease (high level of inoculum, moderately susceptible variety and favourable environment). These are not recommended practices for this region and it is unlikely that such significant yield effects would occur in an environment less conducive to disease or with a more resistant variety or where yield potential is lower, as is shown by the reduced effect of the fungicide sprays in Trial 1 where disease pressure was lower. Previous trials indicate that resistant varieties (eg. Wonga or Tanjil) have had higher yield than any of the spray treatments on Belara where anthracnose is moderate or severe.

These trials indicate that there may be scope for use of fungicide sprays to protect infected crops, particularly those which are susceptible or have high yield potential. Fungicides could also potentially reduce seed infection as part of clean seed production systems. Further research will be aimed at these areas and enquiries are being instigated into registration of fungicides for anthracnose control.

Currently no fungicides are registered for foliar application to lupins; this paper reports on trials established to determine the possible efficacy of foliar fungicides and is not a recommendation for the use of fungicide sprays on lupins.

GRDC Project No.: DAW665
Paper reviewed by: Mark Sweetingham
KEY MESSAGE

Yield losses as a result of anthracnose infection are influenced by seasonal rainfall, variety resistance and seed infection level. A series of tables has been produced estimating yield losses in lupins as a result of combinations of these three factors. These tables can be used with seed testing results to allow growers to make informed decisions regarding suitability of seed. They are available with seed testing results and on the Department of Agriculture web site.

BACKGROUND

A series of trials have been run over the previous four years examining the effects of differing levels of anthracnose infection in a range of varieties in different rainfall zones. The results of these trials have been combined to produce a series of critical seed infection thresholds which have been available in previous crop update articles and are provided with seed testing results. Critical seed infection thresholds provide information as to the threshold level of seed infection, which will result in 5% yield loss. Many growers require more detailed information relating seed infection level, variety and rainfall to likely yield loss, that information is provided in the tables below.

RESULTS

The tables contain three variables, which contribute to yield loss from anthracnose infection:

- Varieties have been grouped by relative susceptibility (see Crop Variety Sowing Guide).
- Rainfall zones used are those from the Crop Variety Sowing Guide, they are roughly described as Low, Medium and High rainfall zones. The range within each zone is large, consequently when interpreting these tables notice should be taken of likely rainfall compared to the applicable zone.
- Seed infection level can be determined by the use of seed testing, transmission from seed can be reduced by thiram seed treatment.

Quantity, frequency and timing of rainfall can have significant effects on anthracnose transmission from seed and subsequent spread within a crop. Therefore variability in rainfall and other environmental factors can greatly affect the yield losses from anthracnose within any year. The yield loss estimates presented here are based on trial results and represent ‘average’ environmental conditions in the High, Medium and Low rainfall zones. Significant variance from average conditions could significantly change yield losses from those presented in the following tables.

Application of a fungicide seed treatment containing ‘thiram’ will reduce seed transmission on average by approximately 75%.

Anthracnose infection can occur as a result of seed infection or from other sources of infection outside the crop (e.g. blue lupins or nearby infected crop). These tables estimate yield losses as a result of transmission from infected seed only, the presence of other sources of infection could result in higher losses than those shown here.
### High rainfall (> 450 mm) zone

<table>
<thead>
<tr>
<th>Variety</th>
<th>Estimated yield loss (% reduction)</th>
<th>Seed infection level sown (%)</th>
<th>Seed infection level sown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no fungicide seed treatment</td>
<td>with fungicide seed treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td></td>
</tr>
<tr>
<td>Kiev Mutant</td>
<td>80 90 95 100 100</td>
<td>50 75 80 90 95</td>
<td></td>
</tr>
<tr>
<td>Wodjil</td>
<td>50 70 80 90 100</td>
<td>20 50 55 80 85</td>
<td></td>
</tr>
<tr>
<td>Myallie, Tallerack, Quilinock</td>
<td>10 20 30 45 60</td>
<td>2 10 15 30 40</td>
<td></td>
</tr>
<tr>
<td>Merrit, Belara, Gungurru</td>
<td>5 10 20 40 50</td>
<td>1 5 8 20 30</td>
<td></td>
</tr>
<tr>
<td>Kalya</td>
<td>3 6 10 25 35</td>
<td>1 3 5 10 15</td>
<td></td>
</tr>
<tr>
<td>Wonga, Tanjil</td>
<td>2 4 5 10 20</td>
<td>1 2 3 5 8</td>
<td></td>
</tr>
</tbody>
</table>

### Medium rainfall (325-450 mm) zone

<table>
<thead>
<tr>
<th>Variety</th>
<th>Estimated yield loss (% reduction)</th>
<th>Seed infection level sown (%)</th>
<th>Seed infection level sown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no fungicide seed treatment</td>
<td>with fungicide seed treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td></td>
</tr>
<tr>
<td>Kiev Mutant</td>
<td>30 35 50 80 90</td>
<td>15 30 30 50 60</td>
<td></td>
</tr>
<tr>
<td>Wodjil</td>
<td>15 20 35 70 85</td>
<td>5 15 20 35 50</td>
<td></td>
</tr>
<tr>
<td>Myallie, Tallerack, Quilinock</td>
<td>5 10 15 30 50</td>
<td>3 5 10 15 25</td>
<td></td>
</tr>
<tr>
<td>Merrit, Belara, Gungurru</td>
<td>5 8 10 20 30</td>
<td>1 5 8 10 15</td>
<td></td>
</tr>
<tr>
<td>Kalya</td>
<td>2 5 7 15 20</td>
<td>0 2 4 7 10</td>
<td></td>
</tr>
<tr>
<td>Wonga, Tanjil</td>
<td>1 2 3 5 10</td>
<td>0 1 2 3 5</td>
<td></td>
</tr>
</tbody>
</table>

### Low rainfall (< 325 mm) zone

<table>
<thead>
<tr>
<th>Variety</th>
<th>Estimated yield loss (% reduction)</th>
<th>Seed infection level sown (%)</th>
<th>Seed infection level sown (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no fungicide seed treatment</td>
<td>with fungicide seed treatment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td>0.01 0.05 0.1 0.5 1.0</td>
<td></td>
</tr>
<tr>
<td>Kiev Mutant</td>
<td>10 15 25 40 50</td>
<td>5 10 12 25 35</td>
<td></td>
</tr>
<tr>
<td>Wodjil</td>
<td>4 5 15 25 35</td>
<td>2 4 5 15 20</td>
<td></td>
</tr>
<tr>
<td>Myallie, Tallerack, Quilinock</td>
<td>2 5 8 10 20</td>
<td>1 2 4 8 10</td>
<td></td>
</tr>
<tr>
<td>Merrit, Belara, Gungurru</td>
<td>2 4 5 8 15</td>
<td>1 2 4 5 8</td>
<td></td>
</tr>
<tr>
<td>Kalya</td>
<td>1 1 4 5 8</td>
<td>0 1 1 4 5</td>
<td></td>
</tr>
<tr>
<td>Wonga, Tanjil</td>
<td>0 1 2 3 5</td>
<td>0 0 1 2 2</td>
<td></td>
</tr>
</tbody>
</table>

**GRDC Project No.:** DAW665  
**Paper reviewed by:** Mark Sweetingham
Effect of variety and environment (northern and southern wheatbelt) on yield losses in lupins due to anthracnose

Geoff Thomas and Ken Adcock, Department of Agriculture

KEY MESSAGE

- Yield losses from anthracnose at both Esperance and Mt Barker were high, indicating that anthracnose can be significant in southern regions, presenting implications for variety selection.
- Late season rainfall in southern regions can produce high percentages of infected pods (therefore infected seed), this has implications for infection levels in the following seasons crop.
- In all trials, Tanjil had significantly lower yield loss and less infection in pods than Quilinock, Belara or Kalya.
- Yield losses from anthracnose are influenced by seasonal rainfall, seed infection level and variety resistance.

AIMS

To make a comparison of yield loss due to anthracnose in a range of lupin varieties across southern and northern agricultural areas.

METHODS

Sites were established at Esperance Downs Research Station, Mt Barker Research Station and Wongan Hills Research Station. Trials were split plot design with 5 replicates. To initiate disease, infected seedlings were transplanted into half of the plots in each trial (infection levels were 0.3% at Esperance, 0.25% at Mt Barker and 0.5% at Wongan Hills). Yields from these plots were compared to those from plots that were regularly sprayed with fungicide to ensure they were uninfected by anthracnose. Varieties tested were Tanjil, Kalya, Belara and Quilinock (Quilinock not included at Mt Barker due to extreme susceptibility). Establishment and growth of Tanjil at Mt Barker was very poor, possibly due to simazine damage.

At leaf drop at each site, incidence of infection on stems and pods was assessed. Trials were harvested and seed samples retained for assessment of anthracnose infection levels.

RESULTS

Early establishment and spread of anthracnose from transplants varied between sites. At Wongan Hills 30 mm of rain fell within 1 week of the introduction of infected transplants and a further 10 mm in the following fortnight, resulting in good early spread of disease. At Esperance and Mt Barker disease establishment was delayed by a three week period of dry weather following introduction of infected transplants. Rainfall increased greatly at the southern sites after this period with the August to October rainfall being 243 mm at Esperance and 180 mm at Mt Barker compared to only 67 mm at Wongan Hills.

At all three sites, the degree of yield loss relates to the variety resistance score, with the exception of Belara at Esperance. Tanjil is the only variety that does not suffer a significant yield loss at any site and although lower yielding in sprayed plots is highest yielding in the presence of anthracnose. Belara has yielded particularly well at Esperance and its yield loss is less than in Kalya.

Pod infection levels are extremely high at Esperance and moderate at both Mt Barker and Wongan Hills. Tanjil had significantly lower pod infection than all other varieties and Quilinock significantly higher pod infection. Kalya and Belara had similar levels of pod infection at all sites.
Table 1. Effect of anthracnose on yield (t/ha) of lupin varieties grown at Esperance (0.3% infection), Mt Barker (0.25% infection) and Wongan Hills (0.5% infection)

<table>
<thead>
<tr>
<th>Variety</th>
<th>Esperance</th>
<th>Mt Barker</th>
<th>Wongan Hills</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No disease</td>
<td>Disease</td>
<td>% Yield loss</td>
</tr>
<tr>
<td>Quilinock</td>
<td>3.18</td>
<td>2.28</td>
<td>28</td>
</tr>
<tr>
<td>Belara</td>
<td>3.15</td>
<td>2.81</td>
<td>11</td>
</tr>
<tr>
<td>Kalya</td>
<td>2.99</td>
<td>2.47</td>
<td>18</td>
</tr>
<tr>
<td>Tanjil</td>
<td>2.87</td>
<td>2.82</td>
<td>2</td>
</tr>
<tr>
<td>LSD</td>
<td>0.23</td>
<td>-</td>
<td>0.35</td>
</tr>
</tbody>
</table>

a  Not sown at this site.
b  Tanjil establishment and growth poor at this site.

Table 2. Effect of anthracnose on pod infection of lupin varieties grown at Esperance (0.3% infection), Mt Barker (0.25% infection) and Wongan Hills (0.5% infection)

<table>
<thead>
<tr>
<th>Variety</th>
<th>% Pods infected (infected plots)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Esperance</td>
</tr>
<tr>
<td>Quilinock</td>
<td>25.2</td>
</tr>
<tr>
<td>Belara</td>
<td>11.1</td>
</tr>
<tr>
<td>Kalya</td>
<td>15.3</td>
</tr>
<tr>
<td>Tanjil</td>
<td>4.1</td>
</tr>
<tr>
<td>LSD</td>
<td>5.7</td>
</tr>
</tbody>
</table>

a  Not sown at this site.
b  Tanjil establishment and growth poor at this site.

CONCLUSIONS

Total rainfall at the three sites varied greatly, as did the distribution of rainfall during the season. At Wongan Hills disease established well early resulting in high levels of stem infection and reducing yield but producing moderate levels of pod infection. At both Esperance and Mt Barker, disease establishment was slow due to dry conditions after introduction of transplants resulting in very low levels of main stem infection. Significant rainfall later in the season exposes pods to more infection opportunities resulting in reduced yield and higher levels of pod infection. Yield losses at both Esperance and Mt Barker would be higher in a season with more rainfall earlier in the season.

Yield losses were similar at all sites despite different levels of introduced infection, again highlighting the interaction between rainfall and seed infection level, with higher rainfall areas requiring lower seed infection levels.

In general, resistance rankings indicate comparative yield loss, the resistant variety Tanjil is significantly better than the other varieties tested. At Esperance, yield loss in Belara is less than in Kalya, possibly due to the difference in flowering time and the period taken for pods to mature in relation to timing of rainfall at this site.

Pod infection levels in Quilinock, Belara and Kalya at all three sites indicate that seed infection levels will be dangerously high, however Tanjil will have significantly lower seed infection.

Anthracnose does pose a threat to lupin producers in southern regions and significant yield losses can occur. Particular importance should be placed on knowing the infection status of seed and using thiram seed treatment as higher rainfall during flowering can lead to high levels of pod (seed) infection.

GRDC Project No.: DAW665

Paper reviewed by: Mark Sweetingham
A decision support system for control of aphids and CMV in lupin crops

Debbie Thackray, Jenny Hawkes and Roger Jones, Centre for Legumes in Mediterranean Agriculture and Department of Agriculture

KEY MESSAGES

• Aphid outbreaks and CMV epidemics are sporadic in lupins, and for virus control, insecticide applications are not recommended, as they are inefficient at controlling spread of virus by aphid vectors.

• A decision support system (DSS), for use by advisers and growers, forecasts the need for integrated control measures at seeding to diminish virus spread by aphids in lupins.

• The DSS successfully forecasted aphid arrival and build-up, CMV spread, resulting yield losses and infection of harvested seed in lupins in different locations within the WA grainbelt.

• A general forecast for the growing season will be made available in April 2002 through the Internet (http://www.agric.wa.gov.au under CMV in search), PestFax, TopLine, radio, etc.

• Personalised forecasts of likely yield losses based on rainfall and temperature for the user's location, level of CMV infection in seed and sowing details, will be obtainable using the Website.

• The Website also provides background information on CMV and aphids, management recommendations, photographs of aphids and virus symptoms, maps predicting different risk areas, and an explanation of the forecasting model and DSS.

BACKGROUND

Widespread cucumber mosaic virus (CMV) infection poses major limitations on grain yields in lupins, particularly in high rainfall agricultural zones of WA, but its epidemics are sporadic. Aphids also cause sporadic yield losses due to direct feeding damage. CMV is spread in lupin crops by both colonising aphids such as green peach aphid (Myzus persicae) and non-colonising aphids such as oat aphid (Rhopalosiphum padi). Annual and perennial weeds surviving the summer are the main reservoirs of aphids between growing seasons, while CMV is introduced to crops by sowing infected lupin seed.

Planning for CMV control should be done before planting crops, so that integrated control recommendations can be followed at seeding. A forecasting/decision support system (DSS) allows growers to anticipate CMV epidemics and use the integrated control strategy when needed. This strategy includes control measures like planting seed with minimal virus content, promoting early canopy development and stubble retention. The success of systemic pyrethroid applications in controlling barley yellow dwarf virus (BYDV) during the critical first 12 weeks of cereal crop growth has led to attempts to control CMV in lupins in a similar way. However, unlike BYDV, CMV is transmitted non-persistently by aphids so like many other similarly transmitted viruses, it is difficult to control with insecticides. In high value seed crops, regular applications of pyrethroids could be worthwhile for CMV control, but otherwise control is insufficient and uneconomic with single or double applications.

METHODS

In the grainbelt of south-west Australia, the survival of aphids over summer/early autumn determines the likelihood of early aphid arrival and consequent damaging virus epidemics in lupin crops. Abundance of over-summering green plant material is dependent on rainfall. The simulation model that forecasts aphid outbreaks and CMV epidemics in lupin crops therefore uses rainfall during late summer and early autumn to calculate an index of aphid build-up on broad-leaved weeds and crop volunteers in each locality before the winter growing season starts. The index is used to forecast timing of aphid immigration into crops in different localities. For each location, aphid build up, CMV spread from sowing infected seed, likely yield loss and infection of harvested seed are calculated, based on local climate data, lupin variety, level of CMV in seed sown, sowing date and plant density.
RESULTS
The model was validated with 3 years’ detailed field validation data from four different grainbelt sites, and with previous field experiment data representing a wide range of pre-growing season rainfall scenarios, sowing dates, levels of seed infection and plant densities. It gave reliable predictions for aphid arrival in lupins for all sites and years. Predictions for CMV spread were also reliable (Figure 1). Predictions for peaks in aphid population numbers during the growing season were generally good but occasionally too low and early. Predictions for yield loss from CMV infection compared favourably with historical field experiment results for different sites. The model was incorporated into the DSS for use in forecasting CMV risk. The inputs required from the user are location, lupin variety, level of seed infection, sowing date, and plant density. Predictions are given for aphid arrival date, CMV spread, potential yield losses, transmission of CMV into harvested seed and whether applying integrated control measures at seeding is warranted. Maps illustrating the risk from CMV for different areas in the WA grainbelt are produced from the DSS outputs for different localities and levels of seed infection with CMV.

Figure 1. Actual incidence of CMV in lupin field experiments compared with model predictions for incidence at Badgingarra over four years.

CMV/APHID WEBSITE AND DECISION SUPPORT SYSTEM
A general forecast of CMV risk based on DSS predictions for the coming growing season in the WA grainbelt will be made available in April through the CMV/aphid Website (http://www.agric.wa.gov.au under CMV in search), PestFax, TopLine, rural radio, etc. Forecasts will be updated regularly during the growing season using the latest climate data. The Website will provide growers and advisers with access to the general risk forecast using maps to illustrate CMV risk in different areas, and will offer personalised predictions of likely yield losses from CMV and the need for integrated control measures at seeding. These predictions will be based on climate data for the user’s location and seeding details (lupin variety, level of CMV in seed sown, sowing date and plant density). The Website also provides background information on CMV and aphids, photographs of aphids and CMV symptoms, management recommendations for CMV and aphid control and an explanation of the forecasting model and DSS. Further refinement of the DSS will provide reliable forecasts for peaks in aphid populations and the need for insecticide applications to control aphid feeding damage in spring, thereby avoiding unnecessary costs, and providing an environmentally responsible approach to control. A DSS for bean yellow mosaic virus (BYMV) in lupin is also being developed.

ACKNOWLEDGMENTS
This work was supported by the Grains Research and Development Corporation. We thank Art Diggle, Françoise Berlandier, and Entomology and Plant Virology Staff for their contributions.

KEY WORDS
CMV, aphids, model, decision support system
GRDC Project No.: UWA 290
Paper reviewed by: Roger Jones and Martin Barbetti
Integrated management strategies for virus diseases of lupin

Roger Jones, Crop Improvement Institute, Department of Agriculture, and Centre for Legumes in Mediterranean Agriculture, University of WA

KEY MESSAGES
In 2001, a review of available control measures for virus diseases of lupin lead to further refinements and additions to the integrated disease management strategies for CMV and necrotic BYMV, and the development of a preliminary strategy for non-necrotic BYMV.

BACKGROUND
The two most important viruses causing diseases in lupins in the ‘grainbelt’ are bean yellow mosaic (BYMV) and cucumber mosaic (CMV), both of which are aphid-borne. There are two types of BYMV strains, necrotic and non-necrotic, the latter having more yield limiting potential because it spreads faster in narrow-leaved lupin crops infecting many more plants. CMV is introduced into lupin crops by sowing virus-infected lupin seed while aphids spread BYMV into the growing crop from adjacent virus-infected, clover-based pastures. Grain yield losses are substantial when virus spread by aphids is sufficient to cause high incidences of infection within crops. Over 15 years of research on virus diseases of lupins, a series of control measures have been devised and incorporated into integrated management strategies developed specifically for CMV and necrotic BYMV. These strategies were gradually improved and expanded as understanding of the epidemiology of viruses in lupins improved and the results of field experiments involving potential control measures became available. The strategies were designed to cause few additional labour demands, and minimal disruption to normal farming operations or extra expense. In 2001, a review of available measures lead to further refinements and additions to the management strategies for CMV and necrotic BYMV, and to development of a preliminary strategy for non-necrotic BYMV.

RESULTS
The individual measures combined within the integrated management strategy for each virus were: sowing seed stocks with minimal virus contents, sowing cultivars with inherently low seed transmission rates and isolation from neighbouring lupin crops (CMV only); perimeter non-host barriers and avoiding fields with large perimeter:area ratios (BYMV only); promoting early canopy development, generating high plant densities, adjusting row spacing, direct drilling into retained stubble, sowing early maturing cultivars, maximising weed control and crop rotation (both viruses). Recommendations to apply insecticide were included solely for spraying high value seed crops (CMV only) or virus-infected pastures next to crops (BYMV only). Table 1 lists each control measure, briefly summarises its mode of action, indicates whether it is appropriate for CMV, necrotic BYMV or non-necrotic BYMV, and the extent which farmers have adopted it as a component of each management package. For each virus, the table also indicates whether a control measure is based solely on our detailed understanding of virus epidemiology in lupin crops, or is derived from the results of replicated field experiments investigating the effectiveness of individual measures.

CONCLUSIONS
Comprehensive integrated virus management strategies developed for controlling CMV and necrotic BYMV in lupin were updated, refined and added to, and a preliminary strategy devised against non-necrotic BYMV.

KEY WORDS
Lupin, pasture, disease, virus, losses, productivity, risks, threat, integrated control measures

ACKNOWLEDGMENTS
The Grains Research and Development Corporation funded much of the research that lead to these management packages.

Paper reviewed by: Martin Barbetti
Table 1. Components of integrated disease management strategies devised against CMV and BYMV in narrow-leafed lupin crops

<table>
<thead>
<tr>
<th>Control measure</th>
<th>Mode of action</th>
<th>CMV</th>
<th>Necrotic BYMV</th>
<th>Non-necrotic BYMV</th>
<th>Adopted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sow seed with &lt; % ‘threshold’ infection for type of crop (seed or grain) and ‘virus risk’ region.</td>
<td>Minimises initial virus infection source within crop.</td>
<td>Yes(^1)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sow cultivars with low ‘intrinsic’ seed transmission rates in high virus risk regions.</td>
<td>Minimises initial virus infection source within crop.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sow perimeter non-host barrier crop in between adjacent pasture and lupin crop.</td>
<td>Decreases virus spread into crop from external pasture source.</td>
<td>No</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Promote early crop canopy development.</td>
<td>Shades over infection sources within crop (seed-infected and/or early infected plants) and diminishes aphid landing rates.</td>
<td>Yes(^1)</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sow at high seeding rates to generate high plant densities.</td>
<td>Minimises infection sources (seed-infected and/or early infected plants) and diminishes aphid landing rates. Dilutes numbers of infected plants.</td>
<td>Yes(^1)</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sow at narrow row spacing (healthy seed) or at wide row spacing without lowering the seeding rate (untested seed).</td>
<td>Narrow spacing diminishes aphid landing rates. Wide spacing with high plant densities within rows shades over seed-infected plants.</td>
<td>Yes(^1)</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Maximise stubble groundcover using minimum tillage procedures that minimise soil cultivation.</td>
<td>Diminishes aphid landing rates until crop canopy develops.</td>
<td>Yes(^1)</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Spray high value seed crops with pyrethroid insecticide.</td>
<td>Suppresses virus spread by killing or repelling aphids.</td>
<td>Yes(^1)</td>
<td>No</td>
<td>No</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Spray adjacent pasture with pyrethroid insecticide in high virus risk regions.</td>
<td>Suppresses virus spread within external pasture infection source by killing colonising aphids.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mixed cropping with non-host.</td>
<td>Diminishes virus spread.</td>
<td>Yes</td>
<td>Yes(^1)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Avoid fields with large perimeter: area ratios adjacent to pastures in high virus risk regions.</td>
<td>Decreases spread of virus into crop from external pasture source.</td>
<td>N/A</td>
<td>Yes</td>
<td>Yes</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Sow early maturing cultivars.</td>
<td>Decreases final infection incidence reached, especially in prolonged growing seasons.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Isolation from neighbouring lupin crops.</td>
<td>Decreases spread of virus from any external infected crop source.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Maximise weed control.</td>
<td>Minimises potential weed virus infection sources within crop (especially clovers for BYMV).</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Crop rotation.</td>
<td>Avoids volunteer seed-borne lupin plant infection sources within crop.</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

\(^1\) Based on results from large-scale replicated field experiments in ‘grainbelt’. N/A = not applicable.
Quantifying yield losses caused by the non-necrotic strain of BYMV in lupin

Roger Jones and Brenda Coutts, Department of Agriculture, and Centre for Legumes in Mediterranean Agriculture

KEY MESSAGE
In two field experiments in 2001, infection with the new, non-necrotic strain of BYMV decreased seed yield of narrow-leafed lupin by up to 63%, thereby confirming that it has substantial yield limiting potential when it infects lupins in the WA grainbelt.

BACKGROUND
In the grainbelt of south-west Australia, aphids spread bean yellow mosaic virus (BYMV) from nearby pastures to crops of narrow-leafed lupin. Crops in high rainfall zones are at greatest risk of infection but the virus sometimes also infects those in medium rainfall zones. There are two types of BYMV strains, necrotic and non-necrotic, the latter having greater yield limiting potential because it spreads faster in narrow-leafed lupin crops infecting more plants. Non-necrotic strains do not kill lupin plants so they remain as virus sources for aphids to pick up the virus and spread it further within the crop. Although they have only been recognised recently, non-necrotic strains are commonly found in high rainfall zones. They cause severe yield losses in individual infected plants, but losses in lupin stands need to be quantified.

METHODS
In the 2001 growing season, field experiments with non-necrotic BYMV and lupin (cv. Tanjil) provided grain yield loss data. Department of Agriculture Research Station sites at Badgingarra and Avondale were used. To obtain a range of different incidences of infection, small numbers of clover plants infected with non-necrotic BYMV and infested with green peach aphids (Myzus persicae) were introduced into plots in each experiment. There were 0, 4, 8 or 16 infector plants/plot at Badgingarra, and 0, 4, 8 or 18 infector plants/plot at Avondale. Each plot was sampled randomly to determine virus incidence. The samples were tested by ELISA using BYMV-specific antiserum.

RESULTS
In the plots, non-necrotic BYMV spread from the introduced infector plants causing obvious symptoms of leaf mottle and plant stunting. Incidence of virus infection within plots was related to the magnitude of the initial virus source, i.e. the introduced clover infector plants. At Badgingarra, yield was decreased by 21%, 39% and 63% in plots with 4, 8 or 16 infector plants respectively (Figure 1). Similar results were obtained at Avondale where yield was decreased by 24%, 31% and 62% in plots with 4, 8 or 18 infector plants respectively (Figure 2).

CONCLUSIONS
This work confirms that non-necrotic BYMV strains have considerable yield limiting potential when they infect lupins in the WA grainbelt. Although the scenario these results represent is a year when aphids arrive relatively early in crops, the increasingly widespread occurrence of non-necrotic strains in the region is cause for concern for the lupin industry.

KEY WORDS
Lupin, virus, disease, yield loss, risks

ACKNOWLEDGMENTS
We thank Jenny Hawkes, Lisa Smith, Rohan Prince, Owen Coppin and Stewart Smith for technical support, and the Grains Research and Development Corporation for funding.
A = no infector plants; B = 4 infector plants; C = 8 infector plants; D = 16 infector plants. Bar = LSD.

**Figure 1.** Effect of BYMV on grain yield of lupin cv. Tanjil, Badgingarra.

A = no infector plants; B = 4 infector plants; C = 8 infector plants; D = 16 infector plants. Bar = LSD.

**Figure 2.** Effect of BYMV on grain yield of lupin cv. Tanjil, Avondale.
Screening for pod resistance to phomopsis in various lupin species

Manisha Shankar¹, Mark Sweetingham¹&² and Bevan Buirchell²
¹Co-operative Research Centre for Legumes in Mediterranean Agriculture, The University of Western Australia, Nedlands WA 6907; ²Agriculture Western Australia, Locked Bag No. 4, Bentley Delivery Centre WA 6983

KEY MESSAGE
Two screening tests for seed resistance have been developed which clearly distinguish between the resistant, intermediate and susceptible types in all lupin species. Inoculating irrigated field plots with a high density of artificially colonised oats is recommended for routine screening. Spray inoculating young primary pods with a concentrated spore suspension and incubating under high humidity in the glasshouse/screenhouse is more sensitive and is used for measuring genetic segregation in single plants.

AIMS
To develop screening tests for pod resistance to Phomopsis in various lupin species.

BACKGROUND
Phomopsis seed infection remains an important issue in emerging human food uses for lupin. ANZFA, European and Japanese food authorities have a 5 ppb tolerance for phomopsin in lupin seed. The sensitivity to phomopsis was clearly evident in recent negotiations, which have seen lupin approved for Japanese shoyu (soy sauce) production. In 1996/1997 more than 20% of the lupins delivered at Trayning, Doodlakine, Cunderdin and Kondut in WA were discounted $3-5 per tonne, and many loads were totally rejected, due to Phomopsis seed discolouration. Losses such as these will be averted by the release of more resistant varieties.

The Phomopsis seed infection can only be controlled by breeding for resistance to pod blight. Earlier work indicated difference in the genetic control of pod and stem infection, as cultivars Gungurru, Myallie and Kalya (L. angustifolius), Kali and Kiev Mutant (L. albus) and Erregulla soft (L. cosentinii) were found to be more resistant in stems than in pods. Screening of pod resistance is currently based entirely on observations in field trials where pod blight occurs sporadically and unpredictably. Improved screening technology for pod and seed resistance sources in L. angustifolius, L. luteus, L. albus and the rough-seeded lupins will enhance the efficiency and ability of breeding varieties with high seed resistance.

METHOD
Test 1. Oat-infested inoculum
This test was carried out over a period of two years. During the first year forty lines of Lupinus angustifolius were tested and during the second year twenty lines were used to further validate the test. Four replicate plots of each lupin line were sown in a randomised block design at Medina Research Station. Diaporthe toxica colonised oat (naked oat, cv. Bandikoot) inoculum (50 gm/sq m) was scattered between plots 5 weeks after sowing. The inoculum was prepared by soaking oat seeds overnight in distilled water and autoclaving twice for 20 min. at 121°C in 120 mL polypropylene vials. Sterile seeds in vials were inoculated with 5 disks (5 mm diameter) from the growing margins of PDA cultures of D. toxica, pathotype A (isolate WAC9513), incubated for one week at room temperature and for another 3 weeks (or until appearance of pycnidia) at 20°C in near UV light.

At maturity pods on the primary rachis were harvested separately from those on the lateral branches. Percentage seed infection was assessed (both for seeds from the primary rachis and lateral branches) on a random sample of ~100 seeds.

-30-
Test 2. Spray inoculation on young pods

This test was also carried out over a period of two years. During the first year the right age of the pod for inoculation was established along with the effect of various pathotypes of \textit{D. toxica} (Shankar and Sweetingham, 2001) on different lupin species. \textit{L. angustifolius} was mainly affected by pathotype A, \textit{L. albus} by pathotypes B and A, \textit{L. luteus} by pathotype L and the rough-seeded lupins by pathotypes C and A. During the second year various lines of \textit{L. angustifolius}, \textit{L. albus}, \textit{L. luteus} and the rough-seeded lupins were used to validate the test. Four replicate plots of each lupin line were sown in a randomised block design at South Perth plots in the screenhouse. Lines of \textit{L. angustifolius} were inoculated with pathotype A (isolate WAC 9513), \textit{L. albus} with pathotypes A and B (WAC 9540), \textit{L. luteus} with Pathotype L (WAC 8787) and the rough-seeded lupins with pathotypes A and C (WAC 9504). Eight lower pods on the primary rachis were sprayed to run-off with the conidial suspension (10\(^7\) mL\(^{-1}\)) using an artist's air brush when the lowest pods were 2-3 cm in length. Inoculated plants were shaded from direct sunlight and provided with high humidity for 72 hours after inoculation.

Assessments were made at maturity on the percentage seed infection in inoculated pods.

RESULTS

Oat-infested inoculum

Seeds from the primary rachis showed more infection and a better distinction of resistance than seeds from the lateral branches. Conidial discharge and spread from the oat inoculum, therefore, must have coincided with the appearance of pods on the primary axis and favourable rainfall events.

Lines 75A:258, Belara, Wonga, Tanjil, 84S017-50S-72, 84S067-66-1:24, 86L802-24-19 and 87A001-61-17 were found to be resistant, Merrit intermediate and Danja, Myallie, Kalya and Unicrop susceptible.

Spray inoculation on young pods

\textit{L. angustifolius}: Lines 75A:258, Belara, Wonga and Tanjil were found to be resistant, Merrit intermediate and Myallie and Unicrop susceptible to pathotype A.

\textit{L. luteus}: The cultivar Motiv was found to be resistant, Reda intermediate and Teo and Wodjil susceptible to pathotype L.

\textit{L. albus}: This lupin species is affected by both pathotypes A and B. Hamburg was found to be resistant, Hetman intermediate and Kiev Mutant and Kali are susceptible to both pathotypes.

\textit{L. atlanticus} and \textit{L. pilosus}: The rough seeded lupins are affected by pathotypes A and C. Line PM1.5S of \textit{L. pilosus} was resistant to both pathotypes. Two lines of \textit{L. atlanticus} (93E15-10 and 93E15-11) were intermediate to both pathotypes while lines 93E002-3-11 and 93E002-3-12 were resistant to pathotype A but intermediate in resistance to pathotype C.

CONCLUSIONS

Similar results were obtained for both tests with a clear distinction between the resistant, intermediate and susceptible lines.

Scattering the oat-infested inoculum in field plots is an easy test to use for routine screening for seed resistance. For good seed infection, early May sowing (Perth) would be advisable to ensure high infection risk at flowering and podding.

The test of spray inoculating young pods is too time consuming for routine screening but is less subject to environmental variation. It is more accurate and is recommended for determining genetic segregation.

REFERENCE


GRDC Project No.: UWA 317

Paper reviewed by: Geoff Thomas
Lupin disease diagnostics
Nichole Burges and Dominie Wright, Department of Agriculture, Western Australia

KEY MESSAGES
• The diagnostic service is a valuable tool for sustaining productive crop industries in Western Australia. The service helps growers to respond appropriately to significant disease constraints, and prevents over reaction to minor or perceived disease threats.
• The majority of pulse and oilseed samples received were from the NorthWest, Central, and NorthEast and Central regions, belonging to the newly defined Agzones 1, 2 and 4.
• Lupin samples made up 64% of all pulse and oilseed samples; the major disorders associated with these samples were physiological damage, rhizoctonia root diseases, and bean yellow mosaic virus.
• Diseases diagnosed in other pulse and oilseed crops were ascochyta blight in chickpeas, black spot, downy mildew and bacterial blight in field peas, and damping-off, blackleg, and rhizoctonia root rot in canola.

SAMPLES RECEIVED
Another late start to the season and dry, warm conditions resulted in low seasonal disease impacts and lower than normal demand for broadacre diagnostic services. A total of 213 samples were received by the service this year. The number of samples has remained low over the past two years due to the late starts to cropping and dry conditions in both 2000 and 2001-growing seasons.

Pulse and oilseed samples made up 23% of the total number of samples received. The breakdown by crop for pulse and oilseed samples was as follows: lupins 64%, field peas 16%, canola 8%, chick pea 6%, faba bean 4%, and lentil 2%.

DISEASES DIAGNOSED
The number of samples received this season with root disease, leaf disease and physiological problems were of equal proportion.

The diseases that occurred with the highest frequency in lupins were:
• Rhizoctonia root diseases (9 samples out of 34);
• Bean yellow mosaic virus (necrotic) (5 samples out of 34);
• Pleiochaeta root rot (5 samples out of 34).

Rhizoctonia root disease in lupins was the most common disease in pulses this season; the percentage of samples with rhizoctonia was higher than for all root pathogens of lupins last season. Samples were received from the NorthWest and Central regions, Agzones 1 and 2.

Table 1. Number of diseased lupin samples submitted over the past 3 growing seasons

<table>
<thead>
<tr>
<th>Growing season</th>
<th>Total number of samples received</th>
<th>Disease (number of samples diagnosed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anthracnose</td>
<td>Brown Spot</td>
</tr>
<tr>
<td>1999</td>
<td>49</td>
<td>12</td>
</tr>
<tr>
<td>2000</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>34</td>
<td>1</td>
</tr>
</tbody>
</table>

GRDC Project No.: DAW 590
Paper reviewed by: Geoff Thomas
To GM or not to GM pulses - that is the question

Dr Susan J. Barker, The University of Western Australia

KEY MESSAGE
Development of genetically manipulated (GM) pulses is a strategic initiative in CLIMA. We now have considerable experience and expertise in techniques and regulatory aspects of this technology. Our main focus is on the development of improved seed quality and disease resistance in the main pulse crops. Recent implementation of Federal GM Legislation and changes to food labelling requirements mean that assessment of future marketability of GM pulse crops should become more feasible by the end of this project (mid-2004).

AIMS
- To ensure continued access by Australian farmers to GM technology in the form of pulse varieties with improved seed protein quality and disease resistance.
- To provide continued training and experience with regulatory requirements for, and intellectual property (IP) constraints on, the use of GM technology.
- To maintain Australia’s position as an international leader in the use of biotechnology in the breeding of pulses.

METHOD
Research in the CLIMA laboratories involves the genetic manipulation of pulse species using techniques and materials with as little associated IP constraints as can be identified. Species for which genetic manipulation is routine are: narrow leafed and yellow lupins; chickpea; field pea; lentil; faba bean. Our current focus is on the production of narrow leafed lupin with improved sulphur amino acid content of seeds, and narrow leafed lupin and chickpea with improved disease resistance (virus and fungus). The researchers in our labs generate plantlets in tissue culture that may contain the new gene of interest, producing seed from those plants, then testing the next two or three generations of progeny to determine that the gene is present and inherited in good working order. Bulked progeny are then collected to test that the new gene is having the desired effect on the plant’s performance. We are also assessing new methodologies for improved efficiency of process and outcome, and accumulating information of importance in addressing regulatory issues. This information includes: the assessment of maximum outcrossing potential for chickpea and lentil and; the assessment of lupin survival and management and monitoring strategies for eradication from past field trial sites.

RESULTS

Seed protein quality
Proof of concept in narrow leafed lupin cv. Warrah was achieved under previous funding. In this project we have generated a significant number of first generation lines in narrow leaf lupin cultivars Kalya and Tanjil. Further work is needed to establish the next generations and test that the same enhanced performance in animal feeding trials occurs.

Virus resistance
Constructs designed to give resistance to CMV in lupin and chickpea, and BYMV in lupin have been prepared using a new construct design for which we have negotiated intellectual property access from CSIRO. First generation narrow leafed lupin progeny containing the BYMV construct are now available for further propagation. The CMV resistance work is at an earlier stage.

Fungal disease resistance
A number of gene constructs are available and in various stages of preparation for testing. Glasshouse trials of fungal resistance are planned to begin this season. Tests are planned for: Pleiochaeta, anthracnose and Phomopsis resistance of narrow leafed lupins; Ascochyta and Botrytis resistance of chickpea; black spot resistance of field pea.
Regulatory issues

Outcrossing in lentil under idealised conditions is currently being assessed. The same experimental design is planned for chickpea starting in the 2003 field season.

Attempted compliance with new bureaucratic requirements for GM field trials has been an interesting experience. These requirements originate from the Office of the Gene Technology Regulator (OGTR) in Canberra. We have been testing them on field trial sites from past field trials run by CLIMA in 1997 and 1998, on what was then thought to be a sure new varietal release; namely Liberty™ resistant Merrit. In the process of attempting to eradicate lupins from these sites we have determined several new recommendations for management of future trial sites. These include: pasture or fallow following the trial; monitoring flexibility to allow for lupin seed germination following every new rain event; two years clear of lupin volunteers on the site required before eradication can be assumed.

CONCLUSION

- Mandatory labelling now in effect in Australia will assist in assessment of consumer response to GMOs.
- Regulatory compliance costs are the most likely restriction to market competition of GM pulses in the longer term.
- The project UWA309 is a strategic investment in future pulse breeding in Australia. Working with the pulse breeders, we will continue to identify useful genes and maintain our expertise in GM technology for future advantage.

KEY WORDS
Genetic manipulation, disease resistance, seed quality, GM regulations

GRDC Project No.: UWA309
Paper reviewed by: Professor K. Siddique, CLIMA
Towards a management package for grain protein in lupins

Bob French, Senior Research Officer, Department of Agriculture, Merredin

BACKGROUND
Most lupin exported from Australia substitutes for soybean meal (SBM) in animal feeds. The protein component of both lupin and SBM is highly valued in animal feed formulations, and the lupin price therefore closely follows the SBM price, adjusted proportionately for protein content. The protein content of narrow-leafed lupins delivered in Western Australia varies from less than 28% to above 36%, but to date all lupin growers have been paid the same price for their product, irrespective of its protein content, so there has been no incentive to manage crops for higher protein content.

Over the past few years, The Grain Pool of Western Australia has been working with their customers to help them recognise that it is worth paying more for lupins with higher protein levels. In the 2001/2002 season, The Grain Pool has offered a premium of $3/t for each 1% protein over a base of 32%, in 0.1% increments.

Our challenge is to discover viable ways to produce lupins with higher, and more consistent, levels of protein than we do now, and at the same time maintain or lift yield.

FACTORS AFFECTING LUPIN PROTEIN
There is only a rudimentary understanding of the factors which influence protein levels in lupin grain. A brief summary of our current knowledge follows.

Genetic factors
There is considerable genetic variation for protein in lupins, and this is reflected in the currently available cultivars. Belara and Tanjil are consistently at the lower end of the protein spectrum and Tallerack and Myallie at the top end. However, this should not be taken to mean that high yield is inextricably linked with low protein, since the most recently released lupin cultivar, Quilinock, has both high yield and mid-range protein levels.

Table 1. Average protein % of lupin cultivars from Department of Agriculture Crop Variety trials, and from GRDC project DAW 583 trials. These figures are adjusted for seed at 10% moisture

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Belara</td>
<td>29.1</td>
<td>30.7</td>
</tr>
<tr>
<td>Tanjil</td>
<td>30.3</td>
<td>31.8</td>
</tr>
<tr>
<td>Danja</td>
<td>30.5</td>
<td></td>
</tr>
<tr>
<td>Kalya</td>
<td>30.7</td>
<td>32.3</td>
</tr>
<tr>
<td>Quilinock</td>
<td>31.0</td>
<td>32.8</td>
</tr>
<tr>
<td>Yorrel</td>
<td>31.2</td>
<td></td>
</tr>
<tr>
<td>Merrit</td>
<td>31.6</td>
<td>33.4</td>
</tr>
<tr>
<td>Gungurru</td>
<td>31.6</td>
<td>33.6</td>
</tr>
<tr>
<td>Tallerack</td>
<td>32.3</td>
<td></td>
</tr>
<tr>
<td>Myallie</td>
<td>32.4</td>
<td></td>
</tr>
</tbody>
</table>

Environmental factors
Environment has at least as large an effect on protein levels as genotype (Table 2). It has been shown in irrigation experiments that lupins that are stressed during grain filling tend to have higher protein levels than those that are not stressed, and late sowing often results in raised protein levels. A series of trials conducted in 1999 and 2000 suggested that wheatbelt locations such as Wongan Hills, Merredin, Mingenew and Newdegate produced higher protein lupins than Esperance. Levels were higher in 2000 than in 1999, but the highest levels were at Mingenew so there must be factors other than the harshness of the season playing a role. The effects of factors such as soil type have not yet been studied.
Table 2. Average protein (%) in several locations in two years

<table>
<thead>
<tr>
<th>Location</th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mingnew</td>
<td>32.5</td>
<td>34.1</td>
</tr>
<tr>
<td>Wongan Hills</td>
<td>31.6</td>
<td>32.3</td>
</tr>
<tr>
<td>Merredin</td>
<td>32.3</td>
<td>33.8</td>
</tr>
<tr>
<td>Newdegate</td>
<td>33.5</td>
<td>-</td>
</tr>
<tr>
<td>Esperance</td>
<td>29.9</td>
<td>31.4</td>
</tr>
</tbody>
</table>

Nitrogen applied at sowing and phosphorus nutrition do not affect grain protein in lupins. Foliar applied N has resulted in slightly elevated protein levels in some experiments but not consistently (other papers in this proceedings). Abul Hashem has shown (this proceedings) that heavy weed competition can reduce protein levels in lupins.

**RESEARCH DIRECTIONS**

Average protein levels can be raised in higher yielding cultivars through breeding. This process has already commenced under the direction of Dr Bevan Buichell as an integral part of the GRDC funded National Lupin Breeding Program.

Improving our understanding of what environmental factors affect grain protein, and how they do it, will form the basis of future agronomic packages. Elucidating the role the weather (over which we have no control) plays relative to agronomic factors (which we can control) in determining the regional variation in grain protein, will be essential to developing such packages. We are currently seeking funding from GRDC to study the impact of such factors as rotation, soil type, plant nutrition, nodulation, and herbicide treatment on lupin protein, and how they interact with cultivar.

**RECOMMENDATIONS FOR 2002**

Given the current price premium for protein the following recommendations can be made.

**Cultivar**

- Myallie and Tallerack do not yield well enough anywhere to be worth planting to chase protein. Tallerack on the South Coast, where it does well in some seasons, is a possible exception anywhere.
- Quillinock is worth trying in L1, L2, L3, L4, M3 and M4 zones, where it has high yield potential and reasonable protein. Elsewhere the risk of anthracnose is too high.

**Agronomy**

- Agronomic practices should still be tailored at achieving the best yields, since yield is still going to be the major determinant of income from a crop.
- In particular, don’t delay sowing to chase extra protein as the yield loss will be much greater than any possible benefit.
- If you are growing Quillinock it is doubly important to make sure seed is free of anthracnose infection, and to treat it with thiram. For all cultivars adequate fertilisers (including Mn where it is necessary), good weed control and good insect control will ensure both good yields and the best possible protein levels.

**KEYWORDS**

Lupins, grain protein, crop management

GRDC Project No.: DAW 583 and new proposal to GRDC
Paper reviewed by: Mark Sweetingham
Yield and seed protein response to foliar application of N among lupin genotypes

Jairo A Palta\textsuperscript{1,2}, Bob French\textsuperscript{2,3} and Neil C Turner\textsuperscript{1,2}

\textsuperscript{1} CSIRO Plant Industry, Floreat Park  WA  6014
\textsuperscript{2} CLIMA, University of Western Australia, Crawley  WA  6009
\textsuperscript{3} Agriculture Western Australia, Merredin  WA  6415

KEY MESSAGE
Foliar application of urea can increase either seed protein or seed yield of lupin depending of the variety. Foliar application at podding increased the seed yield of the lupin varieties Belara and Tanjill and the seed protein of the varieties Kalya and Myallie. The breeding line WALAN 2053 increased grain protein when foliar application of urea was made at podding on the mainstem and seed yield when applied later when podding occurred on the first order apical branches.

AIM
Since 2001 onwards, The Grain Pool of Western Australia has paid lupin growers a premium for each 0.1% above 32% protein, and lupins over 34% protein go into a special ‘HiPro’ lupin pool. Little is known about how to manipulate seed protein content in lupins. One possible management option to increase seed protein in lupin may be the application of N-fertiliser at flowering as has been shown recently in field peas and soybean (Lhuillier-Soundele et al. 1999; Calmes et al. 2000). Alternatively, applied N may increase yield by maintaining the photosynthetic ability of the leaves. The primary aim of this study was to determine whether there is variation among lupin genotypes in the response of seed protein and/or seed yield to foliar application of N at podding.

MATERIALS AND METHODS
A field experiment was conducted over the 2001-growing season (June-November) at Merredin, Western Australia. Five cultivars of narrow-leafed lupin (\textit{Lupinus angustifolius} L), putatively different in seed protein content, were grown in a randomised complete block design, with four replicates. Experimental plots were 1.44 m wide (8 rows) and 22 m long. Two rates of N (0 and 30 kg N/ha) were applied as a foliar spray at pod set on the mainstem and first order apical branches.

RESULTS

![RESULTS Diagram](diagram.png)

\textbf{Figure 1.}  Effect of foliar applications of urea at podding on the mainstem and first order apical branches on the seed yield of five narrow-leafed lupin genotypes at Merredin, WA, 2001. Bars indicates ± s.e.m. for four replicates.
Foliar application of urea at pod set on the mainstem and first order apical branches increased the seed yield of the varieties Belara and Tanjil by 0.7 and 0.6 t/ha, respectively (Figure 1), but did not increase the seed protein content, which remained at 32.4% in Belara and 33.5% in Tanjil (Figure 2). Seed protein contents were inherently high in Myallie and Walan 2053. Foliar applications of urea at either podding on the mainstem or first order apical branches increased the seed protein in Kalya and Myallie by 1.6 and 1.5%, respectively, but did not affect the seed yield. The breeding line WALAN 2053 increased the seed protein content by 2.3% when foliar applications of urea were made at podding on the mainstem and the seed yield by 0.8 t/ha when applications were made at podding on the first order apical branches. The increase in seed yield in Belara and Tanjil when foliar applications of urea were made at podding on either mainstem or first order apical branches resulted from greater survival of pods and seeds rather than from increases in seed size. The use of isotopically labelled nitrogen allowed the efficiency of applied nitrogen used to be calculated. The increase in seed yield in Belara and Tanjil and seed protein content in Kalya and Myallie were not associated with differences in the recovery of the nitrogen fertiliser in the seed.

![Figure 2. Effect of foliar applications of urea at podding on the mainstem and first order apical branches on the seed protein content of five narrow-leafed lupin genotypes at Merredin, WA, 2001. Bars indicates ± s.e.m. for four replicates.](image)

**DISCUSSION**

This study has shown that there are differences among lupin genotypes in the response to foliar application of N at podding. The high yielding varieties Belara and Tanjil responded by seed yield, whereas the high seed protein variety Myallie increased the seed protein content without reducing the seed yield. The response of Belara and Tanjil to foliar application of N was associated with a delay in leaf senescence. The timing of foliar application only had an affect in the response of the restricted branching breeding line WALAN 2053.

**KEY WORDS**

*Lupinus angustifolius* L, seed protein, seed yield, urea, terminal drought

**ACKNOWLEDGMENTS**

We are grateful to Christiane Ludwig and Renee Nuttall from CSIRO Plant Industry for providing technical assistance. The analyses of isotopically labelled nitrogen and seed protein were kindly made by Richard Phillips of CSIRO Plant Industry, Canberra.

**REFERENCES**


Foliar nitrogen application to improve protein content in narrow-leafed lupin

Martin Harries, Bob French, Laurie Wahlsten - Department of Agriculture, Matt Evans - CSBP

AIM
To investigate the effects of timing and rate of foliar-applied nitrogen on yield and protein content in the grain of three narrow leaf lupin cultivars.

INTRODUCTION
The Grain Pool of WA has indicated it will offer a price premium for lupin grain with more than 32% protein in order to improve the marketability of the WA crop. Little is known about what management practices affect protein content in lupin. One possible means of increasing protein content is to apply N as a foliar spray during reproductive growth when it is more likely to be deposited in the seed rather than contribute to further vegetative growth. The CSBP product Flexi-N, consisting of a concentrated solution of urea and NH₄NO₃, is a convenient form for applying late nitrogen to crops.

METHOD
The trial included nineteen treatments and an unsprayed control. It was laid out as a randomised block experiment with three replicates.

Three rates of Flexi-N were applied: nil (there was only one nil treatment, as application time is meaningless in this context), 20 kg/ha and 40 kg/ha. It was applied undiluted, as would be the case if being used as a carrier for herbicide.

This was done at three development stages: when the first pods were observed on the main stem; when the first pods developed on the 1st order lateral branches; and at the beginning of leaf drop. It was anticipated that time of application would have a large effect on both the efficacy of uptake and whether the absorbed nitrogen would be used for vegetative or reproductive growth.

Three cultivars with inherent differences in grain protein content (Belara, Tanjil and Kalya) were used to assess any differences in responsiveness.

RESULTS
The effect of rate and time of foliar nitrogen application on the yield, seed weight and grain protein content of three varieties of narrow leaf lupin. Mingenew 2001.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>N rate</th>
<th>Time</th>
<th>Yield t/ha</th>
<th>100 seed weight (g)</th>
<th>Grain protein %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belara</td>
<td>Nil</td>
<td>Nil</td>
<td>3.28</td>
<td>18.0</td>
<td>30.8</td>
</tr>
<tr>
<td>Belara</td>
<td>20 kg/ha</td>
<td>Main stem pod</td>
<td>3.01</td>
<td>18.2</td>
<td>31.3</td>
</tr>
<tr>
<td>Belara</td>
<td>20 kg/ha</td>
<td>Primary branch pod</td>
<td>3.19</td>
<td>18.2</td>
<td>30.9</td>
</tr>
<tr>
<td>Belara</td>
<td>20 kg/ha</td>
<td>Leaf drop</td>
<td>2.98</td>
<td>18.4</td>
<td>31.2</td>
</tr>
<tr>
<td>Belara</td>
<td>40 kg/ha</td>
<td>Main stem pod</td>
<td>2.90</td>
<td>18.0</td>
<td>31.4</td>
</tr>
<tr>
<td>Belara</td>
<td>40 kg/ha</td>
<td>Primary branch pod</td>
<td>2.96</td>
<td>18.7</td>
<td>31.6</td>
</tr>
<tr>
<td>Belara</td>
<td>40 kg/ha</td>
<td>Leaf drop</td>
<td>3.10</td>
<td>17.9</td>
<td>30.5</td>
</tr>
<tr>
<td>Kalya</td>
<td>Nil</td>
<td>Nil</td>
<td>3.26</td>
<td>16.9</td>
<td>31.9</td>
</tr>
<tr>
<td>Kalya</td>
<td>20 kg/ha</td>
<td>Main stem pod</td>
<td>3.07</td>
<td>16.6</td>
<td>31.7</td>
</tr>
<tr>
<td>Kalya</td>
<td>20 kg/ha</td>
<td>Primary branch pod</td>
<td>3.09</td>
<td>17.0</td>
<td>32.2</td>
</tr>
<tr>
<td>Kalya</td>
<td>20 kg/ha</td>
<td>Leaf drop</td>
<td>3.19</td>
<td>17.0</td>
<td>31.6</td>
</tr>
<tr>
<td>Kalya</td>
<td>40 kg/ha</td>
<td>Main stem pod</td>
<td>3.14</td>
<td>17.9</td>
<td>32.0</td>
</tr>
<tr>
<td>Kalya</td>
<td>40 kg/ha</td>
<td>Primary branch pod</td>
<td>3.01</td>
<td>16.6</td>
<td>32.8</td>
</tr>
<tr>
<td>Kalya</td>
<td>40 kg/ha</td>
<td>Leaf drop</td>
<td>3.02</td>
<td>16.6</td>
<td>32.7</td>
</tr>
</tbody>
</table>
Table continued …

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>N rate</th>
<th>Time</th>
<th>Yield t/ha</th>
<th>100 seed weight (g)</th>
<th>Grain protein %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanjil</td>
<td>Nil</td>
<td>Nil</td>
<td>3.17</td>
<td>16.9</td>
<td>32.0</td>
</tr>
<tr>
<td>Tanjil</td>
<td>20 kg/ha</td>
<td>Main stem pod</td>
<td>3.17</td>
<td>16.9</td>
<td>31.2</td>
</tr>
<tr>
<td>Tanjil</td>
<td>20 kg/ha</td>
<td>Primary branch pod</td>
<td>3.12</td>
<td>16.8</td>
<td>32.0</td>
</tr>
<tr>
<td>Tanjil</td>
<td>20 kg/ha</td>
<td>Leaf drop</td>
<td>3.09</td>
<td>16.9</td>
<td>31.8</td>
</tr>
<tr>
<td>Tanjil</td>
<td>40 kg/ha</td>
<td>Main stem pod</td>
<td>3.03</td>
<td>16.8</td>
<td>32.2</td>
</tr>
<tr>
<td>Tanjil</td>
<td>40 kg/ha</td>
<td>Primary branch pod</td>
<td>3.06</td>
<td>17.3</td>
<td>32.8</td>
</tr>
<tr>
<td>Tanjil</td>
<td>40 kg/ha</td>
<td>Leaf drop</td>
<td>2.94</td>
<td>16.7</td>
<td>32.3</td>
</tr>
<tr>
<td>LSD N rate</td>
<td></td>
<td></td>
<td>0.22</td>
<td>NS</td>
<td>0.30</td>
</tr>
<tr>
<td>LSD Time</td>
<td></td>
<td></td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>LSD Variety</td>
<td></td>
<td></td>
<td>NS</td>
<td>0.23</td>
<td>0.34</td>
</tr>
<tr>
<td>LSD N rate * Time * Variety</td>
<td>0.67</td>
<td>0.74</td>
<td>0.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td></td>
<td></td>
<td>5.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

Yield

The yield of all three varieties was reduced by the application of foliar nitrogen. The rates of nitrogen used in this trial were high and some leaf burn was observed. However, this did not seem to affect yield, since the time of application of foliar nitrogen did not affect yield. If leaf burn were responsible for the yield reductions, losses would be expected to be most severe in the earliest sprayed treatments.

Seed weight

Variety had the greatest effect on seed weight, Belara significantly higher than the other two varieties used. The rate and timing of nitrogen application had no effect on seed weight in this trial.

Protein

Time of Foliar N application had no significant effect on grain protein.

When averaged over times of application and varieties the higher rate of Flexi-N did produce a small but significant positive effect on protein of 0.5%.

Varieties showed no variation in responsiveness to the foliar nitrogen but as with seed weight variety had the greatest effect on protein content. On average Belara had 1.0% lower protein than Tanjil or Kalya.

KEY WORDS

Lupin protein, foliar nitrogen, Flexi-N

Paper reviewed by: Bob French
Effect of time of swathing of lupins on grain protein content

Martin Harries, Department of Agriculture

AIM
To determine if swathing lupins at different stages of physiological maturity influences grain protein content.

INTRODUCTION
The Grain Pool of WA has indicated it will offer a price premium for lupin grain with more than 32% protein in order to improve the marketability of the WA crop. Little is known about what management practices affect protein content in lupin. One practice that is becoming more widely adopted, and could influence protein content, is swathing. It is important to establish if crop topping will result in altered protein content in lupin grain.

METHOD
The trial was conducted at Erregulla on deep yellow sand. Three completely randomised blocks of 20 by 2.0 metre plots were swathed and harvested using the Research Support Unit machinery.

Four methods of harvest were used: Three times of swathing and one direct harvested treatment.

The three swathed treatments were conducted at three distinct physiological stages of the lupin. The first treatment was swathed before seed was fully developed, when the first pods on the main stem turned from green to tan. The second time of swathing was as the majority of seed reached maturity, when pods on the first lateral stems changed colour from green to tan. This is the recommended time to swath lupins. The third time was swathed very late, with 90% of pods a tan colour.

RESULTS
The effect of time of swathing on yield, grain protein content and grain weight at Erregulla Plains, Mingenew in 2001.

<table>
<thead>
<tr>
<th>Harvest treatment</th>
<th>100 seed weight (g)</th>
<th>% Grain protein</th>
<th>Yield t/ha</th>
<th>Total seed loss on ground after harvest (t/ha)</th>
<th>Yield % of direct harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swathed when Pods on main stem were brown</td>
<td>11.06</td>
<td>33.6</td>
<td>1.5</td>
<td>1.0</td>
<td>73.8</td>
</tr>
<tr>
<td>Swathed when Pods on 1st order were brown</td>
<td>13.22</td>
<td>31.7</td>
<td>1.8</td>
<td>1.5</td>
<td>88.7</td>
</tr>
<tr>
<td>Swathed when 90% of all Pods were brown</td>
<td>16.68</td>
<td>30.9</td>
<td>1.6</td>
<td>2.3</td>
<td>77.0</td>
</tr>
<tr>
<td>Direct harvested</td>
<td>16.47</td>
<td>31.6</td>
<td>2.0</td>
<td>0.43</td>
<td>100.0</td>
</tr>
<tr>
<td>LSD</td>
<td>1.2</td>
<td>0.7</td>
<td>0.2</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

Yield
All times of swathing resulted in lower yields than the directed harvested treatment. However, the results confirm the previous finding that there is a safe window in which to swath. Swathing too early, before the grain is fully developed, results in lower yield potential and swathing too late results in unacceptably high levels of shedding.
Seed weight

Early swathing leads to smaller seeds. While expected this could be exacerbated by seasonal conditions; the dry beginning to the 2001 season and good spring rain, after the early swathing treatment.

The large difference in seed size between the recommended time of swathing and direct harvest is a concern. The reduced seed size may adversely affect the seed viability or vigour. Seed from this trial has been retained to examine this.

Protein

Very early swathing resulted in higher protein content while swathing at all other times resulted in similar grain protein.

It was unusual that seed size did not correlate closely to grain protein content. It was expected that larger seed would have a greater proportion of cotyledon to seed coat. The seed coat contains no protein and consequently it is often observed that larger lupin seed does have a higher protein content.

While the highest protein levels were achieved by swathing very early the price premium attracted would not compensate for the large yield reductions. Direct harvesting and swathing at the best time, when the pods on the first order laterals were starting to change colour, gave very similar protein content.

These results indicate that if swathing is undertaken at the correct time yield losses can be minimised while protein content will not be reduced.

KEY WORDS

Lupin, grain protein, swathing, harvesting

Paper reviewed by: Bob French
Putting a value on protein premiums for the animal feed industries: Aquaculture

Brett Glencross and John Curnow, Department of Fisheries - Government of Western Australia, PO Box 20, North Beach, 6020. Wayne Hawkins, Department of Agriculture - Government of Western Australia, Baron-Hay Court, South Perth, 6151

INTRODUCTION

Using lupins in fish diets

Lupins were first identified in the late 1980s as having some potential as a useful feed ingredient in the diets of fish. More recently it was identified that the kernel meals had more value to fish than the whole-seed meals. Over the past ten years an increasing volume of information has been collected on lupins in fish diets, though most of it on the use of Lupinus albus, with recent studies, mostly in Australia, evaluating L. angustifolius and L. luteus. All of this information has been collated and is available in a review format that can be downloaded from the Department of Fisheries Internet site at: http://www.wa.gov.au/westfish/res/broc/report/lupin.

NUTRITIONAL VALUE ASSESSMENT

Why protein and energy content?

As nutritionists, we tend not to look for the ‘perfect’ single ingredient from which to make diets, but rather a range of high quality, complimentary ingredients of consistent composition from which formulations can be tailored to suit the dietary requirements of particular species. In this sense, lupins have proved to be a valuable ingredient for use in aquaculture diets. Unlike the use of lupins in diets for other species such as pigs and poultry, the amino acid composition of lupins is less important. However, critical to their value is both the overall protein and energy content, which is one reason why the use of kernel meals is generally favoured over the use of whole-seed meals. More specifically the value of lupins to fish relates to the amount of digestible protein and energy in the kernel meal. This is the actual component of the lupins that the fish can absorb and begin to use.

Protein variability and value

All grains have a level of variability in their composition. Typically, the levels of the key macronutrients; protein, fat and carbohydrates, vary not only between species and cultivars, but can also vary considerably between samples of the same cultivar grown and harvested differently (Table 1). One of the key differences in composition seen between some lupin kernel meal samples was in their level of protein and carbohydrates. Notably, these two nutrients seem to have a reciprocal relationship in lupin kernel meals, with fat content being relatively constant.

Table 1. Nutrient composition of the lupin kernel meals used (g/kg DM unless otherwise stated)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Myallie 482</th>
<th>Merrit 459</th>
<th>Kalya 429</th>
<th>Gungurru 411</th>
<th>Gungurru 359</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter content (g/kg)</td>
<td>899</td>
<td>903</td>
<td>899</td>
<td>910</td>
<td>845</td>
</tr>
<tr>
<td>Crude protein</td>
<td>482</td>
<td>459</td>
<td>429</td>
<td>411</td>
<td>359</td>
</tr>
<tr>
<td>Total Kjeldhal Nitrogen</td>
<td>77</td>
<td>73</td>
<td>69</td>
<td>66</td>
<td>56</td>
</tr>
<tr>
<td>Crude fat</td>
<td>62</td>
<td>66</td>
<td>54</td>
<td>60</td>
<td>58</td>
</tr>
<tr>
<td>Ash</td>
<td>33</td>
<td>31</td>
<td>31</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td>423</td>
<td>444</td>
<td>485</td>
<td>497</td>
<td>558</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

To examine the influence of this variability in the protein level of lupin (L. angustifolius) kernel meals to fish, some experimental diets were designed with the intention of evaluating the digestible nutrient value of each of the lupin kernel meals. These diets were fed to rainbow trout kept in tanks at the South West Freshwater Research and Aquaculture Centre in Pemberton, WA. A comparison of the
faecal composition to that of the feeds, relative to an inert marker component, allowed the
determination of specific ingredient digestibilities.

The findings of this work show that there is a strong correlation between protein content of a lupin
kernel meal and the nutritional value of that protein (Figure 1). Notably the strongest correlation was
that between kernel meal protein content and nitrogen (N) digestibility ($R^2 = 0.981$). The determination
of this relationship can also be used to allow the calculation of equations to predict the digestible
protein content of lupin kernel meals based on their crude protein content.

The strong relationship between kernel meal protein content and its nitrogen digestibility also had a
direct effect on the relationship with energy digestibility (Figure 1). Notably, the kernel meal protein
content had more influence on its energy digestibility than that of the nitrogen digestibility. This is
primarily related to the fact that a relatively large amount of the dietary energy content of the lupin
kernel meal is derived from its protein content.

![Figure 1. Protein and energy digestibility as a function of crude protein content of lupin kernel meal, when fed to rainbow trout.](image)

The demonstrated relationship, between lupin kernel meal protein content and its nutritional value,
also provides a basis for the attribution of value based on protein content. This can be examined on
both a crude protein and digestible protein content basis (Figure 2). Ideally, with the promotion of
lupin segregation and commodity pricing according to protein content it should be possible to return
greater dividends to growers growing a higher protein product. Notably there are cultivars of *L.
angustifolius* available that have higher protein levels than other varieties.

![Figure 2. Value of *L. angustifolius* kernel meals assessed as a function of gross or digestible protein content when fed to rainbow trout. Indicated by the dashed line (-----) is the present, non-variable price of which lupin kernel meal was benchmarked against.](image)

GRDC Project No.: Grains Research Committee Project
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Progress in selecting for reduced seed hull and pod wall in lupin

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KEY MESSAGE

Lupin grain quality needs to be improved to increase its market value. High indigestible fibre is one of the biggest limitations and most of this fibre is in the seed coat. Monogastric animals in particular do not metabolise this fibre efficiently in feed rations. Lupins plants also partition a large amount of dry matter into pod walls. By screening a wide range of germplasm and mutant lines, genotypes have been selected with up to 25% less seed coat than the current major cultivar, Tanjil. These will contribute to lowering indigestible fibre in lupin grain. Selections with 20% less pod wall could also improve grain yield through more dry matter being transferred to the grain. Good natural sources of reduced seed coat and pod wall have come from countries such as Greece, Cyprus and Morocco that were collected by CLIMA and Department of Agriculture staff. Studies have shown that both seed coat and pod wall proportions are reasonably heritable traits and should be relatively easy to breed for. Data from cultivar testing trials have shown that reduced seed coat is correlated with higher protein and oil content in seed. Further studies will check seed qualities of a range of selections made during this project and advanced progeny from crosses will be provided to the lupin breeding program in Western Australia. The project aims also to develop a rapid screening method for hull thickness in a breeding program. A relatively new scanning technology called optical coherence tomography is showing promise because it is rapid and relatively accurate.

AIMS

- To find lupin genotypes that can lower indigestible fibre in seed and have less dry matter in pod walls.
- Screen lupin germplasm and mutant population for lower per cent pod wall and per cent hull. Grow and verify promising genotypes.
- Analyse per cent pod wall and per cent hull of advanced breeding lines to determine genotype and environment effects.
- Investigate methods for rapid screening of per cent hull and determine the inheritance of reduced hull and pod wall traits.

METHOD

Variation for seed coat and pod wall proportion was sought among a large number of L. angustifolius genotypes including approximately 10,000 mutant lines and 800 wild, semi-domesticated and breeding lines. Pod samples (20-30 main stem pods) from replicated rows grown in screen houses or at Wongan Hills were analysed for pod wall proportion of whole pod and for weight of hull per seed based on 10-12 seed samples. Environmental and genetic effects on hull and pod wall proportions in lupin were examined by analysing data from 125 advanced genotypes at 17 year × site combinations in Western Australia. Preliminary seed quality attributes (fibre, protein, oil contents) were determined for thin hulled mutant and normal parent genotypes. Light and electron microscopy and optical coherence tomography images were obtained from thin-hulled mutants to both examine structural changes in the hull and to develop a rapid screening test for thinner hulls in a breeding program.

RESULTS

L. angustifolius germplasm provided a relatively wider range of hull percentage and pod wall percentage lines for selection compared with breeding lines and cultivars (Figure 1). Several accessions from Greece were found to have the lowest hull and pod wall percentages. Additional sources of reductions in these traits were from Morocco and Cyprus. Mutant populations provided lines with reduced hull percentage, while reductions in pod wall proportion were not as large compared to germplasm sources. In the genotype × environment study, hull percentage was found to decrease by approximately 0.5% for each 10 mg increase in seed weight. Hull thickness was found to correlate with site seasonal rainfall ($r = 0.45^*$). The correlation between genotype means for hull percentage and pod wall percentage was not significant for this set of breeding lines and cultivars, indicating that selection for one will have little effect on the other. Both hull percentage and pod wall percentage...
were found to have a relatively high heritability. A low but significant correlation was identified between hull percentage and protein + oil percentage (r = -0.45**) showing that selection for lower hull proportion could lead to higher protein and/or oil concentration in seed. Yellow lupin (L. luteus) was found to have a similar average hull percentage but a much higher pod wall percentage than narrow-leafed lupin. Selecting for reduced pod wall in yellow lupin could improve harvest index and yield in that species.

Overall, selections of L. angustifolius with up to 25% reduction in hull and 20% reduction in pod wall proportion compared with cultivar Tanjil have been made and these lines are being crossed to current cultivars to produce segregating progenies that can be used by breeders. Preliminary quality analyses have shown that thin hull mutant lines have lower seed fibre contents and slightly raised oil levels. Optical coherence tomography should be a successful method for rapid screening of single seeds with thinner hulls as will be required in any breeding program seeking to introduce this trait into elite lines.

CONCLUSIONS

Lines of narrow leafed lupin have been selected with lower hull and pod wall percentages. Reduced hull lines have the potential to improve seed quality and those with reduced pod wall could contribute to higher harvest index and yield. Both lower hull and pod wall percentage should be relatively easy to breed for and the outputs of this project will facilitate this crop improvement objective.

Figure 1. Distribution of breeding lines and germplasm (wild and semi-domesticated lines) for hull and pod wall percentage.

KEY WORDS

Seed quality, lupin breeding, seed coat, protein
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