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Crop Updates 2001 - Lupins

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- Western Australia

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Compiled and edited by Bill O'Neill

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Introduction

There has been recent concern over the potential decline in lupin production in Western Australia. This has been largely in response to low returns to producers over the past two seasons due to world feed protein prices being at the bottom of long-term cyclical trends. When price expectations are low, considering dropping lupins from paddocks where they perform less reliably is quite sensible. However, there are already strong indications that lupin prices will rise significantly in the short-term partly due to under-supply as a consequence of the dry 2000 season and partly due to international price pressures. Several factors are emerging which are providing new opportunities for lupins in the marketplace. The BSE scare in Europe will fuel demand for vegetable protein and the current anti-GMO sentiment can be used to differentiate lupins from soybean. The dramatic increase in demand for aquaculture feeds to replace fish-meal is another reality.

The future for lupins in Western Australia is very bright. The on-farm performance of the newer varieties, Belara and Tanjil in particular, has been impressive - even in a very difficult season such as 2000. Industry-wide, the threat from anthracnose has been overcome, although more resistant varieties (particularly pod resistance) are needed for high risk environments. Weed management issues continue to be of concern as new farming systems and rotations evolve but significant research investment in this area promises to find solutions.

Importantly, there are several new initiatives in place with a view to increasing the long-term profitability of lupin production. Much of this activity is being undertaken with renewed enthusiasm through both old and new industry partnerships with AGWEST. Research to increase the value of the lupin grain by increasing its nutritional value, exploring new higher paying markets, and continuing to breed for higher yielding and disease resistant varieties is more active than ever.

Some new initiatives AGWEST are involved in include:

- Working with the Grain Pool of Western Australia to develop new marketing opportunities. Japanese Ministry of Health and Welfare approval for lupin in 'shoyu' (soy sauce) production is an example of a recent success.
- Development of on-farm systems to produce Quality Assured grain for high value animal feed and human food markets.
- Joint research with Fisheries Western Australia and the South Metropolitan College of TAFE to demonstrate the value of lupin inclusion in aquaculture diets. This work is now targeting markets where high specification diets are likely to result in a price premium.
- Increasing crude protein content and protein quality through breeding. Other aspects of improving grain composition such as modifying carbohydrate and oil content are under investigation. Both conventional breeding and genetically modified approaches are being pursued to meet current and future consumer requirements. Involvement with UWA, CSIRO and the Chemistry Centre of WA is crucial in this area.
- Assisting European interest in lupin flour and protein isolates as soybean substitutes for food ingredients.
- Collaborating with public and private research groups who are exploring the health benefits of lupin fibre and isoflavones in human diets.

The lupin industry is still comparatively young. In both the short and long term the crop appears set to maintain a major role in farming systems and should contribute increasingly to the prosperity of Western Australia as higher value end uses are developed.

I would like to acknowledge all those working on lupin projects within AGWEST and to thank other R&D institutions, agribusiness, marketers and growers whose collaboration is increasingly important. To the funding bodies, especially the GRDC, your support for much of the work has been vital.

Dr Mark Sweetingham
LEADER - LUPIN RESEARCH AND INDUSTRY DEVELOPMENT

Lupin variety performance: Are you making the most of it?

Bevan J. Buirchell, Senior Plant Breeder, Agriculture Western Australia

KEY MESSAGE

The new lupin varieties (Tanjil, Wonga, Kalya, Belara, Quilinock) offer higher yields than the older varieties (Danja, Gungurru, Merrit and Myallie) and therefore greater economic return to farmers. Economic returns from Tanjil and Belara have been estimated at $12-$25/ha better than old varieties.

AIM

To analyse annual lupin deliveries to CBH and Crop Variety Testing (CVT) data to ascertain what varieties are being grown by farmers and where varieties perform the best.

METHODS

The Grain Pool of Western Australia supplied annual deliveries of lupin varieties to CBH. Data from CVT trials (1990-2000) were used to analyse lupin variety performance across zones and regions, and across soil types.

RESULTS AND DISCUSSION

Production: Approximately 75% of lupin production in Western Australia occur north of the Great Eastern Highway. The dominant varieties for the 1990s have been Gungurru and Merrit. In 1999 these two varieties accounted for 61% of deliveries while in 2000 season this was reduced to 38% (Table 1). This is a large change but these two varieties still account for a significant amount of production. Tanjil and Belara look like becoming the dominant varieties in the future.

Table 1. Annual production of lupin varieties (percentage of annual tonnage) for the years 1995-2000

Released	Variety	1995	1996	1997	1998	1999	2000 est.
1986	**Danja**	5.4	3.9	2.9	1.8	1.6	1.4
1988	**Gungurru**	56.8	54.6	51.4	44.6	32.3	17.2
1989	**Yorrel**	2.2	1	0.8	0.5	0.3	0.2
1991	**Merrit**	34.9	39.7	37.5	35.7	29.3	20.7
1995	**Myallie**		0.4	6.5	10.4	11.9	11.2
1996	**Kalya**		0.1	0.8	6.7	14.2	14.7
1996	**Wonga**					1.3	7.2
1997	**Belara**				0.1	7.6	18.3
1997	**Tallerack**				0.1	1.2	1.4
1998	**Tanjil**					Trace	7.1
1999	**Quilinock**						Trace
	Deliveries (x 1000 tonnes)	860.9	843.6	916.7	947.8	1197.7	416

Distribution: In 1999 Gungurru and Merrit were the preferred variety in the north and central districts. Kalya and Wonga increased popularity in the northern districts especially with the onset of anthracnose in 1996. Belara has been favoured in the eastern area of the north and central districts while Myallie has been the variety of choice in the eastern half of the central and upper southern districts. Danja is still produced but is confined to the eastern part of the central districts. Tallerack has found a niche in areas were crop topping is used for control of herbicide resistant rye grass. However, the higher yielding but early maturing variety, Belara, should dislodge Tallerack from that system.

Yield: The highest yielding variety across the State is Quilinock (Table 2). Belara and Tanjil yield, on average, 7-12% greater than Merrit. With an average yield of 1.2 tonnes per hectare across the State this is the equivalent of $12-$25/ha extra return (lupins at $175/t). In higher yielding environments the extra return would be even greater.

Table 2. Yield of each variety as a percentage of Gungurru for each region/zone

Region/zone variety	VH	H1+H2	H3+H4	H5	M1+M2	M3+M4	M5	L1+L2	L3	L4+L5
Quilinock	115	117	116	115	117	118	116	114	111	115
Belara	111	113	113	114	117	114	113	114	107	107
Tanjil	112	109	109	108	109	111	108	109	108	110
Wonga	111	108	107	107	107	106	105	107	106	108
Kalya	111	110	106	106	105	106	106	105	104	108
Merrit	102	102	102	100	101	102	102	102	102	102
Gungurru	100	100	100	100	100	100	100	100	100	100
Myallie	100	101	98	97	97	100	98	96	96	98
Danja	104	97	96	95	93	96	95	94	93	97
Tallerack	94	101	97	100	94	96	94	89	93	96

Performance across soil types: Analysis of CVT data (Table 3) showed that on the trials conducted on gravel soils Quilinock out performed Merrit 58% of the time and Belara and Kalya were the next best on 20%. For all trials on sandy soils, Quilinock was the best performer (49%) followed by Belara (36.5%), Tanjil (27.3%) and Wonga (24.3%). Quilinock (72%) and Belara (51.5%) were outstanding on loamy soils with Tanjil and Wonga ahead of the rest. On duplex soils, either shallow or deep, the outstanding performers were Quilinock (53.3%) and Belara (43%). All varieties post Kalya offer better performance than Merrit and Gungurru across all soil types.

Table 3. Performance of lupin varieties in trials on different soil types (percentage of trials where the variety had significantly greater yield than Merrit)

	Gravels	Sands	Loams	Duplex soils	Overall
Tanjil	20.0	27.3	28.0	16.9	27.8
Wonga	0.0	24.3	22.0	12.3	23.3
Belara	20.0	36.5	51.5	43.0	39.4
Quilinock	58.0	49.0	72.0	53.3	50.0
Kalya	19.0	19.6	16.6	14.1	17.6
Myallie	0.0	6.0	3.8	2.2	6.2
Tallerack	0.0	14	14.0	14.1	11.1
Merrit	0	0	0	0	0

CONCLUSION

The latest lupin varieties like Tanjil, Belara, Wonga and Kalya offer farmers greater returns through disease resistance, yield and adaptation. Even though Merrit and Gungurru are still the dominant varieties farmers who continue to grow these varieties are loosing approximately $12-$25/ha.

KEY WORDS

lupin varieties, production, yield, soil type

GRDC Project No.: DAW 485

Paper reviewed by: Kedar Adhikari

Adaptation of restricted-branching lupins in Western Australia

Bob French and Laurie Wahlsten, Agriculture Western Australia

In 1997 the first restricted-branching cultivar of narrow-leafed lupin in Australia, Tallerack, was released by Agriculture Western Australia. Restricted-branching lupins retain more main stem pods than conventional branching types as a consequence of less vigorous lateral branch growth. Because they have fewer lateral branch pods to fill they also often mature earlier than conventional types flowering at the same time. For these reasons, they were expected to have a role in high rainfall and low rainfall environments. In high rainfall environments where excessive vegetative growth, and consequently low harvest index, is a problem, limited lateral branch growth and ability to retain main stem pods would be valuable; and in low rainfall environments where terminal drought restricts yield their early maturity would be valuable (Dracup *et al.* 1998).

Adoption of Tallerack has been limited due to its extreme susceptibility to aphids and to anthracnose. The restricted-branching line WALAN 2053, which does not share these faults, has been earmarked for release in 2001. WALAN 2053 also has better yield potential than Tallerack. The performance of this line was tested in the target environments for restricted-branching lupins in 1999 and 2000.

METHODS

In high rainfall environments excessive vegetative growth and low harvest index is most likely to occur with early sowing. WALAN 2053 was tested against conventional narrow-leafed lupin genotypes Tanjil and WL318 at Mt Barker in 1999, and against Tanjil, Kalya and WL318 at Badgingarra in 2000. Tanjil and Kalya are high yielding cultivars that are recommended in high rainfall regions of WA, and WL318 is a late flowering breeding line from New South Wales that has done well in variety trials on the south coast.

WALAN 2053 was also tested against Belara, Kalya and Merrit at Mullewa in 2000. In this trial half of the plots were given a total of 50 mm irrigation during August and September to simulate a less harsh seasonal finish than was experienced by the controls.

RESULTS

High rainfall trials

We did not experience pod set failure due to excessive vegetative growth in either of these trials. In both trials conventional branched narrow-leafed lupins outyielded WALAN 2053 at the earlier time of sowing, but not at the later time (Table 1).

Table 1. Grain yield (t/ha) of restricted-branching lupin line WALAN 2053 compared to conventional types in high rainfall environments in Western Australia

Cultivar	Mt Barker 1999		Badgingarra 2000	
	Sown on 7 June	Sown on 5 July	Sown on 8 May	Sown on 9 June
WALAN 2053	3.09	3.08	2.63	2.59
Tanjil	3.31	3.26	3.04	2.58
WL 318	3.47	3.11	2.40	2.09
Kalya	N/A	N/A	3.20	2.61
LSD (P = 0.05)	0.248		0.268	

We suspect that this is due to an inability of restricted-branching lupins to respond to the extra resources for growth made available by early sowing rather than to a greater resilience under the stress of late sowing. There is 3-fold evidence that WALAN 2053 is stretched in its capacity to fill its pods, therefore setting more would not lift yields. Firstly, it has up to 6% more empty pods at maturity; secondly, it has significantly fewer seeds per pod; and thirdly, these seeds are smaller than in conventional branching genotypes (data not presented but available from author).

Perhaps a better model for high rainfall southern environments would be a late flowering conventional branching genotype like WL318, which flowered at least a week later than Tanjil and Kalya at Badgingarra in 2000. The later start to its reproductive period gives a similar spread of yield across branching levels as WALAN 2053, yet it did not suffer from a source limitation. It also has the flexibility to respond to kind seasonal conditions by further branching. The growing season at Badgingarra is too short for it, but it was the highest yielding cultivar when sown early at Mt Barker.

Low rainfall trial

Despite a very dry finish in the 2000 growing season at Mullewa, lupin yields in excess of 2 t/ha were realised in the control treatments (Table 2). This probably reflects the use of water stored in the soil from the preceding wet summer. Nevertheless, WALAN 2053 yielded as well as the high yielding conventional cultivars, and significantly better than Merrit. It exhibited the same yield response to irrigation as the conventional cultivars.

Table 2. Grain yield (t/ha) of restricted-branching lupin line WALAN 2053 compared to conventional types at Mullewa, Western Australia, in 2000. Irrigated treatments were given 50 mm extra water during August and September

Cultivar	Control	*Irrigated*
WALAN 2053	2.16	2.51
Belara	2.05	2.55
Kalya	2.16	2.47
Merrit	1.80	2.25
LSD (*P* = 0.05)	0.18	

In this trial WALAN 2053 again had fewer seeds per pod and lighter seeds than the conventional cultivars (data not presented but available from author), but the early maturing conventional cultivar Belara had a significantly higher harvest index.

Data presented in Table 3 shows that Belara matured as rapidly, if not more so than WALAN 2053, and it filled its seeds more rapidly.

CONCLUSIONS

We were not able to test the performance of restricted-branching lupins under low harvest index conditions, but under normal circumstances in high rainfall environments WALAN 2053 does not have the yield potential of the best conventional branching lupin cultivars. This was probably due to insufficient source capacity to fill all of its pods. It yielded as well as high yielding conventional genotypes in a low rainfall environment with a very dry finish. Tallerack also performed well in other trials in the dry 2000 growing season, in contrast to the above average years of 1998 and 1999 (R. French and L. Wahlsten, unpublished data). This suggests that restricted-branching lupins are more likely to find a role in low rainfall than high rainfall farming systems.

Table 3. Average main stem seed size at early and mid pod fill, and senescence scores (% plot senesced) on 20 September of lupins grown at Mullewa, Western Australia, in 2000

Cultivar	Average main stem seed weight (g)		Senescence (%)
	23 August	20 September	20 September
	Control		
WALAN 2053	0.010	0.065	50
Belara	0.018	0.100	65
Kalya	0.008	0.066	27.5
Merrit	0.012	0.069	32.5
	Irrigated		
WALAN 2053	0.009	0.063	20
Belara	0.012	0.080	27.5
Kalya	0.013	0.057	2.5
Merrit	0.003	0.066	7.5
LSD (*P* = 0.05)	0.007	0.010	17.4

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M. Dracup, W. Cowling and B. Thomson (1998). Growing Tallerack narrow-leafed lupin. Agriculture Western Australia Farmnote No. 26/98.

GRDC Project No.: DAW 583WR

Paper reviewed by: Bill O'Neill

Isolated microspore culture of lupins for production of doubled haploids

Dr Janet Wroth, Dr Kirsty Bayliss and A/Prof. Wallace Cowling, Plant Sciences, Faculty of Agriculture, The University of Western Australia

KEY MESSAGE

Doubled haploid technology has the ability to produce homozygous progeny from cross hybrids, which accelerates selection of progeny exhibiting important characters such as disease resistance, yield, drought tolerance or quality traits. Cereal and Brassica breeding programs worldwide routinely use doubled haploid technology to accelerate the development and release of new cultivars. To date, no research group has developed doubled haploid plants from any legume.

Research into the development of methods for doubled haploid technology in lupins commenced at The University of WA in 1995. Considerable progress has since been made towards doubled haploid lupins, with key steps in the production pathway now identified. In this paper we report some of the major findings from GRDC research project UWA 167 and the continuing research being conducted in project UWA 341.

AIMS

1. To develop protocols for isolation and induction of lupin microspores leading to cell division.
2. To improve cell division to complete the process of embryogenesis and produce the first haploid lupin embryos.

METHOD

Lupins are grown in a controlled environment at 18/13°C (day/night), with a 16 h daylength. Approximately 30 buds of 5-7 mm are picked and stored for 3-4 days at 4°C to synchronise the number of pollen microspores at the late uninucleate stage of cell division. Buds are surface sterilised, crudely macerated and blended using a Ystral blender to release the microspores into solution. The concentration of microspores is adjusted at this stage to 100,000 cells/mL which is the optimum for cell division. Microspores are subjected to heat stress in a starvation medium for 24 hours which effectively halts gametogenesis. They are then transferred to a medium which induces cell division. Initially microspores are stabilised in culture at low temperature with high osmoticum levels before continuing culture at 25°C with normal osmoticum levels.

RESULTS

In project UWA 167, the basic requirements for the early stages of lupin doubled haploidy were developed. Major achievements included:

- identification of growth requirements of donor plants;
- selection of buds containing pollen microspores at a defined developmental stage;
- pre-treatment of buds to synchronise cell division;
- stress treatment of anthers to release microspores and cease gametogenesis;
- purification of microspores and adjustment of osmoticum to stabilise cells;
- induction of microspore cell division leading to embryogenesis.

In project UWA 341 we have continued to refine the techniques and commenced testing a range of hormones and compounds for the promotion of cell division. A significant improvement has been made in the microspore isolation technique using the Ystral blender with the density of microspores isolated increased more than 10-fold, from approximately 300 to 3000 per bud. The large increase in microspores allows us to test a variety of treatments simultaneously.

CONCLUSION

Microspores isolated from lupin buds have been induced successfully to undergo cell division. It is now possible to regularly produce cultures with 2% of cells dividing into 2, 4 and 8-celled structures. We are currently refining culture conditions to prevent the stalling of cell division. Successful embryogenesis requires the synchronous development of multiple clumps of dividing cells, which can then differentiate into haploid embryos. Research is now targeted towards inducing embryogenesis from dividing cells and regeneration of haploid and doubled haploid plants.

KEY WORDS

lupin, haploid, embryogenesis, breeding

GRDC Project No.: UWA 167 and 341

Paper reviewed by: Dr Michael Francki

Banding manganese fertiliser below the seed increases seed yields of narrow-leafed lupins

R.F. Brennan, Agriculture Western Australia

SUMMARY

As measured in 31 field experiments, placing Mn fertiliser 8 cm below lupin seed while sowing at 4 cm (banded Mn) was the most effective method for grain production of lupin compared with placing fertiliser Mn with the seed (drilled Mn) or spreading Mn fertiliser over the soil surface before sowing (broadcast or topdressed). Topdressing Mn before sowing was the worst treatment, followed by drilling the fertiliser with the seed. Seed yield responses to applied Mn were larger when fertiliser was banded below the seed and less fertiliser Mn needed to be applied to produce the same grain yield than the other two methods.

Mn fertiliser banded below the seed, depending on growing season rainfall and rainfall during grain production in August-early November, was about twice as effective as Mn fertiliser drilled with the seed The Mn banded below the seed was more effective than drilled with the seed at 70% of experimental sites over 4 seasons. Topdressed Mn was less effective than Mn drilled with the seed at all sites in all seasons.

It is recommend that Mn is banded 7 to 8 cm below the seed while sowing at 4 cm, rather than the practices of either drilling the Mn fertiliser with the seed, or topdressing it before sowing.

INTRODUCTION

Grain yield of narrow-leafed lupins (*Lupinus angustifolius* L.) grown in Western Australia (WA) often is limited by manganese deficiency. Manganese (Mn) deficiency causes a seed disorder called split seed where the seed coat splits open, the seed leaves (cotyledons) protrude and the seed shrivels in the pod. Seed (grain) yields of lupins are can be reduced by up to 70% by split seed. Mn fertiliser needs to be applied to overcome the deficiency. Many WA soils are naturally deficient in Mn for maximum seed yields of lupins. Mn deficiency of lupins has been observed on the slightly acidic deep grey sands, the pale yellow sands and the deep white sands of WA where seed yields are devastated without the application of Mn fertiliser. Manganese deficiency of lupins occurs on severely deficient soils regardless of seasonal conditions. However, on soils that have a marginal supply of Mn, the deficiency usually occurs in spring after a dry period followed by rain. This is because Mn is immobile in the plant so fresh Mn needs to be taken up from the soil by plant roots to supply adequate Mn for new growth, including grain. Plant roots can only take up nutrient elements, including Mn, from moist soil. No Mn can be taken up from dry soil, even if there is sufficient Mn in the topsoil for grain production. The seed yields of lupins grown on these soils is greatly reduced unless Mn fertiliser is applied. Manganese fertiliser, usually as manganese sulphate is usually applied when lupins are sown. The fertiliser is usually drilled with the seed about 4 to 5 cm below the soil surface. However, Mn can be applied to the soil surface before sowing. As a result of these shallow placements, Mn is often unavailable for plant uptake in periods during the growing season when the soil surface dries out between rains. As split seed is worse, where the soil dries out rapidly in spring Mn should be applied deeper in the soil so that there is a continual supply of soil Mn to the lupin plant. Banding Mn fertiliser about 8 cm below the seed should improve the effectiveness of Mn for grain production of lupin. This is because the banded Mn is likely to be in moist soil for longer periods than drilled or topdressed Mn, as has been found for banded fertiliser P for lupin grain production (Jarvis and Bolland 1990, 1991).

MATERIALS AND METHODS

Field experiments: The effectiveness of application of Mn fertiliser for lupin grain production was measured using *Lupinus angustifolius* L. cv. Gungurru in 31 experiments done in the year of Mn application in Western Australia. The Mn was applied in 3 ways: (i) placed in bands at 8 cm below the seed (13 cm below the soil surface) while sowing the seed at 5 cm (hereafter called banded Mn); banded with the seed (hereafter called drilled Mn) at 5 cm depth, or applied to the soil surface just before sowing for some of the Mn was incorporated into the top 5 cm of the soil by seeding and cultivating tines when sowing the lupin seed at 5 cm (hereafter called topdressed Mn). Three amounts of Mn were applied in each experiment (0, 3.5 and 7.5 kg/ha), while for the topdressed Mn treatment 15 kg Mn/ha was also applied.

The design for all experiments was a complete randomised block of 3 methods of Mn application by 3 amounts of Mn for 2 methods and 4 for one of the methods, with 4 replications. The topdressed Mn

fertiliser was applied to the soil surface immediately in front of the seeding tines while sowing and adding basal P fertiliser so some of the topdressed Mn would have been incorporated into the top 5 cm of the soil surface.

Insects and weeds were controlled as required.

MEASUREMENTS

The number of lupin plants per m^2, Mn concentration in whole shoots, and the Mn concentration in stem was measured to assess the procedure as a possible prognostic test for Mn deficiency for seed production of lupin. Twenty lupin plants were taken at maturity, the pods removed, air-dried and then hand threshed to examine seed weights (1000 seed wt) and percentage of split seed.

Analysis of data

The relationship between grain yield and the amount of Mn applied was fitted to a Mitsherlich equation ($y = a - b \exp(-cx^n)$).

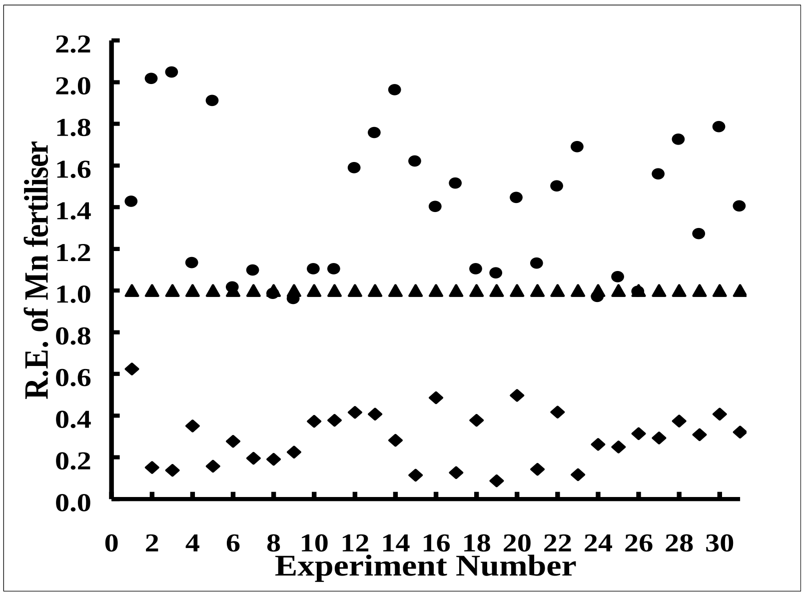
RESULTS

Mn fertiliser was better used by the lupin plant for seed production by banding Mn directly below the seed while sowing, compared with drilling the fertiliser with the seed or topdressing before sowing. In all experiments, the best result was with the greatest placement depth for Mn fertiliser. Banding Mn fertiliser below the lupin seed greatly increased seed yield of lupins on all soil types where Mn was deficient.

Lupins are grown on sandy soils that rapidly dry between rains during the growing season, restricting the uptake of Mn from the dry soil. Manganese placed below lupin seed remains in moist soil for longer periods during the growing season, allowing the roots to take up Mn over longer periods and increasing Mn fertiliser effectiveness for lupin production. By contrast, topdressed or drilled Mn, which is usually confined to the surface 5 cm or less, may be positionally unavailable to the lupin roots for a large part of the growing season. The poor response of seed yield increases to topdressed Mn in most experiments was no doubt due to the dry, late winter-spring period.

Our experiments confirm the advantage of banding Mn for seed yield of lupins, but we strongly recommend against topdressing, as final seed yield is reduced compared with drilling Mn with the seed or banding Mn below the seed. Banding the fertiliser below the seed greatly increases fertiliser effectiveness and lupin yields, and is recommended for lupin production on sandy-textured soils in WA.

Figure 1. **The effectiveness of Mn fertiliser for that topdressed to the soil surface and that banded below the seed compared to that drilled with the seed. Mn drilled with the seed the RE = 1.0. RE for Mn (i) banded below the seed (λ), (ii) drilled with the seed (σ) and for that (iii) topdressed to the soil surface before seeding (υ) for all 31 experiments.**



Residual value of manganese fertiliser for lupin grain production

R.F. Brennan, Agriculture Western Australia

SUMMARY

The residual value of manganese fertiliser for seed (grain) production of lupin (*Lupinus angustifolius* L.) was measured in 2 field experiments on 2 different soils (sand, lateritic ironstone gravel-sand) when manganese sulphate was placed (drilled) with the seed at about 5 cm while sowing. Relative to the nil-Mn treatment, additions of Mn fertiliser increased yields by about 1.0 t seed/ha and decreased the amount of split seed from about 80% to less than 5%. The residual value (RV) of Mn fertiliser was measured in 1994 for grain production of lupin, for Mn applied either in 1994 (current Mn) or in a previous year (previous Mn), applied in one of the following years: 1978, 1982, 1988, and 1991. The RV of previous Mn for grain production decreased relative to the effectiveness of current Mn, the decrease being larger with increasing time since application. The decline in the RV varied with soil type.

INTRODUCTION

Lupinus angustifolius L. (lupin) is the major grain legume grown on the acidic to neutral sandy surfaced soils of Western Australia (WA). A major problem for lupin grain production is manganese (Mn) deficiency. Mn deficiency usually does not affect yield of lupin shoots. However, Mn deficiency causes a seed disorder, called split seed, where the testa splits open, the cotyledons protrude and the seed shrivels, reducing the grain yield. Manganese fertiliser is usually applied at about 7.5 kg Mn/ha when lupin is grown. The length of time that fertiliser Mn meets the requirements of lupin [residual value] sown on the Mn-deficient soils in WA is not known. This information is required for profitable lupin grain production.

AIMS

This paper reports the results of 2 long-term (16 years) field experiments done on different soil types suitable for lupin to assesses whether the original applications of Mn applied to the soil up to 16 years before are still sufficient for profitable lupin grain production.

MATERIALS AND METHODS

The same experiment was done on 2 different soil types near Badgingarra. The 2 experiments were done in 1994. In each experiment, different amounts of Mn fertiliser (0, 3.7, 7.4, and 14.8 kg Mn/ha as manganese sulphate) were applied in different years when lupin was sown: 1978, 1982, 1988, 1991, and 1994. The first soil was lateritic ironstone gravel sand (gravel sand). The second soil was a deep grey sand (sand).

RESULTS

The Mn treatments had no affect on the density of lupin seedlings. There was a mean of 55 plants/m^2 for all Mn treatments. The Mn treatments also had no effect on the dry matter yield of lupin shoots.

Grain yield

Current and previously applied Mn increased yield of lupin (Table 1). Relative to the nil-Mn treatment, additions of Mn fertiliser in 1994 increased grain yield on the gravel sand by 790 kg seed/ha and 970 kg seed/ha on the sandy soil. The yield increases tended to be smaller as the time from application of fertiliser Mn increased.

Split seed

Current and previously applied Mn decreased the amount of split seed. The RV of the Mn fertiliser for the amount of split seed appears to be lower than that required for seed production. As the percentage of split seed increased, there was a decline in grain yield of lupin.

Manganese concentration in apical growth and in main stems

There was a good relationship between Mn in youngest tissue (YVB) and main stem, and the relative grain yield. The critical Mn concentration related to 90% relative yield was in YVB that was about 48 mg Mn/kg for youngest bud tissue and 21 mg Mn/kg in the main stem.

There was a good relationship between Mn concentration in YVB and the amount of split seed of lupin produced for both soils. A concentration of about 50 mg/kg in the bud was required before amounts of split seed were less than 5%. There was a good relationship between Mn concentration in the main stem and the amount of split seed of lupin. A concentration of about 21 mg/kg in the main stem was required before amounts of split seed were less than 5%.

Relationship between soil extractable Mn and grain yield and split seed

There was an increase in the concentration of soil extractable Mn as the amount of Mn fertiliser applied increased. In addition, the amount of Mn extracted by each soil extractant tended to decrease with increasing time since the Mn fertiliser had been applied. There was a good relationship between the soil extractable Mn by DTPA, AmAc and AmAcHQ and grain yield of lupin grown on each soil. The soil extractable levels associated with 90% of the relative grain yield varied with chemical extractant and soil type. Similarly, there were good relationships between the soil extractable Mn by DTPA, AmAc (Ammonium acetate) and AmAcHQ (ammonium acetate and hydroxyquinone) and the percentage split seed of lupin. For the sand, there was a close agreement between the critical soil Mn levels determined for maximum (95%) grain yield and minimum amounts of split seed (5%). However, for the gravel soil the critical levels determined for amounts of split seed were significantly higher for the DTPA and AmAcHq extractants.

DISCUSSION

The residual value of the Mn fertiliser for lupin grain production decreased as the length of time that Mn fertiliser was in contact with the soil increased. Applications of Mn fertiliser in the current year was about 3 to 5 times more effective, depending on soil type, than the same amounts of Mn applied 16 years previously. The decline in effectiveness of Mn fertiliser measured in both experiments is attributed to the continued slow reactions of Mn with the soil.

The concentration of Mn in the YVB and in the stem appears to be reliable methods for the determining future Mn deficiency (prognosis) in lupins.

In the 2 experiments reported here, the RV of Mn fertiliser, and the calibrations relating lupin grain yield to soil test Mn values, were measured in one year (1994). Under these circumstances, all data fall on the same line, regardless which year the Mn fertiliser was applied. The relationships are likely to differ in different years due to the major effect of different seasonal conditions on the release of Mn from insoluble sources in the soil, on plant production, and on the use of Mn taken up from the soil to produce grain. Deep placement of the Mn fertiliser has been shown to result in Mn being more available in the growing season. However, the deep placed Mn fertiliser is placed beyond the soil sampling depth (10 cm) used for soil testing of all nutrient elements in WA, decreasing the reliability soil testing for Mn.

Table 1. Values of the coefficients of the Mitscherlich equation fitted to the relationship between grain yield (kg/ha) and the amount of Mn fertiliser applied to a sand and a gravel sand, and residual value (RV_{Mn}) of Mn fertiliser applied to lupin in WA

Years[a]	*a*	*b*	*c*	r2	*bc*	RV_{Mn}
			Sand			
0	1371	992	0.477	0.999	472.807	1
3	1389	1002	0.288	0.999	288.676	0.61
6	1372	993	0.202	0.999	200.864	0.42
12	1434	1057	0.12	0.989	126.84	0.27
16	1382	1007	0.094	0.993	94.155	0.2
			Gravel sand			
0	1084	696	0.538	0.997	374.17	1
3	1040	652	0.453	0.996	295.617	0.79
6	1007	628	0.373	0.998	234.244	0.63
12	973	595	0.289	0.989	172.074	0.46
16	894	513	0.222	0.999	113.937	0.3

[a] Year 0 = 1994, 3 = 1991, 6 = 1988. 12 = 1982 and 16 = 1978 when Mn fertiliser was applied when lupin was sown.

Paper reviewed by: M.D.A. Bolland

Lupin seeding density

Miles Dracup, Agriculture Western Australia, **Nick Galwey**, University of Western Australia and **Bob Thomson**, University of Western Australia

SUMMARY

Having less branching, restricted branching varieties such as Tallerack might require higher plant densities. This study compared the optimal plant densities of Tallerack and Merrit over three years at 10 diverse sites. It found that both varieties had the same optimal density at each site. However, between sites, the optimal density varied between 35 and 57 plants/m^2 and was not related to site yield.

INTRODUCTION

New lupin varieties with restricted branching have been and are being bred; they appear to be suited to sites where crop biomass is high but transfer into grain is poor due to either rapid finishes or dense canopies. Lupin yield is sensitive to plant density and modern varieties require higher densities for optimum yield than did earlier varieties. Tallerack is the first restricted branching variety released, and, having fewer orders of branching than other modern varieties, it may require higher densities. This study compared density requirements for Tallerack with the variety Merrit, which is a widely adapted, modern, normal branching variety

METHODS

Tallerack and Merrit were grown in ten field trials over the course of three seasons throughout the grain belt. The trials contained the two varieties, each at 4-7 densities (range = 10-100 plants/m^2) in 3-6 replications and optimum yield at each site varied between 1 and 2.7 t/ha. Relationships between density and yield were analysed using advanced statistical techniques which remove effects of within-site variation (spatial adjustment by REML) and which fit an empirical curve to the data (spline-fitting, also by REML) rather than use a curve of pre-determined form. Yield components were determined on the basis of hand samples from field plots taken prior to machine harvest.

RESULTS AND DISCUSSION

Tallerack outyielded Merrit at some sites (e.g. Figure 1 and Figure 1b, Tardun) while Merrit was superior at others (e.g. Figure 1b, Mullewa). In Figure 1b, environments were similar but the soil at Tardun led to a faster finish, apparently favouring Tallerack. The two varieties had a similar optimal density at each site, and except for one site (not shown), this optimal density varied between 35 and 57 plants/m^2, consistent with previous recommendations for lupin density.

There was no relationship between yield potential of a site and the optimal density at the site, preventing a closer prediction (than 35-57 plants/m^2) of optimal seeding rate. However, a simple calculation of yield penalties from sowing at low rather than high density indicates that erring on the side of high density is judicious. The cost of establishing 60 rather than 30 plants/m^2 is about $10, while the average yield improvement is 0.16 t/ha - worth about $30. High densities also help control weeds, brown spot, viruses and soil erosion, loosen compact soil, and increase residual nitrogen, harvest height and individual grain weight.

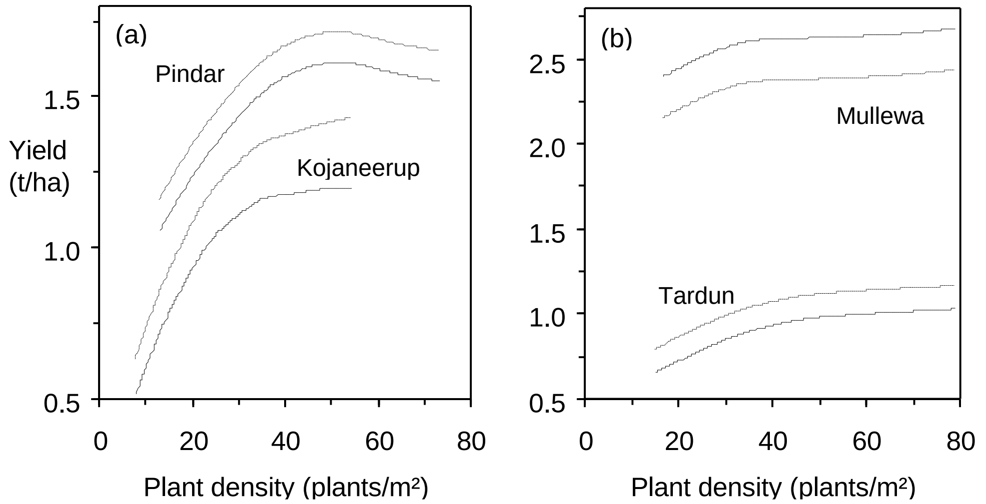


Figure 1. **Fitted relationships between density and yield for two representative trials in 1996 (a) and 1997 (b). Solid lines represent Merrit and Tallerack is represented by long dashes.**

Establishment of both varieties varied between 50 and 90%, but overall, Tallerack was 15% poorer than Merrit. This poorer establishment of Tallerack was mainly due to greater mechanical damage during harvesting, which highlights the need for care when harvesting seed crops. Germination testing is crucial to deciding how much seed to sow, whichever variety is being sown - the yield penalty from sowing seed with low germinability can be considerable.

As plant density increased, individual plants retained fewer pods and seeds but individual seed weight increased by a small amount (0.07 mg for each additional plant per m^2). There was also a small increase of 0.07 percentage points in grain protein between the lowest and highest densities, and restricted branching tended to be associated with higher grain protein. Grain from restricted branching varieties also had significantly higher concentrations of P, K, S, Mg and Mn, which could be an advantage is establishing new crops. In addition, the higher Mn concentration might reduce incidence of split seed on soils low in Mn.

ACKNOWLEDGMENTS

This research was funded by the Grains Research and Development Corporation and supported by Agriculture Western Australia, CLIMA and the University of Western Australia.

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Anthracnose in lupins - understanding the risk

Moin Salam, Art Diggle, Geoff Thomas, Mark Sweetingham and Bill O'Neill,
Agriculture Western Australia

KEY MESSAGES

A computer model, 'Anthracnose Tracer', has been developed to produce site and season specific information about management of anthracnose in lupins. The model calculates the day-to-day state of the disease during the whole growing season and allows the effectiveness of control strategies to be evaluated. Consultants, researchers and development officers will find that the model can help to address their particular problems.

The following questions have been addressed here and on the Crops Update CD to highlight the potential applications of the model:

- Why wasn't anthracnose a problem last (2000) year?
- How much crop damage can you expect in your area? How bad could it get in a bad year?
- Is it worth using clean seed if you have infected blue lupins on the fence line?
- How much good are fungicides and resistant varieties?

BACKGROUND

Since the outbreak of anthracnose in 1996, Agriculture Western Australia (AGWEST) scientists have made important progress in understanding the disease and its control. The results from this research have been incorporated in a computer model that predicts how the disease will spread. The model can handle any combination of weather, initial level of seed infection, variety, spread of the disease from outside, and control with fungicides, so it can be tailored for any situation.

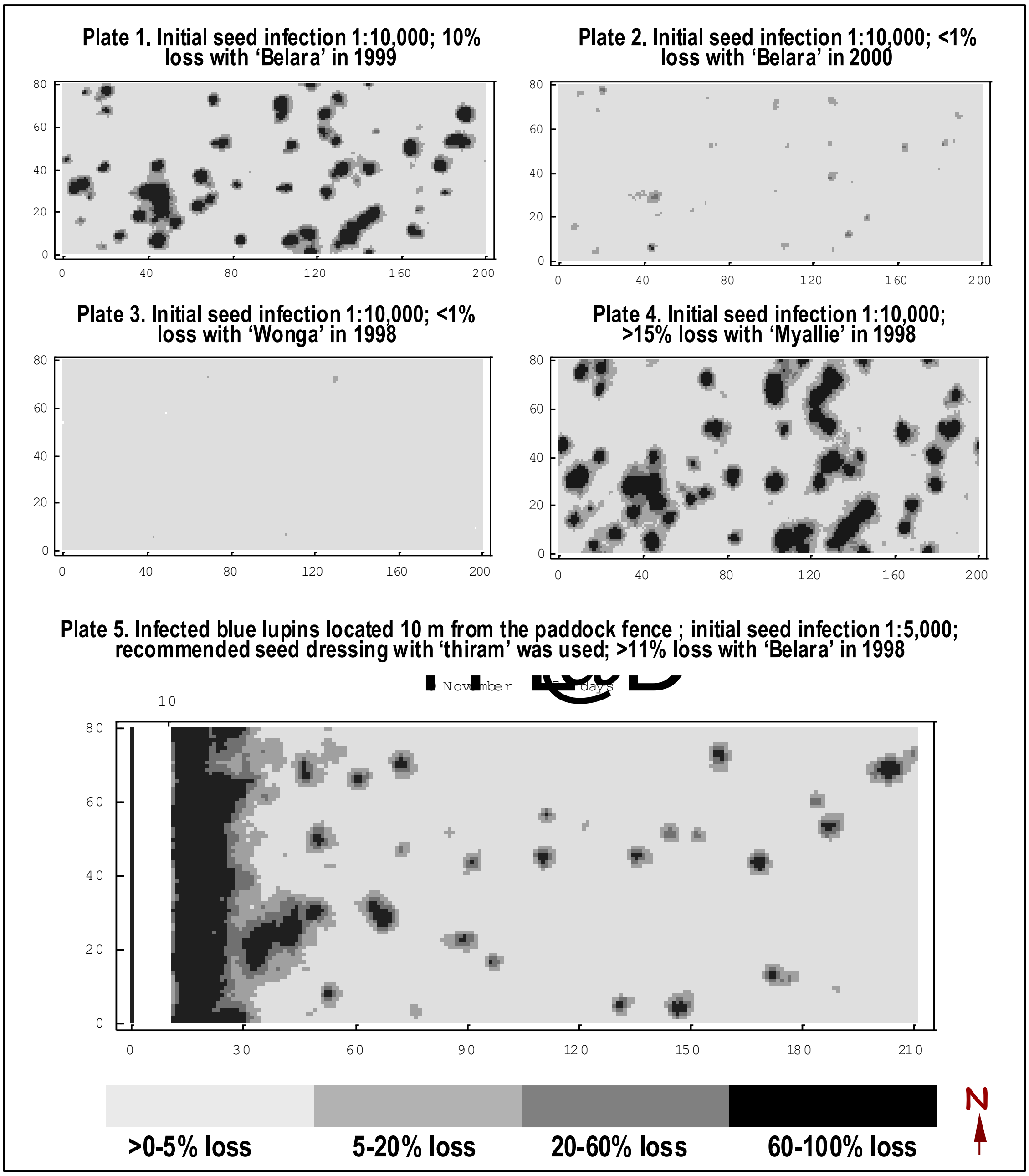
In this paper we explore the potential impact of anthracnose in the Geraldton area. We look at the effect of variety, the effect of fungicides and the initial level of seed infection, the effect of blue lupins outside the paddock, and the reason why 2000 wasn't a big problem. On the CD for the conference we include results for many combinations of rainfall zone, variety, initial level of infection, average vs bad years, and presence or absence of blue lupins. In these results, you will be able to find situations that apply to you.

RESULTS AND DISCUSSION

Dry weather curbed the spread of anthracnose last season (2000). In the Geraldton area, the model estimates about a 10% loss in 1999 for the variety Belara with a 1 in 10,000 level of seed infection (Plate 1). This compares to < 1% loss in 2000 with the same variety and seed infection level (Plate 2). The difference in rainfall in the first month of the growing seasons explains most of this striking difference.

The level of seed infection has a profound effect on anthracnose damage. The model shows, based on Geraldton weather in 1998 (one of the worst years for anthracnose spread in that area), that a 1 in 10,000 level of seed infection would have produced over 15% loss in Myallie (Plate 4). For the extremes, 1 in 640,000 infection would have caused little loss (0.03%), and 1 in 1,000 would have caused total (100%) loss. A more resistant variety like Wonga would have suppressed the disease to a considerable extent (Plate 3 compared to Plate 4).

The presence of infected blue lupins on the fences especially in the up-wind direction can spoil the benefits of using clean seed. A 1 m wide infected blue lupin fence, 10 m west of the paddock, would have caused about 1% loss in Wonga, 6% in Belara and 9% in Myallie (Geraldton 1998 season). These levels of damage are comparable to those caused by 1 in 10,000 seed infection (Plates 3 and 4 for Wonga and Myallie). Plate 5 shows the combined effects of infected blue lupins in the fence and 1 in 5,000 seed infection in Belara. These conditions would have caused about 11% loss even with the use of 'thiram'.



A BIT ABOUT THE MODEL

'AnthracnoseTracer' simulates splash of spores from infected to healthy plants in a lupin paddock. It uses hourly weather data to account for the wind speed, wind direction, and the variability in the wind throughout the season. The model takes into account the effect of temperature on the length of the latent phase of the infection, and it accounts for the effect of duration of leaf wetness on chance of infection. The model also estimates growth of new growing points by the lupins and the degree of compensatory growth when disease strikes. Disease status is described as the per cent loss of healthy (uninfected) lupin growing points in each 1 m^2 segment of a paddock. The model produces animated maps of the paddock through the growing season showing the intensity of the disease at each location. For the details of the model, see Diggle *et al*. (2001).

THE FUTURE

This model will be useful in providing location and season specific forecasts of anthracnose risk. These forecasts will make use of seed testing data from the AGWEST Plant Laboratories to indicate probable levels of infection of seed around the State, and as far as possible will use long range forecasts to refine estimates of rate of spread early in the season. Seed tests reports may in future

include reports of risk of loss that are tailored for the individual seed samples and the locations where they will be sown.

ACKNOWLEDGEMENTS

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KEY WORDS

anthracnose, lupin, model, seed infection, blue lupin, seed treatment, rainfall pattern

GRDC Project No.: DAW 621

Paper reviewed by: Dr Bill Bowden

Implications of the ‘green bridge’ for viral and fungal disease carry-over between seasons

Debbie Thackray, Agriculture Western Australia and Centre for Legumes in Mediterranean Agriculture

KEY MESSAGES

- Some viral and fungal diseases of broad-acre crops can only survive from the end of one winter growing season to the start of the next on green plant material - the so-called ‘green bridge’.
- The aphid vectors of many crop viruses also require this ‘green bridge’ to survive between crop growing seasons.
- In WA, with its Mediterranean climate, the survival of aphids over the hot summer is critical in determining the likelihood of aphid outbreaks and virus epidemics in broad-acre crops.
- The abundance of green plant material is dependent on summer and early autumn rainfall.
- Summer and early autumn rainfall is being used in computer models developed to forecast aphid outbreaks and virus epidemics in broad-acre crops in different zones of the WA grainbelt.
- Predictions can be used by advisers and growers in planning management of aphids and viruses in broadacre crops. Decision support systems (DSSs) are being developed to aid in this.
- Summer surveys and paddock inspections before the start of the growing season can further assist in decisions both before and during the growing season about prevention and management of fungal and viral diseases in crops.
- Early destruction of the green bridge to create a fallow before sowing can greatly reduce disease and insect pressure on emerging crops.

BACKGROUND

In the Mediterranean-type climate of Western Australia, it is the survival of pests and diseases over summer that is often critical in determining the likelihood of pest outbreaks and disease epidemics in broad-acre crops. Whilst some pests and diseases can persist in seed, stubble or soil, others require green plant material to survive, the so-called ‘green bridge’ between growing seasons. For example, both the aphid vectors of viruses and many of the viruses they transmit must have live plant hosts to survive the summer. These viruses include the luteo-viruses, barley yellow dwarf virus (BYDV) in cereals, beet western yellows virus (BWYV) in canola and bean leaf roll (BLRV - not confirmed in WA) in pulses. Other diseases requiring live plant material to survive summer include rust in cereals and downy mildew in canola. Root lesion nematode populations are also enhanced by the presence of live root tissue. The abundance of green plant material is dependent on summer and early autumn rainfall. However, the anticipated increase in warm season (summer) cropping and lucerne plantings will increase the survival rates between winter growing seasons for some pests and diseases, which previously persisted over summer only on weeds and crop volunteers (see Jones in 2001 Pastures Update). Monitoring the abundance of green material surviving through the summer and the incidences of pests and diseases associated with it can aid in planning appropriate management of these before or after winter crops are sown. In particular, early control of weeds and crop volunteers to create a fallow before sowing can greatly reduce disease and insect pressure on emerging crops. For many pest and disease problems, the greatest damage is done when they occur early in the life of the crop. Computer forecasting models based on summer and early autumn rainfall are being developed to predict aphid outbreaks, and viral and fungal disease epidemics in broadacre crops and their effects on crop yields and quality. Decision support systems based on these models will aid growers and advisers in their management of aphids, viruses and fungal diseases using cultural and chemical methods of control before or after sowing winter crops.

FORECASTING MODELS FOR APHIDS AND VIRUSES

The forecasting model developed for lupins is used to predict yield losses both from direct aphid feeding damage and from cucumber mosaic virus (CMV), which is transmitted by aphids, in different

zones of the grainbelt. CMV can cause yield losses of up to 60% when aphids arrive and spread virus early the crop's life. Conversely, in years when aphids arrive late there may be little or no loss in yield from virus infection. The model calculates an index of aphid activity in the vicinity of the crop prior to the growing season. This is based primarily upon rainfall during late summer and early autumn (February-April), which determines soil moisture and the availability of green plants on which aphids build up before moving into crops. The model then predicts aphid arrival and build-up and the spread of CMV from seed-borne infected plants within the crop. It also evaluates the effects of different sowing dates, proportions of seed-borne infected plants and plant densities on aphid numbers and on virus spread. Grain yield loss and the proportion of harvested seed infected with CMV are estimated.

The lupin model successfully predicted the time of arrival and build up of aphids, spread of CMV, yield loss and CMV transmission into harvested seed found in four years of field experiments at Badgingarra, WA. These experiments represent a range of scenarios for February-April rainfall, sowing date, level of infection in seed sown and plant density. Further validation using data from different years and sites is being done. The model is being incorporated into a decision support system (DSS) for use by advisers and growers in WA. This will predict the risk of aphid outbreaks and virus epidemics in lupins and demonstrate the effects of cultural control measures at seeding on disease progress and yields in different districts each year. Inputs that will be required from the user will be the variety sown, sowing date, % CMV infection in seed sown and geographical location. The DSS will use climate data from the locality to calculate predictions. The DSS should give growers greater confidence in growing lupins in medium to high virus risk areas, by enabling them to anticipate problem years and to plan appropriate management strategies, thereby reducing yield losses.

This modelling approach, based on summer and autumn rainfall, has also been used in the development of a forecast and DSS for aphid and BYDV control in cereal crops grown in WA (see Thackray *et al*. in 2001 Cereal Update). It will be adapted in the development of further models and DSSs for management of aphids and viruses in canola and chickpeas (see Thackray *et al*. in 2001 Canola Update). There is potential to transfer the technology to other pests and diseases which are dependent on the ‘green bridge’ to survive between growing seasons.

OVER-SUMMERING SURVEYS AND PADDOCK INSPECTIONS

A number of surveys have been done in the past 10 years in WA to determine the occurrence of aphids and viruses in herbaceous plants surviving over summer (e.g. see Hawkes and Jones in 2001 updates). The information from these surveys helps determine the likely proportion of aphids carrying virus into crops and is being used in the development of the predictive models for aphid and virus incidence in winter crops. Growers and advisers can also gain valuable knowledge in years with summer rain by inspecting their paddocks prior to the start of the growing season for pest and disease incidence, as well as for natural control agents such as predatory beetles and pathogenic fungi infecting aphids. Where disease and pest pressure is high, chemical control of the ‘green bridge’ should be done to produce a fallow period of around 6 weeks. Generally, delaying sowing is to be avoided as the loss in production outweighs the benefits of reducing insect and disease pressure (e.g. aphids and BYDV in cereals). For some diseases, early sowing enhances control, such as with lupins where a rapidly established plant canopy shades out CMV-infected plants.

IMPLICATIONS FOR GROWERS

Growers and advisers can use pre-growing season paddock inspections, risk forecasts and their knowledge of the effects of the ‘green bridge’ on pest and disease carry-over, to prepare for the growing season ahead. They should:

- control crop volunteers and weeds early, so as to reduce pest and disease pressure on newly emerging crops, e.g. BYDV and aphids in grass weeds, aphids and rust in cereal volunteers;
- consider the risk associated with planting infected seed, e.g. If aphids are expected to arrive early following a wet summer, then CMV-infected lupin seed should not be sown. With little rain and little green vegetation, aphids will be late, and the risk from planting infected seed decreased;
- consider cultural management strategies before or at seeding for aphid and disease control, e.g. cultivation for rust control, increased plant densities and narrow row spacing for CMV control.

- utilise predictions based on summer rainfall as to if and when to apply insecticides. This is especially useful when it is hard to find aphids and virus symptoms in crops, as considerable virus spread can occur with low aphid numbers and before symptoms can be seen;
- request seed tests for lucerne, so as to prevent introduction of seed-borne diseases such as alfalfa mosaic virus to areas previously unaffected, with subsequent spread to other legume crops.

Decision support systems will aid growers and advisers in these considerations by forecasting pest and disease pressure, demonstrating the effects of management strategies and predicting timing of these for different areas of the WA grainbelt. Early control of the 'green bridge' will assist the establishment of roots in a less hostile soil environment (root diseases including root lesion nematode) and decrease disease spread and impact (leaf fungal and viral diseases).

ACKNOWLEDGEMENTS

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GRDC Project No.: UWA 290, UWA 313, DAW 609

Paper reviewed by: Christine Zaicou-Kunesch and Rob Loughman

Insect pest development in WA via the 'green bridge'

Kevin Walden, Agriculture Western Australia

KEY MESSAGES

- Summer crops and out of season crop volunteers and weeds that enable larger than normal populations of crop pests and diseases to carry over to the next growing season are defined as the green bridge.
- Unusually wet summers that produce the green bridge are seen as being responsible for subsequent pest and disease outbreaks.
- Responses to summer rainfall by insect pest species are varied; summer rainfall events can be either advantageous, detrimental or have no influence on survival.
- If vegetation is abundant in paddocks planned for seeding, those paddocks should be sampled for insect pests.
- Habitat destruction can be a management tool. A fallow period of three weeks for caterpillars and one week for mites before the crop is sown is required to starve these pests. Insecticide treatments at the time of application of herbicides can be cost effective.

INTRODUCTION

Extensive summer rainfall in the Wheatbelt of WA, like that experienced in 1999/2000, is an unusual event that has major implications for the survival and development of insect pest species. The responses of insect pests vary from enhanced survival and reproduction, to little if any response, to sharp increases in mortality and a rapid decline in numbers. Knowing the responses of insect pests to summer rain gives us the opportunity to define the most effective management practices.

Example 1 - Aphids

Several species of aphid are pests of cereals, pulses, lupins, canola and pastures. Not only can they cause significant damage to crops and pastures due to their feeding when they are present in very high numbers, but they can also inflict considerable damage in low numbers as vectors of a number of viruses. Aphids have several generations in a season and characteristically their numbers fluctuate widely. Aphids are extremely difficult to find after spring and are thought to survive by taking refuge in small, isolated pockets of suitable habitat. Recent studies are suggesting that summer and autumn rainfall may be critical to the initial development and migration of a number of aphid species into crops and pastures. These studies could lead to accurate predictions of the timing and size of aphid infestations to assist with the management of these pests.

Example 2 - Webworm

Several species of Hednota (Pyralidae), collectively called webworm, are pests of emerging cereal plants (except oats). They have one generation each year. Adult moths emerge between March and May and eggs are laid within four days of emergence. Incubation time varies from six to 30 days depending on temperature. Webworm are in the larval stage for ten to 11 months of the year and in the final stages of larval development become dormant, in late September to early October. Before entering dormancy, a larva will deepen its web-lined tunnel to 3 to 12 cm and spin a heavily webbed cap over the tunnel entrance. The larva will remain dormant over the summer months and pupate in March or April. Moths emerge three weeks later.

Survival can be enhanced over summer if moderate rains replenish body moisture, especially when conditions have been particularly hot. The dormant larvae are not prone to drowning in their tunnels. However, the larvae are prone to fungal infections and high levels of mortality can occur if the rainfall is prolonged. Survival of eggs and larvae emerging in autumn is enhanced if late summer rain has produced a dense grass cover over the paddock. The response of webworm to summer rain is variable and depends primarily on both its timing and the amount that falls but will also be influenced by temperature, the capacity of the soil to hold moisture and the vegetative cover.

Example 3 - Native budworm

The native budworm (NBW), *Helicoverpa punctigera*, is a major pest of lupins, pulses and canola. Moths fly into crops and lay eggs in late winter and early spring. The larvae feed on leaves and fruiting bodies and complete their development just prior to harvest. They pupate in the ground at the base of plants and most emerge as moths two weeks later. Given that conditions are usually dry at this time, female moths will not mature but will disperse, sometimes over very large distances. NBW populations contract to the south over summer and numbers are greatly diminished. The reappearance of moths in crops in late winter appears to be the result of successful breeding in autumn and early winter in pastoral regions and a migration of moths into the Wheatbelt.

The summer of 1991/92 gives an example how an unusually wet summer in the Wheatbelt impacts on NBW. A major outbreak of NBW occurred in the 1991 growing season and despite extensive spraying by farmers, extremely large numbers of moths were produced in October and November 1991. Extensive rainfall over most of the Wheatbelt from October 1991 to March 1992 (8-10 decile) resulted in continued breeding in the region and a very much larger than usual population of NBW in March. These NBW would have been able to enter a pupal diapause and remain under the ground until late winter when they would have emerged as moths and infested crops. However, moth production in late winter and early spring of 1992 was the lowest over 10 years of recording. A drought had occurred over autumn and winter in the pastoral regions, thought to be the origin of most NBW moths that infest crops in the Wheatbelt during late winter and early spring. Continued development and reproduction of NBW in the Wheatbelt over summer resulting from high rainfalls that were frequent and extensive had little influence on the number of NBW occurring in the subsequent season.

MANAGEMENT TECHNIQUES

Regular surveillance is the key to the management of most insect pests. If summer rain produces out of season weeds and crop volunteers just prior to seeding, these paddocks should be surveyed for the presence of pest species. Paddocks can be surveyed by close inspection of plants, the use of a sweep-net to collect any insects present, and by removing the surface layer of soil for observation of subterranean species.

If large infestations of insects that pose a potential threat to the planned crop are found in summer or autumn up to a month prior to expected seeding date, the destruction of their habitat may be considered. However, summer populations may not carry over into the growing season if conditions deteriorate. If large infestations are found around the time of seeding, an insecticide treatment can be applied very economically along with herbicides.

When considering management techniques for insect pests that may take advantage of summer rain, each situation and species must be taken on its merits. The pest obviously must be one that can take advantage of summer rain and the method of destroying its habitat (herbicides, cultivation, burning or grazing) must be compatible with other farming practices. There would be very few cases where the implementation of such management practices could be justified solely on the pretext of minimising the subsequent impact of an insect pest. Controlling summer weeds is likely to reduce numbers of insect pests such as webworm, lucerne flea, mites, slugs and beetle larvae.

Special thanks to Josslyn Else for her assistance with this paper

Paper reviewed by: Mark Sweetingham

Lupin anthracnose - seed infection thresholds

Geoff Thomas, Agriculture Western Australia

KEY MESSAGES

- Despite low levels of anthracnose in 2000, seed infection can still occur, infecting 2001 crops.
- Seed should be tested for anthracnose levels before sowing and test results compared with maximum seed infection threshold.
- Maximum seed infection thresholds are updated annually as new trial results become available.

METHODS

Trials were established at Mullewa and Badgingarra to assess effects of seed infection levels on anthracnose severity and yield loss. At Badgingarra only Wonga lupins were used, as more susceptible varieties are not recommended in high rainfall zones. At Mullewa comparisons were made of the effect of 4 levels of seed infection on Wonga and Myallie lupins.

Another trial at Mullewa assessed the relative effect of anthracnose on yield of a range of varieties. Yields from fungicide sprayed plots (five fungicide applications through season) were compared with yields from anthracnose infected plots (1% seed infection) to assess relative effects of anthracnose.

The results from these trials are combined with results from previous year's trials to create a maximum seed infection threshold table.

RESULTS

At Mullewa, low to moderate levels of anthracnose infection occurred in both trials. There appears to be a downward trend in yields with increasing seed infection sown, particularly in Myallie (Table 1), although it was not statistically significant. In Myallie, increasing seed infection increased anthracnose severity, however the ability of the plant to compensate and increase seed weight reduced the effect on yield. Seed infection was not detected in the harvested Wonga seed, however significant levels of infection were found in Myallie seed from the two most infected treatments.

In the variety yield loss trial, significant yield losses occurred in the more susceptible varieties Quilinock, Myallie and Belara whereas no yield loss occurred in Kalya and Tanjil (Table 2).

Table 1. Yield of Wonga and Myallie lupins sown with three rates of seed infection at Mullewa

Variety	% Seed infection sown	Yield (t/ha)	% Infection harvested seed
Wonga	Nil	2.43	0.0
	0.08	2.43	0.0
	0.4	2.33	0.0
	2	2.29	0.0
Myallie	Nil	2.23	0.0
	0.08	2.24	0.0
	0.4	2.07	0.3
	2	1.93	0.8
lsd		ns	0.3

Table 2. Effect of anthracnose (1% seed infection) on yield of lupin varieties grown at Mullewa

Variety	Yield (t/ha)		
	Sprayed	Infected	% Yield loss
Quilinock	2.78	2.14	23
Myallie	2.63	2.26	14
Belara	3.00	2.62	13
Gungurru	2.59	2.36	9
Kalya	2.63	2.61	1
Tanjil	2.70	2.74	-
lsd	0.36		

At Badgingarra, seasonal conditions were favourable for anthracnose development and moderate amounts of disease built up in plots with high levels of seed infection. The number of pods produced in infected plots was significantly reduced, however the ability of the plant to compensate and increase seed weight in the remaining pods reduces the effect on yield. There is a significant linear trend of reduced yield with increasing seed infection; yield from 1% infected seed is significantly lower than from uninfected seed.

Table 3. Yield of Wonga lupins sown with five rates of seed infection at Badgingarra

Variety	% Seed infection sown	Yield (t/ha)	% Infection harvested seed
Wonga	Nil	3.52	0.0
	0.06	3.54	0.2
	0.12	3.41	0.2
	0.25	3.34	0.4
	0.5	3.32	0.4
	1.0	3.15	0.4
lsd		0.36	0.3

MAXIMUM SEED INFECTION THRESHOLD TABLE

Seed with less than the infection level shown in Table 4, sown in the specified rainfall zone, should suffer less than 5% yield loss due to anthracnose in a typical season. *This assumes no spread from infected lupin regrowth or infected stands of blue lupins.*

Table 4. Maximum seed infection levels for different lupin varieties, sown in different rainfall zones in Western Australia

Variety	*Relative anthracnose resistance*	High rainfall*	Medium rainfall*	Low rainfall*
Tanjil, Wonga	*Resistant*	0.2%	0.5%	1.0%
Kalya	*Moderately resistant*	0.05%	0.1%	1.0%
Belara, Gungurru, Merrit,	*Moderately susceptible*	0.01%	0.05%	0.5%
Myallie, Tallerack, Quilinock	*Susceptible*	Nil	0.02%	0.2%
Wodjil	*Very susceptible*	Nil	0.01%	0.05%
Kiev Mutant	*Extremely susceptible*	Nil	Nil	0.02%

* High rainfall zone (> 450 mm), Medium rainfall zone (450-325 mm), Low rainfall zone (< 325 mm).

- Thiram seed dressing is recommended for use on all lupin seed and will provide additional benefit by reducing anthracnose transmission from infected seed, therefore reducing yield loss.
- These seed infection thresholds are derived from trials performed by Agriculture Western Australia, using Western Australian varieties and carried out in Western Australia.

CONCLUSIONS

- All varieties are susceptible to yield loss from anthracnose (e.g. resistant varieties in higher rainfall).
- Yield loss can occur in all climatic zones (e.g. susceptible varieties with high seed infection in lower rainfall).
- Variety resistance, rainfall zone and the level of infection in seed affect anthracnose severity and subsequent yield loss.
- Anthracnose infection not causing significant yield loss can produce significantly infected seed.
- Seed should be tested for anthracnose levels before sowing and test results compared with maximum seed infection thresholds, which are updated annually with new trial results.
- Thiram seed dressing is recommended for use on all lupin seed and will provide additional benefit by reducing anthracnose transmission from infected seed, therefore reducing yield loss.

ACKNOWLEDGMENTS

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Paper reviewed by: Mark Sweetingham

Identification and characterisation of resistance genes to Phomopsis blight in narrow-leafed lupin

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KEY MESSAGE

Resistance to Phomopsis stem blight in narrow-leafed lupin is controlled by two dominant genes, one in the very resistant breeding line 75A:258 (*Phr1*) and the other in cultivars Gungurru and Merrit (*Phr2*). Crosses between 75A:258 and Merrit resulted in some progeny with higher resistance than 75A:258. We hypothesise that gene modifiers are responsible for the range of resistance observed in the progeny of this cross. *Phr1* and *Phr2* were not linked to late flowering in 75A:258. This result is promising for breeders who wish to increase resistance to Phomopsis stem blight in commercial varieties.

AIMS

Studies were conducted to determine the inheritance of resistance to latent stem infection by Diaporthe toxica in F_1, F_2 and F_3 progeny of three crosses of narrow-leafed lupin (*Lupinus angustifolius*) involving very resistant (75A:258), resistant (Merrit) and susceptible (Unicrop) lines. In order to achieve this, we developed a non-destructive microscopical test for resistance.

METHOD

Crosses in all combinations were made between *L. angustifolius* cv. Unicrop (susceptible, early flowering), cv. Merrit (resistant, early flowering) and breeding line 75A:258 (very resistant, late flowering). F_1, F_2 and F_3 plants were assessed for resistance non-destructively as described below.

Non-destructive assessment of resistance

Young seedlings were excised above the 2nd leaf node and allowed to regenerate till the appearance of the first internodes of the two lateral branches. One of the branches was maintained for seed production while the internode of the other branch was inoculated with a spore suspension (10^7 mL^{-1}) of *D. toxica* and used for microscopic assessment. Inoculated stem pieces were frozen for later microscopical examination.

The epidermal layer of each thawed internode was peeled and assessed microscopically for the presence of coralloid hyphae (infection structures).

Table 1. Resistance categories in *Lupinus angustifolius* based on percentage and size of coralloid hyphae

Resistance ranking	Length category of coralloid hyphae				
	Category I (< 10 μm)	**Category II (10-25 μm)**	**Category III (25-50 μm)**	**Category IV (50-100 μm)**	**Category V (> 100 μm)**
	Percentage of coralloid hyphae per peel -				
Extremely resistant (ER)	>40	21-40	0	0	0
Very resistant (VR)	21-40	>40	0-5	0	0
Resistant (R)	6-20	>40	21-40	0-5	0-5
Moderately resistant (MR)	0-5	21-40	21-40	21-40	0-5
Susceptible (S)	0	0-5	6-20	21-40	>40

Latent infection structures (coralloid hyphae) were classified on the basis of length into five groups, viz., <10 μm, 10-25 μm, 25-50 μm, 50-100 μm and >100 μm (Table 1). Resistance categories could be consistently separated on the basis of number of coralloid hyphae in each group. Reduction in resistance was associated with the increase in the number of larger coralloid hyphae.

RESULTS AND DISCUSSION

Cross 75A:258 × Unicrop: The F_1 progeny were very resistant, suggesting that the resistance gene(s) in 75A:258 was dominant. The F_2 progeny (188 plants) segregated into four phenotypic groups: 62 VR, 30 R, 48 MR and 48 S (Table 2). After combining the VR, R and MR types, genetic analysis supported a segregation ratio of 3:1 ($\chi 2 = 0.03$, $P = 0.87$) for a single dominant gene (*Phr1*) in 75A:258 (Table 2). Selfed parent seed of line 75A:258 was uniformly VR and of Unicrop was uniformly S.

Cross Merrit × Unicrop: The F1 progeny were moderately resistant, and the F2 progeny segregated into three phenotypic groups; 46 R:97 MR:45 S, which fitted a ratio of 3:1 ($\chi 2 = 0.11$, $P = 0.74$) and supports the single dominant gene (Phr2) hypothesis (Table 2).

Cross 75A:258 × Merrit: The F1 progeny were very resistant, suggesting that the Phr1 gene in 75A:258 is dominant and epistatic to the Phr2 gene in Merrit in the F1. The F2 progeny segregated in a ratio of 13 ER, 108 VR, 24 R, 24 MR and 12 S (Table 2). After combining the ER, VR, R and MR types, the data fitted a ratio of 15:1 ($\chi 2 = 0.05$, $P = 0.83$) (Table 2), supporting the hypothesis that there were two genes for resistance segregating in this cross, one from each parent. The extremely resistant plants appeared to have higher resistance than 75A:258 (most coralloid hyphae in the < 10 μm category).

Table 2. Genetic analysis of phomopsis resistance in lines of *Lupinus angustifolius*

Cross	F_1 reaction	Grouping of F_2 plants		Expected ratio	χ^2 value	*P* value
		Resistant	Susceptible			
75A:258 × Unicrop (VR × S)	VR	140 (62VR+30R+48MR)	48	3:1	0.03	0.87
Merrit × Unicrop (R × S)	MR	143 (46R+97MR)	45	3:1	0.11	0.74
75A:258 × Merrit (VR × R)	VR	169 (13ER+108VR+24R+24MR)	12	15:1	0.05	0.83

ER = Extremely resistant; VR = Very resistant; R = Resistant; MR = Moderately resistant; S = Susceptible.

F3 families: Twenty-one F3 families (15 to 45 plants per family) of the cross 75A:258 × Unicrop were assessed microscopically. All the susceptible families tested were found to be uniformly susceptible. The very resistant families were either uniformly resistant or segregating for resistance and susceptibility, confirming that heterozygotes will be difficult to distinguish in this cross. The resistant and moderately resistant families were all segregating for resistance and susceptibility.

Four extremely resistant and four susceptible families of cross 75A:258 × Merrit were assessed. Two of the extremely resistant families were found to be uniformly ER or VR. Two other families segregated for various levels of resistance but did not have S progeny. All the susceptible families were uniformly susceptible confirming the presence of different genes in Merrit and 75A:258.

CONCLUSION

The identification of two dominant genes for resistance, which are not linked to late flowering, provides a good opportunity for direct transfer of resistance genes by traditional breeding to early flowering genotypes. The evidence suggests that *Phr1* is subject to gene modification, which may permit the selection of extremely high resistance in future commercial varieties. Furthermore, varieties carrying more than one resistance gene (combining *Phr1* and *Phr2*) will offer greater prospects of durability.

KEY WORDS

Lupinus angustifolius, *Diaporthe toxica*, Phomopsis stem blight, resistance genes

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Paper reviewed by: B.J. Buirchell

Pulse disease diagnostics

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In July 1998, a broadacre diagnostic service for the grain growers of Western Australia commenced as a section of *AGWEST* Plant Laboratories. This service was set up in response to the increasing demand for disease diagnostic services due to the dramatic expansion in cropping activity in recent years and a greater awareness of disease through the increased use of private agronomists by growers and the TOPCROP initiative.

The diagnostic service is a valuable tool for sustaining productive crop industries in Western Australia. Growers are able to respond appropriately to significant disease constraints, and the service prevents the over reaction to minor or perceived disease threats.

Each year, the service has received an increasing number of samples and a positive response from clients towards the service. Even with the introduction of a fee-for-service in July 1999, demand remained high with a total of 876 samples being received during the growing season. This year (2000) a lower number of samples (550) were received, due to the late start in the season and the dry conditions that followed. Of these, 17% were pulse and oilseed crops. The break down by host; was: Canola 24%, Chickpea 24%, Lupin 41%, Peas, 5%, Faba beans 6%.

The most common diseases diagnosed by host were:

Lupins

Because of the unusual growing conditions there were samples submitted that had either physiological damage or a nutrient deficiency causing symptoms similar to Brown Spot. Brown spot was diagnosed from the North Central and North agricultural zones with also some samples from the Esperance district.

Several samples were seen with onion thrip (*Thrip tabaci*) damage this year. The damage on the plants looked similar to a virus. The older leaves tended to curl upwards and look a bit leathery. The younger shoots were slightly twisted and in general looking very malformed. It is not likely to be a major problem in the future, as it will probably on persist if a green bridge occurs over the summer months and winter is mild.

The amount of anthracnose infection in crops was a lot less this year due to the dry conditions. This in turn reduced the amount of pod infection in the crops and therefore less seed was infected with anthracnose. At present 89 seed samples have been submitted for anthracnose testing using the new quantitative PCR based detection method. Anthracnose was not detected in the majority of the seed samples submitted.

Other pulses

Ascochyta blight was detected for the first time in the Narrogin and Esperance districts this year in chickpea crops. At present 11 seed samples have been submitted for ascochyta testing. Over 60% of the samples had a high infection present and all the samples submitted are from the North Central agricultural zone.

As it was a dry season very little botrytis grey mould has been detected on the seed samples submitted.

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Paper reviewed by: Mark Sweetingham

Detection of strains of Phomopsis exhibiting species preference in lupins

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KEY MESSAGE

The Phomopsis pathogen (*Diaporthe toxica*) exists as strains which vary in their relative virulence towards narrow-leafed, yellow, albus and rough-seeded lupins. Screening for Phomopsis resistance in yellow, albus and rough-seeded lupins will have to be done using appropriate strains. Of some concern is the yellow lupin strain which is common in wild stands of bitter yellow lupins in some high rainfall regions. While the yellow lupin cv. Wodjil is quite resistant to the narrow-leafed lupin strain of *Phomopsis*, it is very susceptible to the yellow lupin strain. No resistance is currently known in *L. luteus* to this strain. This strain has recently been discovered on two yellow lupin populations (one wild and one commercial) in the central wheatbelt of WA. A survey of wild and commercial populations of yellow lupins is being conducted throughout the State to monitor the spread of this strain and provide advance warning of lupinosis risk to yellow lupin growers.

AIMS

To investigate variation in virulence of Phomopsis isolates on lupin species across Australia and determine their host preference.

METHOD

Microscopic assessment of virulence of Phomopsis *isolates on* L. angustifolius

One hundred and fifty isolates of *Phomopsis* were collected from different lupin species and different geographic regions around Australia and were assessed for relative virulence microscopically on cv. Yandee of *L. angustifolius*. Plants were inoculated 21 days after sowing with a conidial suspension (10^7 mL^{-1}) of *D. toxica* (isolate WAC 8771). The inoculum was applied to the cotyledonary internode of the main stem. Twenty-one days after inoculation, the cotyledonary internode was excised and frozen for 12 h. The epidermal layer was peeled from the entire circumference of stems, cleared with 3% KOH and stained with lactoglycerol cotton blue (aniline blue, 0.02 g; glycerol 20 mL; lactic acid, 10 mL; distilled water, 10 mL). Stained epidermal peels were viewed under a light microscope. Latent infection structures (coralloid hyphae) greater than 10 µm in length were counted per square centimetre of epidermal tissue. Relative virulence was classified into three main types, viz., high (many large coralloid hyphae) (100-600 µm), moderate (mixture of large and small coralloid hyphae) and low (many small coralloid hyphae) (<100 µm).

Assessment of virulence of Phomopsis *isolates on various lupin species*

Sixty-nine selected isolates were assessed for virulence on various lupin species both in the field and glasshouse by tests involving inoculation of young plants and observation of symptom development on senescing tissues. A disease rating scale of 0 to 5 was used. An average rating of 3.5-5 was classified as high virulence, a rating of 2-3.4 as moderate virulence and a rating of < 2 as low virulence.

RESULTS

Microscopic assessment of virulence of various isolates of *Phomopsis* on susceptible cultivar Yandee of *Lupinus angustifolius* showed that isolates varied widely in relative virulence. The classical high virulence was observed mostly among isolates originating from *L. angustifolius*. Isolates originating from other lupin species showed moderate or low virulence on *L. angustifolius*.

Field and glasshouse tests for virulence of selected isolates showed that high relative virulence tended to be expressed by isolates on the host species from which they were isolated. This was especially true for isolates of *Phomopsis* from mono-specific stands of wild lupins. Isolates could be classified as four strains based on the relative virulence on all four lupin species.

The most widespread angustifolius strain (A) was present across all regions and is highly virulent on susceptible cultivars of narrow-leafed lupin such as Yandee, but weakly virulent on yellow lupin. By contrast the luteus strain (L) was only found in wild mono-specific populations of yellow lupin in high rainfall areas of Western Australia and is highly virulent on yellow lupin and less virulent on the other lupin species. The L strain was also discovered on two yellow lupin populations (one wild and one commercial) in the central wheatbelt of WA. No resistance is known in *L. luteus* to the L strain. It can be distinguished from strain A by RAPD-PCR analysis.

The rough-seeded lupin strain (C) is prevalent in pasture and roadside *L. cosentinii* populations of Western Australia and is highly virulent on this species and on *L. atlanticus*, *L. pilosis* and *L. digitatus*. The albus strain (B) was obtained from a few albus crops in Western Australia and SA but was only moderately virulent on most cultivars of this species.

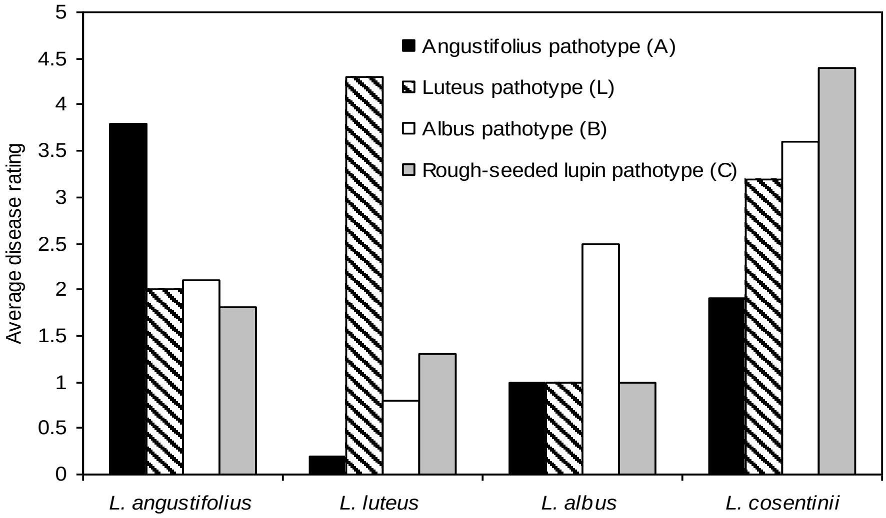

Figure. Average virulence of *Phomopsis* strains on different lupin species.

The angustifolius (A), rough-seeded lupin (C) and luteus (L) strains produced highly virulent reactions on their specific hosts while the albus (B) strain was only moderately virulent on *L. albus* (Figure). *L. cosentinii* showed variable reaction to strains A, B and L but was preferentially susceptible to its specific strain C.

CONCLUSIONS

The variation in the Phomopsis pathogen in response to different lupin species probably arises where the pathogen has co-existed with a wild population, allowing local adaptation to build up in relative isolation. There may be benefit realised by confronting the pathogen population with different host genotypes simultaneously or in rotation, thereby, slowing down the process of adaptation and the establishment of highly aggressive strains.

Of some concern is the yellow lupin strain which may eventually spread throughout the wheat belt with time as the spores of this fungus can disperse to long distances. A survey of all yellow lupins is being conducted throughout the State to monitor the spread of the strain. In the meantime some extra vigilance of sheep grazing yellow lupin stubbles is advisable. The yellow lupin breeding program at AGWEST will work to improve resistance in new varieties to the yellow lupin strain whilst maintaining resistance to the widespread narrow-leafed lupin strain. It is important to note that the yellow lupin strain does not pose an increased risk to narrow-leafed lupins.

KEY WORDS

phomopsis stem blight, variation in virulence, host preference, yellow lupin strain

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Potential alternate hosts for the lupin anthracnose pathogen

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SUMMARY

- Of 16 grain, pasture and tree legume species tested, only tagasaste, lotus and sweet pea showed symptoms of infection by lupin anthracnose under ideal glasshouse conditions for infection.
- Anthracnose caused minor stem and leaf lesions on tagasaste, lotus and sweet pea.
- In the field, tagasaste and lotus growing in close proximity to infected blue lupins have become mildly infected with lupin anthracnose.
- Nether tagasaste nor lotus should be considered as significant alternate hosts for lupin anthracnose.

BACKGROUND

Lupin anthracnose is carried over between seasons primarily by infected seed and to a limited extent on infected lupin stubble (particularly standing blue lupins). Western Australia's agricultural regions carry large areas of other grain, pasture and tree legumes species which if susceptible to anthracnose infection (particularly if very susceptible) may also maintain and spread the disease. A series of glasshouse tests were established to identify the host range of lupin anthracnose and isolations made from infected plants in the field.

RESULTS

Glasshouse testing

Using a lupin anthracnose strain isolated from lupins in Western Australia a range of grain, pasture and tree legumes were tested for susceptibility to lupin anthracnose in 1996 and 2000. All plants were artificially inoculated with anthracnose spores and incubated in conditions conducive to anthracnose development. Of the 16 species tested only sweet pea (*Lathyrus odoratus)*, lotus (*Lotus pershiana*) and tagasaste (*Chamaecytisus proliferus*) developed any anthracnose infection. The severity of infection and spore production on lesions was far less than in narrow leafed (cv. Belara) and blue lupins inoculated at the same time. Lesions on sweet pea, tagasaste and lotus did not kill either the whole plant or even the stem on which the lesion occurred.

The legume species tested which were not affected by anthracnose were Lucerne (*Medicago sativa*), Field pea (*Pisum sativum*), Faba bean (*Vicia faba*), Chick pea (*Cicer arietinum*), Sub. clover (*Trifolium subterraneum)*, Serradella (*Ornithopus compressus*), Pink serradella (*Ornithopus sativus*), Lathyrus (*Lathyrus sativus)*, Vetch (*Vicia sativa*), Lentil (*Lens culinaris*), Sub. clover (*Trifolium subterraneum*), Biserulla (*Biserrula pelecinus*), Crotalaria (*Crotalaria novae-hollandiae*) and Cassia (*Cassia artemisioide).*

Field isolations

In 2000, lupin anthracnose was isolated from Lotus at Medina Research Station and from Tagasate at Dongara. The source of inoculum was highly infected blue lupins directly adjacent to both sites.

Anthracnose was isolated from small stem and leaf lesions from several lotus varieties growing 2-10 metres from infected blue lupins. These infected plants were able to continue to grow and showed very few negative effects from the anthracnose infection, when observed 6 weeks later. DNA testing of the fungus isolated showed that it was identical to lupin anthracnose and glasshouse inoculations confirmed that it could mildly re-infect lotus plants and also infect narrow leaf lupin plants.

In June of 2000 anthracnose was isolated from stem and leaf lesions on tagasaste plants growing amongst a heavily infected stand of blue lupins. By October 2000, the tagasaste plants were growing strongly and very little infection was found, despite significant levels of infection in surrounding blue lupins. DNA testing of the fungus isolated showed that it was identical to lupin anthracnose and glasshouse inoculations confirmed that it could mildly re-infect tagasaste plants and also infect narrow leaf and blue lupin plants.

CONCLUSIONS

- *Colletotrichum gloeosporioides*, which causes lupin anthracnose, can infect sweet pea, tagasaste and lotus under ideal conditions.
- Anthracnose infection severity and spore production in sweet pea, tagasaste and lotus is far lower than in lupins.
- Lupin anthracnose poses no significant risk to Tagasaste or Lotus producers.
- Neither tagasaste nor lotus are considered a significant threat as an alternate host for lupin anthracnose in the Western Australian agricultural region.

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Paper reviewed by: Bill O'Neill

Wild radish - the implications for our rotations

Dr David Bowran, Centre for Cropping Systems, Northam

INTRODUCTION

Wild radish remains one of the most severe weed problems in cropping systems in Western Australia. There appears to be a general trend towards increasing amounts of the weed in northern agricultural regions. Many farmers in southern regions are now experiencing the problem. In addition the increasing levels of resistance to many common and cheap herbicides will pose very real problems for its management into the future.

Despite this there are still many effective control measures available for the weed. It is the process of placing these measures into biologically and economically realistic systems that is probably the greatest challenge.

COMPONENTS

For IWM to be successful a good understanding of the weed and its possible control measures is necessary. However the real value of any program will lie in the ability to place it in context - that is within the context of management of all weeds within the system and in an economical manner. Various parts of the system require careful attention if this is to be achieved.

Understand the weed

Wild radish has characteristics in common with many weeds that lead to its successful growth in our farming systems.

It has substantial plasticity in response to its environment, especially in regard to seed production. The characteristics of its seed pods ensure that even after 5 years viable seed can still be present in most soils, and in non-wetting soils where biological degradation is minimised, carryover is likely to be very significant.

Seed pods are readily shed at maturity ensuring minimal harvest capture, yet harvested pods are light enough to ensure that when harvested with large seeded crops most pods are returned to the paddock from the harvest operation.

When germinating early in autumn seeds may be set in as little as 60 days. Radish is quite drought tolerant and appears able to produce seeds under severe competition from other species. Being an outcrossing species it can recombine genes quickly to ensure the next generation is better adapted. As with many weeds herbicide resistance can occur quickly with some groups of herbicides such as the ALS inhibitors (Group B herbicides).

Understand the management practices

The majority of management practices for effective control of wild radish are similar to those used for control of most other weeds. In continuous cropping selective herbicides remain the primary method of control. Most selective herbicides can achieve 95% control if used at rates and under conditions favourable to a particular herbicide. Problems arise when reduced rates are used under less than optimal conditions, and poorer control is achieved. The crop into which the herbicide is used can also play a significant role. Lupins are largely sown dry, ensuring the pre-emergent triazines have reduced efficacy, while if non-wetting soil is present much of the herbicide may be unavailable to the weed.

The extent to which herbicide groups can be used will be largely determined by use of the other groups in an alternative phase of the rotation. Therefore where simazine or atrazine are used in lupins the strictest interpretation of the guidelines would suggest that no diuron, bromoxynil or terbutryn be used in the cereal. If Brodal is used in lupins, then no Tigrex or Jaguar be used in cereal. Were Eclipse to be used on flowering radish in lupins then in theory no sulphonyl urea herbicide should be used in wheat.

However the system nearly always has more than one weed and particular herbicides may be desirable to remove some weeds. Thus sulfonylureas provide good doublegee control, and to remove them from the system would require an effective alternative (e.g. dicamba, either alone or in mixture). It must also be borne in mind that a weed like wild radish shows numerous germinations in one season and early applications for yield response may result in sufficient later germinations to re-build the seed bank for future years. Consequently herbicide based management systems may become extremely difficult to use once resistance to one or more groups is present on a farm.

Other management practices are available which can be extremely useful. Pasture combined with spray-grazing, hay or silage making, green (brown) manuring or fallowing should all be able to reduce seed set by 100% in a particular year. Seed catching should provide some level of control in early harvested crops, while crop-topping with non-selective herbicides can be effective in minimising seed set in crop. Reduced disturbance seeding systems may reduce plant establishment but require other measures for good control to be achieved. Cultivation will effectively control small germinated wild radish, though disturbance may provoke additional germinations to occur within crop.

Design the rotation - use as many control options as possible

Improving system design to ensure weed management is optimised would seem a desirable path to adopt. However any change to the current system will have both costs and benefits, and achieving a better-balanced system may not always be possible. Any new system which is advocated, if widely adopted, may lead to broader economic impacts which reduce overall gross returns, e.g. every farmer cutting hay to sell on the local market. Rotation design should also aim to ensure optimal pest management, nutrient flows, soil management, water use efficiency and effective management of other weeds in the system. Getting the system balanced so effective management of a particular weed is maximised, while the rest of the system is still optimal is not as easy as it seems!

- **Aim to reduce the seedbank inputs to zero in at least two consecutive years - 3 or 4 is better still**

If in an ideal world herbicides were able to control 100% of a weed population in a paddock in every year, with no resistance evolving, seedbank inputs would become zero! The fact that weeds haven't disappeared from continuous crops implies we can't achieve this goal.

It is necessary to effectively lower seed numbers returning to the seedbank if competition in future crops is to be minimised. This is particularly important for longer-lived seedbanks. Even having 5% of a seed rain still present (in the seedbank) after 5 years will be sufficient to cause problems. Achieving 2 years of zero input while maintaining economic viability on a paddock is difficult, so whole systems approaches become necessary.

It is important to be aware that seed is being set. While the weed may not be flowering visibly above the crop, seed set can and does occur within crops. This has important ramifications in achieving multiple years with no seed set. Radish plants germinating following summer rain can contribute large quantities of seed to the seedbank. This is often seed that has high levels of dormancy.

- **Once weed numbers are low keep them low**

This is much easier said than done. Yet the tools are generally available but do come at a cost. In most cases herbicides are required and the tradeoffs between higher rates under low weed burdens and very high levels of seed set control, versus reduced input costs but longer-term higher weed burdens have to be carefully considered.

- **Calculate rotational gross margins - use models**

Modelling is by far the common sense way to look at new systems of weed management. As models such as RIM are provided, sufficient flexibility for real time analysis then becomes easier. Single year gross margins can never truly capture the true returns of different practices. What looks expensive in a given year (e.g. sacrificing of a crop) can have long term benefits and payoffs that will never be captured by a single year calculation.

DOES THE SYSTEM MAKE SENSE

The lupin-wheat rotation classically builds up radish numbers very quickly, with evidence from both farmers and trials supporting this view. In contrast rotations which include significant amounts of well-grazed pasture have little build up and may decline in radish numbers. A balance between these two systems which allows grain legumes to be effectively grown would be ideal.

Table 1 illustrates the effects of different rotations on relative wild radish buildup after 8-10 years (2-4 cycles) of a number of rotations using a spreadsheet model in which the following parameters were used:

- Seedbank germination - 33% yr 1, 20% yr 2, 7% yr 3 and 3% yr 4 with 37% of the total seedbank being lost to other factors.
- A herbicide efficacy of 90% in lupins or grain legume, 95% in cereal and 100% in spray grazed pasture.
- Seed production ratio for wild radish for lupin against wheat of 2:1.

Table 1. Relative change in wild radish seedbank with different rotations

Rotation sequence	Relative radish seedbank compared to start
L :W (4 cycles)	159
L : W : W (3 cycles)	23
L : W :C : W (2 cycles)	10
L : W : GM : W (2 cycles)	2
L : P : W : W (2 cycles)	0.6
L : P : P : W : W (2 cycles)	0.14
P : W : W (3 cycles)	0.05
P : P : W : W (2 cycles)	0.01

L = lupin, W = wheat, C = canola, GM = green manure lupin, P = sown pasture.

The classic lupin-wheat rotation shows high levels of enrichment of the seedbank, and even if we start with low seed numbers in the seedbank we should anticipate that system failure should occur given the levels of control and seed production indicated. Reducing the amount of lupins in the rotation reduces radish buildup, and a single break year of no seed set has dramatic effects on the enrichment process. Increasing the level of cereal also has an impact due to higher competitiveness and generally better weed control from herbicides. The use of single pasture years with 100% control has the ability to reduce radish buildup and appears to run seedbanks down. It is important to note that two of the pasture containing rotations which contain lupins have relative seedbank changes of less than 1.0.

By taking two of these rotations and changing the parameters of seedbank characteristics, efficacy of herbicides or seed set it is possible to test the robustness of the system. The effects of these changes are shown in Table 2.

In the rotation in which a single year of break is used (LWGMW) changing germination patterns to either more germinating in the first year after seed production, or delaying the germination of the seedbank as might occur with non-wetting soil increase the radish buildup. The two year pasture rotation is more effectively buffered against such changes in germination patterns. The effect of changes in herbicide efficacy in lupins are significant and should be carefully considered. In drier seasons efficacy of 80% may just be achievable, while in high rainfall years the 95% is possible. The use of reduced rates of herbicides combined with dry seasons may have led to the increases in wild radish in the northern wheatbelt.

Reduced efficacy in lupins has a strong effect in the rotation with the pasture phase also showing increases in wild radish - the combination of reduced efficacy with non-wetting soils could make this rotation have a net increase in radish. The effect of delaying germination of wild radish by 20% so that higher seed production were to occur later in the crop is consistent with the view that later emerging weeds have less impact on seedbank return. The most dramatic effect is with reducing seed input at harvest by 50%. Even in the non-pasture rotation it becomes possible to contemplate long term reductions in the seedbank.

Some of the rotations presented represent a series of possible solutions to wild radish management but they are by no means the only solutions. The use of mechanical methods of control such as with hay cutting and silage making should also be considered, and are likely to be of increasing importance where high value crops such as chickpea and lentils are considered.

The stability of rotations must be considered from both biological and economic viewpoints. The lupin:wheat rotation has been extremely profitable for much of the northern wheatbelt and to dramatically alter such a rotation will require excellent alternative solutions

Table 2. Effect of changing biological and control parameters on relative wild radish seedbank

Parameter	LWGMW (2 cycles)	LPPWW (2 cycles)
As above	2	0.14
Change germination pattern (50,20,10,3)	5.5	0.6
Change germination pattern (25,25,15,10)	4	0.6
95% herbicide efficacy lupins	0.6	0.14
80% herbicide efficacy lupins	7.3	1
Delay germination of 20% radish in lupins	2.8	0.19
50% reduction in radish seed set both crops	0.1	0.01

CONCLUSION

Wild radish poses a significant threat to cropping rotations, with the lupin-wheat rotation particularly at risk from both weed increase and herbicide resistance. Management practices which reduce this threat such as longer term breaks without seed set, improved herbicide efficacy and improved seed set control can all contribute to reducing the threat but will come at a cost. The longer-term challenge is to manage wild radish within the perspective of all weeds in the system and for maximum economic return.

Competitiveness of wild radish in a wheat - lupin rotation

Abul Hashem, Nerys Wilkins, and **Terry Piper**, Agriculture Western Australia

KEY MESSAGE

- Wild radish is highly competitive to wheat and lupins.
- Presence of 10-75 radish plants/m^2 at the reproductive stage of crops can reduce wheat yield by 7-56% and lupin yield by 28-92%.
- Competition from radish not only reduces yield but also increases wheat screening.

BACKGROUND

Wild radish is one of the most competitive weeds in cereal, legumes, and oilseed crops in WA. The extent of yield loss in crops due to competition from radish has not yet been quantified.

AIM

The aim of this study was to quantify the yield loss in crops due to competition from radish.

Additional aspects of this study are reported in this proceeding in the paper titled: *Population explosion and persistence of wild radish in a wheat/lupin rotation.*

METHODS

Wheat-lupin-wheat-lupin rotation trial in Merredin (1997-2000)

In 1997 wheat of this rotation, 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.

For more details on the experimental procedure see the paper titled *Population explosion and persistence of wild radish in a wheat/lupin rotation* also included in this proceedings.

Radish plant density at reproductive stage of wheat or lupins, yields of wheat and lupin, and screening of wheat, were recorded in all treatments in each year. Losses in yields were estimated separately for wheat (1997 and 1999) and lupin (1998 and 2000) by regression analyses.

RESULTS

Competition between radish and crops in Merredin

Wheat yield loss

Competition from radish greatly reduced yields of wheat and lupin in Merredin. Linear regression on the effect of radish density on the yield of wheat in 1997 and 1999 predicted that the presence of 10, 25, 50 and 75 radish plants/m^2 at reproductive stage of wheat, reduced wheat yield by 7, 20, 37 and 56% respectively. These yield losses occurred when compared to an expected maximum yield of 3010 kg/ha in a wheat crop free of radish at the reproductive stage (Figure 1A).

Wheat screenings

Competition from radish not only reduced wheat yield but also increased wheat screenings. Presence of 5, 10, 25, 50, and 75 radish plants/m^2 at the reproductive stage of wheat, increased wheat screening to 3.7, 4.1, 5.3, 7.4, and 9.5% respectively as compared to the 3.2% screening in a wheat crop free of radish at the reproductive stage (Figure 1B).

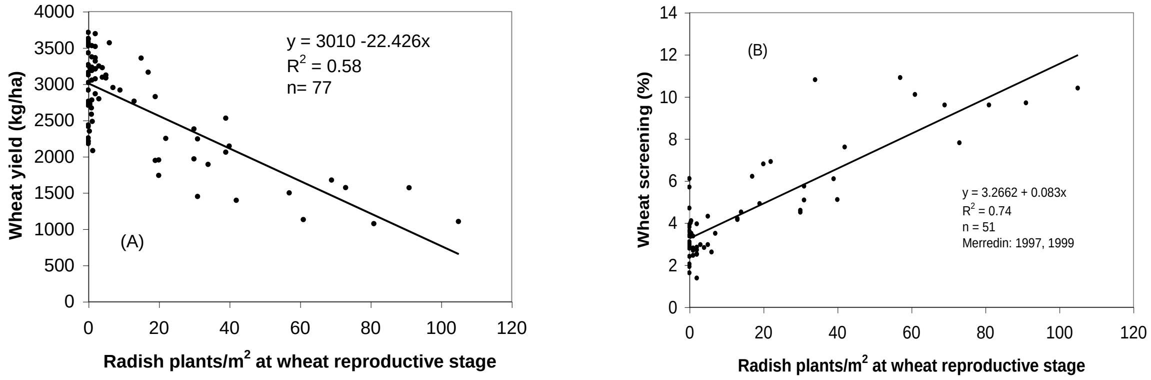


Figure 1. **Regression equation predicting the effect of radish density on (A) wheat yield and (B) wheat screenings in a wheat/lupin rotation, Merredin.**

Lupin yield loss

Presence of 10, 25, 50 and 75 radish plants/m² at the reproductive stage of lupins reduced lupin yield by 28, 56, 81, and 92% respectively. This is compared to the 541 kg/ha produced in a lupin crop with no radish at reproductive stage (Figure 2).

The yield loss data of wheat and lupin clearly established that radish is highly competitive to crops and it is more competitive to lupin than wheat.

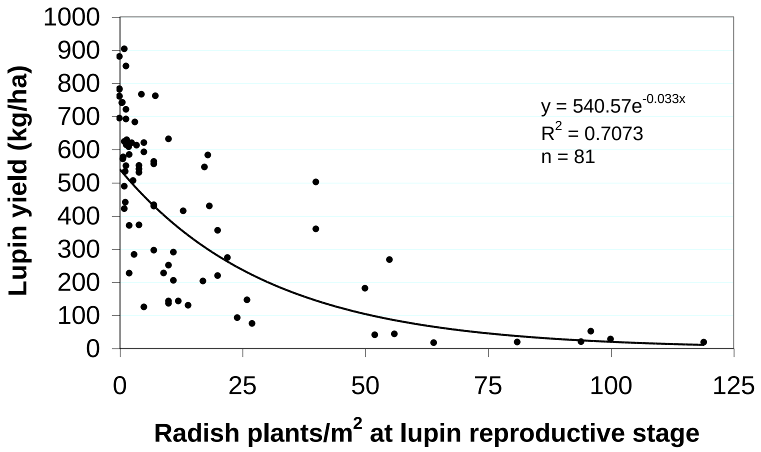


Figure 2. **Regression equation predicting the effect of radish density on the yield of lupin in 1998 and 2000 in a wheat/lupin rotation in Merredin.**

CONCLUSIONS

Yield loss due to competition from radish is much higher in lupins than in wheat. Competition from radish increases percentage of wheat screening.

ACKNOWLEDGEMENTS

We are thankful to GRDC for funding the project.

GRDC Project No.: DAW 535 WR

Paper reviewed by: Ms Vanessa Stewart and Dr Terry Piper

Population explosion and persistence of wild radish in a wheat-lupin rotation

Abul Hashem, Nerys Wilkins, Aik Cheam and **Terry Piper,** Agriculture Western Australia

KEY MESSAGE

- Five successive applications of Group B herbicides in a 3-year period can significantly build up the number of resistant radish plants/m^2 in wheat/lupin/wheat rotation.
- In contrast, rotation of triazine in lupins and the use of a Group B followed by a phenoxy application in wheat in a wheat/lupin/wheat rotation provides up to 100% control of radish. This was also observed when a triazine application was used in TT canola and Group B followed by a phenoxy in wheat phases of a wheat/TT canola/wheat rotation.
- In the absence of fresh seed production, at least 3% seeds of the original seed bank of radish can persist for up to 4 years.

BACKGROUND

Radish has evolved resistance to Group B, C and F herbicides in WA. Herbicide use history in many resistant populations in WA has revealed that this species evolves resistance to Group B herbicides after only 4-5 persistent applications. It has not been experimentally demonstrated in WA situations as to how many applications are required to build up a population of a resistant biotype in a radish population with a known initial low level of Group B resistance.

Radish is thought to be persistent in the cropping system although information as to how long a radish population can persist in a viable condition, in the absence of seed production is scarce for WA cropping situations.

AIMS

The aims of this study were to:

1) quantify the yield loss in crops due to competition from radish, (reported in paper included in this proceedings, *Competitiveness of wild radish in a wheat/lupin rotation*);
2) monitor how population of a resistant biotype builds up under persistent selection pressure; and
3) examine the persistence of radish under various management systems in a wheat/lupin rotation.

METHODS

Wheat-lupin-wheat-lupin rotation trial in Merredin (1997-2000)

In 1997 wheat of this rotation, autumn tickling, wheat seed rates, and low and high level of herbicides from various groups, were combined to achieve eight treatments including the following four:

(a) Untreated control.
(b) Treatment with high seed rate of wheat + 2,4-D ester as crop topping.
(c) Treatment with standard seed rate of wheat + Jaguar® or 2,4-D amine; and
(d) Total prevention of radish seed production.

About 350 pods fragments/m^2 of a known Group B-susceptible population of wild radish were introduced in 1997 before autumn tickling and seeding wheat.

The herbicides used in wheat were rotated with herbicides of different modes of action in subsequent crops: lupin (1998), wheat (1999), and lupins (2000). In the 1998 and 2000 lupin crops, simazine 2.0 L/ha was used uniformly in all plots at pre-seeding (PS). Metribuzin and Brodal® were sprayed at post-emergence (PO) only in the lupin plots where total prevention of radish seed production was planned (Treatment D).

Radish plant emergence before and after crop seeding, radish density at reproductive stage of wheat, yields of wheat and lupin, and screening of wheat, were recorded in all treatments in each year.

Trial in Avondale (1998-2000)

Two rotations: wheat/lupin/wheat (designated as CP) and wheat/TT canola/wheat (designated as AP) were initiated with wheat in 1998. The following treatments were among the 5 treatments investigated in each rotation:

1. CP-M1: wheat (2 ALS)-lupin (1 PSII, 1 ALS)-wheat (2 ALS).
2. CP-M2: wheat (1 ALS, 1 phenoxy)-lupin (1 PS II)-wheat (1 ALS, 1 phenoxy).
3. AP-M1: wheat (2 ALS)-TT canola (2 PSII)-wheat (2 ALS).
4. AP-M2, wheat (1 ALS, 1 phenoxy)-lupin (2 PSII)-wheat (1 ALS, 1 phenoxy).

The plots of control treatments (CP-M1 and AP-M1) in both the rotations were treated with 2 applications of Group B herbicides in wheat. In CP-M1, lupin received 1 application of Group B. Thus, the control treatment in the CP rotation received 5 applications of Group B and that in the AP rotation received 4 applications of Group B herbicides in the 3-year period. Emergence after crop seeding and survival of radish at reproductive stage of wheat or lupin were recorded in each treatment in each year.

RESULTS

Effect of selection pressure on resistant radish population dynamics

The population of the resistant biotype in the wheat/lupin/wheat rotation, infested with a radish population with 1.3% resistance to Group B, built up to 5 plants/m^2 in the 2nd year after 3 applications of Group B herbicides. This had exploded to 29 plants/m^2 in the 3rd year after 5 applications of Group B had been applied (Figure 1). This occurred even though simazine was applied once at pre-seeding in the lupin crop (1999) in this rotation.

This explosion of the resistant biotype population did not occur when 1 application of Group B herbicide was followed by 1 application of phenoxy in the same wheat crop, regardless of crop rotation (Figure 1).

In the wheat/lupin/wheat rotation, 1 application of Group B followed by 1 application of phenoxy in the same wheat crop and 1 application of simazine in lupin resulted in total control of radish. In the wheat-TT canola-wheat rotation, 1 application of Group B herbicide followed by 1 application of phenoxy in the same wheat crop and 2 applications of triazines in TT canola also resulted in total control of radish by 2000. However, 2 applications of only Group B herbicides in the same wheat crop rotated by 2 applications of triazines in TT canola appear to build up resistant biotype population to 3 plants/m^2 in wheat-TT canola-wheat rotation in 2000 (Figure 1).

These results clearly suggest that rotation of Group B herbicides with other herbicides with a different mode of action is essential to delay build up of a resistant population of radish.

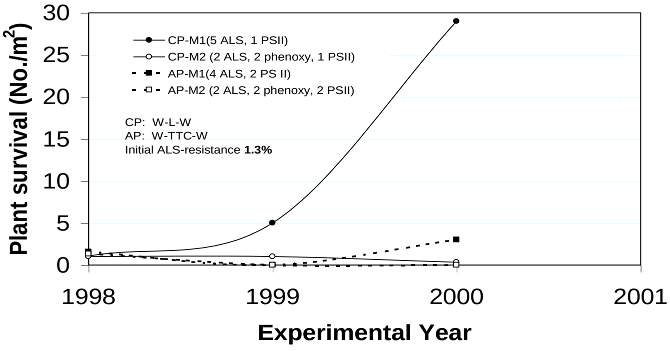


Figure 1. Effect of different herbicide management systems in two rotations, (wheat/lupin/wheat and wheat/TT canola/wheat), on the dynamics of a Group B-resistant radish population in a 3- year period from 1998 in Avondale.

Persistence of radish in a wheat-lupin rotation

Total emergence (pre- and post-seeding of wheat) of radish plants in 1997 varied from 186 to 225 plants/m^2 in 1997 wheat. Although radish emergence was greater in treatments with autumn tickling than no tickling, on average 60% of the initial radish seed bank emerged in 1997 (Figure 2).

The emergence of radish in the 1998 season in treatments B, C and D was reduced by 82-95% as compared to untreated control (Treatment A) because of good control of radish in 1997 wheat (Figure 2). In spite of effective control of radish in 1997 and 1998 in treatments B, C and D, its emergence in 1999 went up to 57-89 plants/m^2.

In the absence of any seed production of radish (Treatment D), about 5% of the original seed bank of 350 pod fragments/m^2 emerged in 1998, 16% in 1999 and 3% in 2000 (Figure 2). These results indicate that at least 3% of viable seeds in the original seed bank can persist in the soil under continuous cropping systems for up to 4 years. The remaining seeds may still be viable, may have partly decayed or been predated.

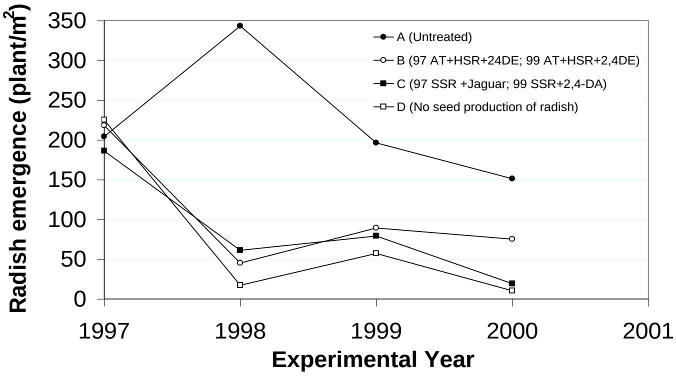


Figure 2. Effect of different management systems on the persistence of wild radish in a wheat/lupin rotation, 1997 to 2000 in Merredin.

AT, autumn tickle; SSR, 60 kg/ha seed rate; HSR, 120 kg/ha seed rate; 2,4-DE, 2,4-D ester; 2,4-DA, 2,4-D amine.

CONCLUSION

Viable seeds of radish can persist in soil for at least 4 years in absence fresh input of radish seed. Rotation of Group B herbicides with herbicides with different modes of action is essential to control radish and delay build up of resistant population of radish.

ACKNOWLEDGEMENTS

We are thankful to GRDC for funding the project and Dr Harmohinder Dhammu for his technical assistance.

GRDC Project No.: DAW 535 WR

Paper reviewed by: Ms Vanessa Stewart and Dr Terry Piper

Inter-row knockdowns for profitable lupins

Paul Blackwell, Agriculture Western Australia and **Miles Obst**, Mingenew

KEY MESSAGE

Better lupin yields and less weed infestation than normal agronomy was achieved with inter-row knockdowns on a blue lupin paddock at Mingenew. Estimates of ryegrass seedbank control for modelling with RIM showed average gross margins over a lupin/wheat phase could be about $135/ha with the best in-row grass control. This is about double the estimated average gross margin for the period from normal agronomy or green manure. Tramlines enable the use of inter-row knockdowns inside protective 'row-cropping' shields and are very compatible with the needs of tramline farming technology. The financial benefits of this system could be employed to help underwrite the needs for farm conversion to tramline farming.

Methods and agronomy

The trial was done with farmscale equipment on plots 36 m x 250 m (one farm boom width) and with 4 replicates. The soil was grey sand over gravel, with a blue lupin history. Sowing was on 3 May, dry over moisture. There were only a few light showers until the middle of June. 192 mm fell between May and October. Wonga was seeded at 120 kg/ha on 560 mm rows with knifepoints and presswheels. Fertiliser at seeding was 100 kg/ha of 'pasture potash'. Herbicides were: pre-seeding 1 L/ha Roundup, 2 L/ha simazine, 300 mL/ha Sprayseed; 5 July; 750 mL/ha simazine, 100 mL/ha brodal (not treatments 2,3 and 4) 1 August; 280 g/ha fusion (not treatments 2 and 3). Reglone was used for crop topping in late October.

Inter-row spraying was with 'Red Ball®' conservation spray shields mounted on a 9 m wide three-point linkage frame. The spraying tractor ran on 600 mm wide tramlines. 'Fuzzy' tramlines were used in the whole trial, i.e. seed sprayed from two hoses at about 800 mm height in front of frame and airbox wheels which rolled the seed into the soil in a broad band. Thus the tramlines resembled broad green bands, rather than bare, grey strips. Then the shields were used the crop in the tramlines was killed, as well as the weeds between the rows. The inter-row roundup, at 1.5 L/ha was sprayed when the primary flowers of the lupins were opening. The shields sprayed 350 mm width of the 560 mm rows. Green manuring was done with an offset disc plough on 28 August and brown manuring (1 L/ha of roundup) was done on 12 September. A small trial on the same site also used knockdowns in the row. The range of treatments used are shown in Table 1. Shields gave the largest yield and had the lowest growth of blue lupin weeds. Presumably the large blue lupin weeds competed for soil moisture in this dry season and contributed to a reduction of yield in the other treatments. There must have also been some compensation in the shielded crop for the lack of crop in the tramlines, compared to the other treatments. Grass weed control with inter-row hoods because grass selectives were also used, as in the normal agronomy. This was done to simulate weed control by other methods, e.g. in row Kerb® or

Table 1. Plant establishment, growth and yield; * = significantly different to normal agronomy

Treatment	Yield (t/ha)	Plants (/m^2)			Dry matter (g/m^2)			Gross income ($/ha)
		Lupin	Blues	Grass	Lupin	Blues	Grass	
1. Normal agronomy	1.067	44	2.3	4	184	29	6.4	181
2. Green manuring	0	53	3	16*	237	48	38*	0
3. Brown manuring	0	55	3.8	4	273*	64	16*	0
4. Crop topping	1.042	37	1.5	2	287*	25	0.2	177
5. Hoods and topping	1.186*	42	0.5*	3	255*	0.5*	7.5	202
LSD (5%)	0.082	17	1.9	10	69	30	22	($170/t)

late spray seed from 'lay by' nozzles on the shields. 2 L/ha of roundup in the row killed all grasses. At WHRS, Kerb® in-row has shown 97% grass control, little yield penalty and a cost of about $18/ha. Crop topping may be the best current option for the in-row weeds. Wheat yields and weeds will be followed in the 2001 season for the same treatments.

Estimates of weed control, yields and gross margins in a lupin-wheat phase by RIM

For the model run we used a lupin yield of 1.2 t/ha and a wheat yield of 2.34 t/ha ($170 and $180/t respectively). No grass selectives could be used in the lupins and there was 25% carry-over of the initial 500 seeds/m^2 rye grass into the wheat phase. The wheat was grown with delayed sowing and high seeding rates to maximise weed control. The shield treatments were estimated as the worst scenario with only 80% control by inter-row shields, or the best case scenario with additional Kerb® in the row (paid for by saving the cost of simazine) and 98% weed control. Table 2 shows the results.

Table 2. Estimates of ryegrass and gross margins for different systems over a lupin/wheat phase

		Lupin year		Wheat year	
Ryegrass (seeds or plants/m^2)	**% Control**	**Seeds; April**	**Plants; Nov.**	**Seeds; April**	**Plants; Nov.**
Res. RG no G. selective, normal agronomy	70	500	151	5195	1173
Green manure with simazine	99	500	3	155	35
IR shields on 80% width, no in-row control	80	500	38	1487	336
IR shields + in-row control; 98% grass control	98	500	17	591	134

	Gross margin $/ha		**2 years**	**Average over 2 years**
Res. RG no G. selective, normal agronomy	**21**	110	**131**	65.5
Green manure with simazine	**-130**	275	**145**	72.5
IR shields on 80% width, no in-row control	**29**	172	**201**	100.5
IR shields + in-row control; 98% grass control	**59**	212	**271**	135.5

The best IR shield treatment gave the best gross margin in the lupin year and averaged over the two years, ryegrass numbers were also kept relatively stable. This encourages the development of low cost shields for use on normal farm spraying equipment.

CONCLUSIONS

- These results are encouraging for inter-row hoods in a Tramline farming system using row-cropping technology.
- Tramlines enable the use of inter-row knockdowns inside protective ‘row-cropping’ shields and are very compatible with the needs of tramline farming technology. The financial benefits of this system could be employed to help underwrite the needs for farm conversion to tramline farming.
- These techniques may also be useful in other legume crops with a ‘bushy’ growth habit, which is easily accommodated between inter-row shields, e.g. chickpeas.

ACKNOWLEDGMENTS:

The Obst family for hosting the trial, Nichols Concaves, for providing equipment, Maurice Black and Mike Collins for technical assistance, Peter Newman for help with RIM, WAHRI and GRDC for funding.

GRDC Project No.: DAW 505

Paper reviewed by: Bill O’Neill

Paper reviewed by: Mark Sweetingham

Is it safe to use 2,4-D Ester 80% pre-sowing when furrow sowing lupins?

Andrew Sandison, Elders Ltd

KEY MESSAGE

This trial supports the hypothesis that it is safe to use low rates (150-300 mL/ha) of 2,4-D Ester 80% 2-3 weeks prior to sowing when furrow sowing narrow leaf lupins in the Northern Agricultural Region.

AIMS

A furrow sowing system such as direct drilling lupins on wide row spacings with knife points and presswheels has become a common lupin establishment practice in the Northern Agricultural Region. In many seasons paddocks have large broadleaf weed burdens of Wild Radish, Doublegee and Capeweed present prior to sowing. Within this system growers commonly use a Glyphosate Atrazine herbicide mix to control these weeds pre-sowing. Is relatively common to have knockdown failures using this mix under minimum tillage systems especially when conditions are hot/dry and dusty. A spike to this mix of 2,4-D Ester 80% at 150-300 mL/ha greatly improves the reliability of control. The 2,4-D Ester 80% label stipulates a 28 day plant back for lupins in Western Australia.

A trial by AGWEST at Wongan Hills in 1993 demonstrated that rates of low as 250 mL/ha applied the day before sowing reduced lupin plant numbers and crop biomass, however there was no significant effect on grain yield (Weed Update Number 33: 8 December 1993). This trial was sown with a full cut seeding system which would have placed herbicide treated soil in contact with germinating seed. Furrow sowing systems greatly reduce the risk of herbicide treated soil coming in contact with germinating seed as the top 50-100 mm of soil is graded into ridges in the inter row and away from the seed row. It is therefore hypothesised that furrow sowing will improve crop safety when using 2,4-D Ester 80% pre-sowing.

METHOD

Narrow leaf lupins *cultivar Belara* were sown into low levels of standing wheat stubble on the 24 April 2000 with a Ryan DBS Auseeder bar. 100 kg/ha of seed was furrow sown on 300 mm row spacings at a depth of 50 mm (seed depth measured from the base of the furrow) . 18 days prior to sowing the 2,4-D Ester 80% treatments were sprayed using a 50 L/ha water rate. The soil type was yellow Eradu sandplain. Weed burdens were extremely low within the trial area and conditions were warm to hot during the month of April. Six rates of 2,4-D Ester 80% were tested. The treatments were replicated 3 times and randomised within blocks. Microsoft Excel 97 was used to conduct the analysis of variance.

RESULTS

Table 1. Effect of varying rates of 2,4-D Ester 80% applied 18 days before sowing on lupin establishment and grain yield

2,4-D Ester 80% (mL/ha)	Establishment (plants/m^{2})	Yield (kg/ha)
0	58	1308 a
150	46	1358 a
300	48	1366 a
600	48	1244 a
1200	50	1000 b
lsd $p < 0.05$	not significant	168

CONCLUSION

Table 1 shows that the highest rate of 2,4-D Ester 80% reduced lupin yield compared to nil by 308 kg/ha or 24.5%. The lower rates (150-600 mL/ha) had no effect on yield. 2,4-D Ester 80% did not effect lupin establishment (plants/m^2), however it was observed that the highest rate of Ester 80% reduced plant biomass.

There was an 18 day time delay between the 2,4-D Ester 80% treatments and sowing. This was 10 days shorter than the herbicide label plant back. This trial supports the hypothesis that it is safe to use low rates (150-300 mL/ha) of Ester 80% 2-3 weeks pre-sowing when furrow sowing narrow leaf lupins in the Northern Agricultural Region.

Further research is required to determine a minimum plant back period for rates of 2,4-D Ester 80% up to 300 mL/ha when furrow sowing.

The author warns against extrapolating these results to other regions in the State where temperatures and soil conditions are less favourable for lupin establishment and growth.

ACKNOWLEDGEMENTS

I would like to thank Steve Cosh and Deranie Kirby (AGWEST) for harvesting the trial and thank Mick and Alan Desmond for providing the trial site on their farm at Tenindewa.

Paper reviewed by: Dr Paul Blackwell

Lupin protein – what we know

Bill O'Neill, Agriculture Western Australia

At the recent Lupin Industry Forum (October 2000) Mr Robert Nelson, Lupin Marketing Manager with the Grain Pool of WA, discussed the fact that lupins are priced mainly on their protein content. Therefore, one potential avenue to improve the value of lupins is to research increasing the protein content of the grain.

To date grain quality has not been considered by the industry to the same extent as other grains. Grain discolouration and monitoring of alkaloid levels has been the main concern. With market signals emerging quality will become an important component of maximising the returns from lupin production. The Grain Pool of WA is considering paying a premium for lupins with a higher protein content in the next two years. At this stage it is too early to put a precise $ value of increased protein in different markets. The Grain Pool of WA and AGWEST are investigating this.

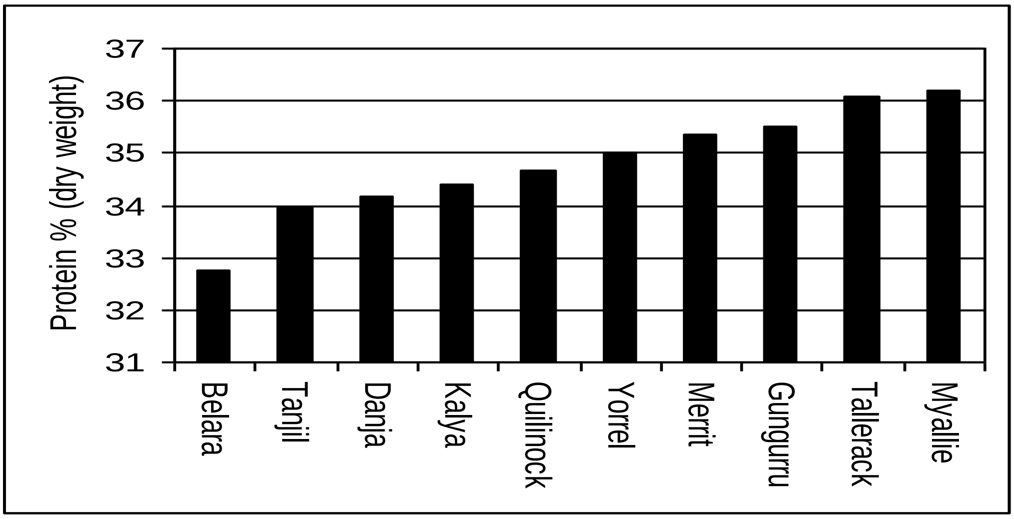
Varietal variation

Genetic variation occurs within *L. angustifolius* lines over a range from 27% to 41% (Technical Bulletin No. 43, Agriculture Western Australia). The level of variation within wild types of *L. angustifolius* lines provides opportunity for improvement in protein through breeding. Dr Bevan Buirchell, Senior Lupin Breeder, AGWEST believes this provides a real opportunity to lift protein levels in future high yielding and disease resistant varieties by around 3%.

An analysis of crop variety testing (CVT) data shows the range of variation that occurs between the current varieties (Graph 1). At present choosing varieties with high protein means accepting a yield penalty.

From a plant physiology viewpoint most of the nitrogen is fixed by the lupin plant prior to seed filling with storage in the leaves, stems, pod walls and other parts. The nitrogen is collected very efficiently from these areas during seed development and is a key component of protein. Carbohydrate is another major component of the seed but is relatively immobile in the plant as much of it is used in permanent structures in the plant such as stems.

The breeding challenge will be to achieve improvements in protein and yield.



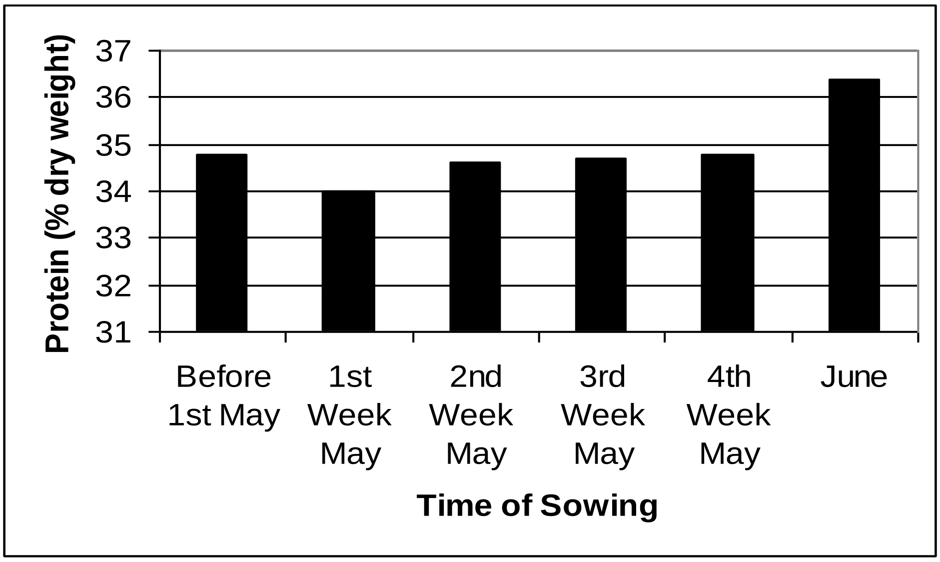
Graph 1. Grain protein by variety (CVT 1988-1998).

The variety Wodjil has significantly higher protein (42%, dry weight) and a better amino acid profile than *L. angustifolius*. The development of improved varieties of yellow lupin (*L. luteus*) is still an active component of the AGWEST breeding program.

Agronomic variation

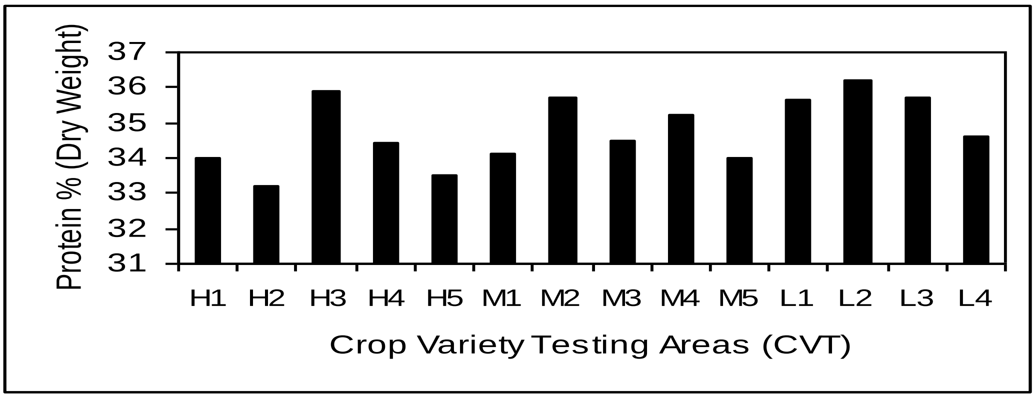
Unfortunately there seems that there is limited scope to increase lupin protein by agronomic means.

- Starter N has shown no consistent effect (Bob French pers comm.).
- P rates have no effect (but the up side is high rates to increase yield does not seem to reduce protein).
- Late sowing may increase protein but big yield trade-off (Graph 2).
- Seeding rate probably has limited effect.
- Foliar applications of liquid N has produced inconsistent results from a trial at Mingenew (Weeks, Hasson and Moreschi, Agribusiness Crop Updates 2001) and a trial at Merredin (French and Wahlsten, Agribusiness Crop Updates 2001) increased protein but decreased yield.



Graph 2. Time of sowing affect on grain protein (CVT 1989-98).

Regional variation in protein from the CVT program is illustrated in Graph 3. Although these differences were statistically significant, there is no clear north-south or rainfall trend. Soil type variation may need to be explored further to exploit the differences in protein.



Graph 3. Grain protein by CVT areas (CVT 1988-1998).

Work will continue this year to look at, K nutrition which has shown to influence other quality characteristics, regional variation, variety differences and foliar N applications.

ACKNOWLEDGMENTS

Thanks go to Rob Nelson and Mark Tucek, Grain Pool of WA and the Lupin Breeding and Crop Variety Testing teams at AGWEST for their assistance.

Paper reviewed by: Mark Sweetingham

Foliar N application increases grain protein in lupins

Bob French and Laurie Wahlsten, Agriculture Western Australia

INTRODUCTION

The Grain Pool of Western Australia has recently floated the idea of offering a premium for higher protein in lupin grain in order to improve market prospects for WA lupins. At present there is no indication of how much this premium might be, and there is very little knowledge of how agronomic treatments affect grain protein in lupins. It is therefore not possible to advise farmers about practical ways to increase protein content.

One possible agronomic means of increasing lupin grain protein is by the application of N during reproductive growth when it is more likely to be used by the growing seed than for further vegetative growth. This approach works in cereals. Because the reproductive physiology of indeterminate legume crops such as lupin is very different from that in cereals there is some doubt to whether this will be successful in lupin.

Here we describe a trial conducted at Merredin in 2000 to find whether the CSBP product 'Flexi-N' (a liquid form of N fertiliser, consisting of concentrated solution of urea and NH_4NO_3) applied to a lupin crop during flowering and podding would lead to changes in grain protein.

METHOD

An area of a bulk crop of Kalya lupins, sown on 17 May 2000 with 50 kg/ha double super on a sandy gravel at the Merredin Research Station, was chosen for the trial. Ten or 20 kg N/ha were sprayed onto the crop at main stem flower, at 1st order lateral branch flower, and at 1st order lateral branch pod fill.

RESULTS AND DISCUSSION

Grain yield and protein (by NIR, courtesy of CBH) results are shown in Table 1.

Table 1. Effect of foliar N application on grain yield (kg/ha) and grain protein (%) of Kalya lupins at Merredin, WA, 2000

Treatment	Grain yield (kg/ha)	Grain protein (%)
Control	445	33.4
10 kg N/ha @ main stem flower	431	34.2
20 kg N/ha @ main stem flower	380	34.3
10 kg N/ha @ 1st order branch flower	428	34.0
20 kg N/ha @ 1st order branch flower	416	34.8
10 kg N/ha @ 1st order branch pod fill	400	34.3
20 kg N/ha @ 1st order branch pod fill	416	34.8
LSD (P = 0.05)	33.5	0.79

The foliar application of N significantly increased grain protein, but it also reduced yield. The timing of application did not seem to matter in this experiment. Even 10 kg N/ha raised protein by an average of 0.8%, and 20 kg N/ha by 1.2%. The corresponding yield declines were, in this experiment, were 26 kg/ha and 41 kg/ha.

The response observed in this experiment may not be typical for two reasons. Firstly, due to the dry season at Merredin in 2000, canopy cover at the time of was not complete, so some N was lost on the soil surface. Therefore we might expect a larger protein response in better seasons. On the other hand, lateral branch growth was curtailed by water stress soon after application, so this may have helped the partition of applied N into growing seeds rather than into new leaves and stems, suggesting a smaller protein response in better seasons, but perhaps a positive yield response. Finally, in higher yielding crops the applied N will be spread amongst more seed than in this experiment, so a higher

rate of N may need to be applied to realise the same protein response. Further research is therefore necessary before yield and protein responses of lupin to late applied N are fully understood. However, coupled with the results of similar research at Mingenew (Weeks *et al.* 2001) and the likely premium that the lupin market could support (O'Neill 2001) that manipulation of grain protein by late foliar application of N will be uneconomic. Research into other means of raising lupin grain protein, by genetic improvement of current narrow-leafed lupin varieties, and by improving the productivity of yellow lupins in Western Australia may be more valuable in the long run.

ACKNOWLEDGMENTS

We are grateful to CSBP Futurefarm for supplying the Flexi-N used in this experiment, and to Peter Nelson (GPWA0 and CBH for organising the grain protein measurements.

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C. Weeks, E. Hasson and L. Moreschi (2001). Can lupin grain protein be increased with flexi-n? Crop Updates 2001.

Paper reviewed by: Bill O'Neill

Can lupin grain protein be increased with Flexi-N?

Cameron Weeks, Erin Hasson, Mingenew-Irwin Group and **Luigi Moreschi**, CSBP futurefarm

KEY MESSAGES

- In a trial at Mingenew, lupin grain protein was not affected by late applications of either 'Flexi N' or urea.
- Markets have indicated they will pay for protein. Growers will be rewarded accordingly.
- Recent work by researchers in Germany has shown an increase in lupin pod set through an application of liquid nitrogen applied at flowering.
- It is thought that a timely application of Flexi N may be able to increase lupin grain protein, however more work is required to test this theory.

BACKGROUND AND AIM

If lupins are to be considered for higher value human consumption markets, grain protein must be high. Markets throughout the world have already indicated that they will pay for protein, which in turn will lead to protein based payments being made to growers (Peter Nelson, pers comm.).

Plant breeding and selecting for high protein varieties is the obvious way to achieve this outcome. Another prospect is to manipulate grain protein with a late application of nitrogen. Research by AGWEST in the 1990s with nitrogen applications at seeding, suggest this is possible, but results were extremely variable. More recently German research has shown an increase in lupin pod set with nitrogen applied at flowering.

With the advent of the liquid nitrogen product, Flexi-N produced by CSBP, it is wondered whether optimum results could not be achieved. Flexi-N is a premium liquid nitrogen fertiliser, containing 32% N, 25% of which is in the nitrate form, 25% as ammonium and 50% as urea. World wide about 15 million tonnes is manufactured and applied each year.

The aim of this experiment was to determine whether lupin protein and/or yield can be increased with a timely application on Flexi-N.

METHOD AND TRIAL DETAILS

Reps:	3
Plot size:	25 m x 1.8 m
Seeding date:	24 May 2000
Seeding rate:	80 kg/ha
Seeding machinery:	Flexicoil, knife points and press wheels
Fertiliser:	100 kg Super + 50 kg Potash pre spread 75 kg Agstar at seeding
Nitrogen timing:	Flexi N time 1 - 4 September - First flower on primary stem Urea top dress - 29 August Flexi N time 2 - 19 September - Small pods on primary stem, second order branches flowering
Nitrogen applications:	20 N - 50 L/ha Flexi N 40 N - 100 L/ha Flexi N 40 N as urea - 87 kg/ha urea

RESULTS

There were no significant differences between treatments in either yield or protein.

Treatment	Yield (t/ha)	Protein (%)
Control	2.23	31.8
20 N as Flexi N - time 1	2.21	31.5
40 N as Flexi N - time 1	2.18	31.5
20 N as Flexi N - time 2	2.21	32.2
40 N as Flexi N - time 2	2.02	32.3
40 N as Urea - time 1	2.25	31.9
LSD 5%	NS	NS

DISCUSSION

- A trial of similar nature to this was carried out in the eastern wheat belt in 2000. Here a response of up to 2% increase in grain protein was observed.
- Further work is required to better define whether lupin grain protein can be manipulated with liquid nitrogen applications. Applications will focus on nitrogen applied at or soon after flowering, as this is the period when nitrogen requirements of the lupin plant are greatest.
- Based on the German work it may be possible to get a yield increase through an increase in lupin pod set.

ACKNOWLEDGEMENTS

Thanks to Garry for the trial site and to CSBP Futurefarm for supplying the Flexi N.

Paper reviewed by: Peter Nelson, Grain Pool of WA

Putting a value on lupin use in the aquaculture industry: A fishy business?

Brett D. Glencross, Fisheries WA, Fremantle Maritime Centre, Fremantle, WA 6160

INTRODUCTION

Fishmeal replacement in fish diets

Of all animal production industries, none has equalled the growth rate experienced by that of aquaculture over the past ten years. While this boom in fish production bodes well for those who want to keep eating fish, it has begun to present problems in that we are now asking, what do we feed the fish to keep this industry growth going? World supplies of fishmeals and oils are already static in supply, so any increase in feed production for the aquaculture industry must necessarily come from elsewhere to provide the necessary protein for these animals.

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 other species.

NUTRITIONAL VALUE ASSESSMENT

Protein content and composition

As nutritionists, we tend not to look for the 'perfect' single ingredient from which to make diets, but rather a suite of high quality, complimentary ingredients of consistent composition from which formulations can be tailored to suit the needs of specific species, with varying dietary requirements. In this sense, lupins have proved to be a good 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 their overall protein content, which is one reason why the use of kernel meals are generally favoured over whole-seed meals. More specifically this relates to the amount of digestible protein. Most fish obtain no value from the carbohydrate fraction of lupins.

Nutritional utilisation of lupins by fish

To determine the level of digestible protein of lupins to fish, it is pretty obvious that you need to begin by feeding them to the animal. Typically the digestible or useable protein is determined by including the lupins in a diet which includes an indigestible marker. The concentration of this marker is then compared between the feed and the faeces, along with any changes in protein content, thereby allowing the calculation of the relative rates of loss of protein and as such the level of protein digestion and absorption. Similarly the utilisation of other key nutrients such as energy and phosphorus can also be assessed in this manner.

Recent work at Fremantle has evaluated the nutritional value of each of the three key lupin species (*L. angustifolius, L. albus* and *L. luteus*) when fed to rainbow trout (*Oncorhynchus mykiss*) being grown in saltwater. This fish species was chosen because it is one of the family of fishes that is presently the greatest user of aquaculture feeds worldwide. This should mean the greatest prospects for getting lupins into aquaculture diets.

The nutritional value of the three lupin species was also compared against that of a high protein (48%) solvent extracted soyabean meal, the key competitor for lupin meals in the worldwide feeds market. Each of the lupins was dehulled, and the kernels milled to a similar particle size before being included into the fish diets.

Assessment of the apparent nutrient digestibilities of each of the lupin kernel meals clearly supported that these grains have excellent protein qualities, highly suitable for use in aquaculture diets. Protein digestibilities of each of the lupin kernel meals were higher than that of solvent extracted soyabean meal, with the highest being that of *L. luteus* kernel meal (Table 1). Energy digestibilities of the lupin kernel meals were generally lower than that of the solvent extracted soyabean meal, with the highest

of the lupin kernel meals again being that of *L. luteus* kernel meal (Table 1). This effect is most likely a response to the overall levels of protein in each of the meals, and the negligible amount of carbohydrate digestion. Phosphorus digestibilities were considerably higher than that of the solvent extracted soyabean meal, with the highest being that of *L. angustifolius* kernel meal (Table 1). This finding has considerable implications for the marketing of lupin kernel meals in general as high quality, ingredients that also have potential environmental benefits for the aquaculture industry.

Table 1. Nutritional value as apparent digestibility of lupin kernel and solvent extracted soyabean meals when fed to salt-water reared rainbow trout

Apparent digestible nutrient	*L. luteus*	*L. albus*	*L. angustifolius*	Soyabean
Nitrogen (%)	102.1	96.7	95.3	86.7
Energy (%)	74.2	71.2	70.0	79.8
Phosphorus (%)	45.8	48.1	53.8	28.5

ECONOMIC VALUE MODELING

Floating against the soyabean meal market

It is common knowledge that the market value of lupins is greatly influenced on the value of soyabean meal on the worldwide feeds market. On that basis, the value of lupin kernel meals should also reflect their nutritional value relative to soyabean meals. To achieve this comparison the apparent digestibility figures were used to determine the amount of useable protein in each meal. The amount of useable protein in solvent extracted soyabean meal was used as the standard, with the standard soyabean meal price derived from US Department of Agriculture data (http://www.usda.gov/[January 2001]).

Variation between fish and other domestic animal species

The value of lupins to the various aquaculture species as determined by this method is influenced primarily by the protein content of grain and also relative differences between the nutritional value of the lupins and soyabean meal within a particular species. Based on standardised processing costs and milling losses, the relative value of the whole-seed can also be determined (Table 2). Using this method of assessment lupins had greater value in most fish species than they had to pigs. Of the fish species examined, including some additional ones from the literature, greatest value was shown for the barramundi. Second was trout, suggesting that there may be greater value for lupin kernel meals in industries farming carnivorous fish than the omnivorous species like silver perch and prawns. This method of economic assessment is somewhat simplistic, but it does begin to allow value assessment across species on a more equal footing. Relative values in any market place will also be influenced by freight costs, tariff, and non-tariff trade barriers, as well as the prices of other commodities.

Table 2. Relative value ($AUD per tonne) of *L. angustifolius* kernel meal based on the nutritional value of the protein to that of high protein solvent extracted soyabean meals valued at $364 per tonne

	Barramundi	Trout	Silver perch	Prawns	Pigs
Kernel meal	$328	$316	$303	$294	$290
Relative whole-seed	$180	$172	$162	$156	$153

GRDC Project No.: Grains Research Council Project and GRDC Project DAW 555

Paper reviewed by: David Petterson

Selection for thinner seed coats and pod walls in lupins

Jon Clements, Centre for Legumes in Mediterranean Agriculture and **Miles Dracup**, Agriculture Western Australia

KEY MESSAGE

Lupin grain quality needs to be improved to increase its market value and high indigestible fibre is one of the biggest limitations to lupin grain quality. Most of this fibre is in the seed coat. We have selected a number of lines of lupins which have thinner seedcoats and therefore contain lower fibre. Thinner seed coat genotypes are being incorporated into the Western Australian lupin breeding program.

A large amount of dry matter remains in pod walls at harvest, limiting grain yield. We have identified wild, mutant and domesticated lupins that have lower a lower proportion of pod wall , which we will try to exploit to improve yield.

BACKGROUND AND AIMS

Lupins are mainly used as sources of protein for ruminant and monogastric animals but there is also promise in aquaculture feeds and niche markets as a human food ingredient. About 1.5 million tonnes of lupins, worth $200 million, are produced each year in Australia. The grain has relatively high protein and low levels of anti-nutritional compounds. Despite these attributes, its value in animal feed markets is reduced due to its hard hull and milling difficulties, high cellulose, non-starch polysaccharide and oligosaccharide content of the whole grain, low sulfur-amino acid levels, protein degradation in the rumen and low metabolisable energy for non-ruminants. One way to create a greater demand or value for lupins is to improve the quality of the grain product. Metabolisable energy and protein are two target characteristics for improvement. The current project is aiming to raise metabolisable energy through reducing the proportion of grain weight in the seed coat of narrow-leafed lupin (*L. angustifolius*).

Narrow-leafed lupins have a high proportion of dry matter in the pod walls (24%) and reducing this is expected to increase yield. Therefore, lower pod wall proportion is sought among a diverse range of lupin genotypes - both wild and breeder's lines and mutant populations.

METHODS

Artificially induced as well as natural variation for seed coat and pod wall proportion was sought among a large range of *L. angustifolius* genotypes. Seed of a breeder's line (83A:473) was treated with the mutagen, ethyl methane sulphonate (EMS), and after successive screening and selection, M3-derived single plant lines were grown in replicated rows in a screenhouse in 1999 and 2000. In addition, a range of wild, semi-domesticated and breeders genotypes were assembled and grown in replicated rows in a screenhouse in Perth and at Wongan Hills. Seed coat and podwall proportions by weight were determined from 10-seed or 15-30 pod samples. The seed coat structure of parent and mutant lines was studied with microscopy. Chemical composition was analysed by standard analytical techniques for protein, oil, fibre and other components by the Chemistry Centre of WA. Advanced breeder's lines were also surveyed across up to six sites during the years 1996 to 2000.

RESULTS

Reduced seed coat proportion

Analysis of a broad range of narrow-leafed lupin germplasm and mutant material shows that proportion of seed coat ranged from 19.1 to 28.5%. The mutants (designated 11257 and 11255a), had seed coat proportions of whole grain (averaged over 1999 and 2000) of 19.8 and 20.3% which were lower ($P \leq 0.001$) compared with 25.4% for 83A473 (parent type), and 25.2 and 24.2% for the test cultivars Tanjil and Merrit respectively. Additional mutant genotypes have been verified in the screenhouse in 2000, that have similar reductions in seed coat proportion (Table 1). The cells of the palisade layer of the seed coat were shorter and broader in the mutants and the hourglass and parenchymatous layers were thinner when compared to the parent. Thickness of the seed coats of

mutant 11257 compared to parent 83A473 was determined by environmental scanning electron microscopy to be 149 (±25) and 193 (±13) μm respectively. Crude, dietary and acid-detergent fibre contents were all lower [quantify]in 11257 ($P \leq 0.05$) compared to the parent and Tanjil. Oil content of 11257 was 7.2% compared to 5.7 and 6.0% in parent and Tanjil respectively.

Table 1. Reduced seed coat selections in comparison with control lines (Merrit, Tanjil and parent line of mutant population, 83A473) and species (Pea, *L. albus* lupin and *L. mutabilis*). Results from screenhouse 2000

Genotype	Origin	Seed coat %
Pea (cv. Mukta)	Control	**9.3**
L. mutabilis (Inti)	Control	**16.4**
L. albus (Kiev)	Control	**18.2**
11254a1	Mutant	**19.1**
V2	Mutant	**19.4**
11257	Mutant	**19.6**
2152A	Mutant	**19.6**
2152B	Mutant	**19.7**
11255a	Mutant	**19.8**
F	Mutant	**20.1**
Q2	Mutant	**20.2**
Q	Mutant	**20.3**
P28163	Russia	**20.9**
Danja	WA	**21.2**
WALAN2113	WA	**21.6**
Merrit	WA	**23.0**
Tanjil	WA	**24.0**
83A473	WA	**24.0**

Table 2. Reduced pod wall selections in comparison with control lines (Merrit, Tanjil and parent line of mutant population, 83A473) and species (Pea and *L. albus* lupin). Results from screenhouse 2000

Genotype	Origin	Pod wall %
Pea (cv. Mukta)	Control	**13.2**
L. albus (Kiev)	Control	**26.2**
P26576	Greece	**26.9**
P27898	Morocco	**27.3**
P26552	Greece	**28.0**
4812	Mutant	**28.2**
P28130	Morocco	**28.2**
11728a	Mutant	**28.2**
11225	Mutant	**28.4**
13678d	Mutant	**28.4**
M	Mutant	**28.4**
3094	Mutant	**28.6**
WALAN2113	WA	**28.7**
P26474	Greece	**28.8**
11630a	Mutant	**28.8**
Merrit	WA	**30.0**
83A473	WA	**30.0**
Tanjil	WA	**31.4**

Pod wall variation

Pod wall proportion ranged from 26.9 to 60% in narrow-leafed lupin germplasm (wild and domesticated) and from 28.4 to 34.8% in breeding lines and cultivars. A Greek wild genotype (P26576) had the lowest proportion of pod wall (26.9%) and the lowest mutant line (4812) had a proportion of 28.2% compared to 30% for the parent (83A473) and 31.4% for cv. Tanjil (Table 2).

CONCLUSIONS

Genotypes have been selected that will contribute to lowering indigestible fibre in lupin grain and improving yield through reducing the proportion of dry matter remaining in the pod wall. These lines are being included in the lupin breeding program.

KEY WORDS

seed quality, fibre, seed coat, hull, *Lupinus angustifolius*, pod wall

ACKNOWLEDGEMENTS

The Grains Research Development Corporation funds this research. Mark Reader began the mutant and wild germplasm selection programmes.

GRDC Project No.: UWA 295

Assessing the nutritional benefits of Australian sweet lupin *(Lupinus angustifolius)* in human foods

Ramon Hall (SPIRT PhD scholar), **Stuart Johnson, Madeleine Ball**, Deakin University, Melbourne, **Sofia Sipsas and David Petterson**, Agriculture Western Australia

KEY MESSAGE

Few nutritional studies in humans have been conducted on Australian sweet lupin (ASL) and any benefits of lupin consumption determined in the present study should stimulate increased consumption of lupin as human food. We will conduct a sensory and nutritional evaluation of lupin kernel flour in a range of products. This should provide roll-on benefits to growers through increased demand for lupin from the high value human food market.

INTRODUCTION

Legumes, including ASL, are in the 'Eat More' category of the healthy eating pyramid produced by the Australian Nutrition Foundation. On average however, Australians have relatively low intakes of legumes and very little of the vast ASL crop is used for human consumption.

There are very few published studies on the nutritional effects of lupin in the human diet. Deakin University researchers have found that highly palatable foods including bread, muffins, breakfast bars and pasta can be made using dietary fibre purified from ASL kernels. Similar studies are now required to ensure that acceptable foods can be made from ASL kernel flour. The Deakin University group have also found that ASL kernel fibre can be used to formulate low-fat meat products of high palatability and increased satiating (filling) effects. This indicates the possible value of ASL kernel fibre in diets for weight control. Human studies are now required to determine the long-term effect of consuming lupin-based foods. Of particular interest would be effects of high-lupin diets on physiological parameters that are linked to risk of heart disease, some cancers, diabetes and gastrointestinal health.

AIMS

The aims of the AGWEST/Deakin University study are to:

(a) Determine the acceptability, by sensory evaluation, of a range of food products formulated using ASL kernel flour.

(b) Determine health-related physiological effects of consuming a high-ASL diet (based on acceptable food products developed in part (a) using a dietary intervention study.

METHODS

(a) Product development and sensory evaluation (Deakin University, Melbourne)

In order to determine the palatability of ASL in food products, ASL kernel flour will be used to replace wheat flour in the development of a range of food products such as bread, muffins and breakfast cereal. Appearance, texture, flavour and overall acceptability of the wheat based control foods and the ASL-based foods will be evaluated by approximately 50 non-expert taste panellists.

(b) Dietary intervention study (Deakin University, Melbourne)

In order to determine the physiological effects of consuming ASL, up to 40 subjects will be recruited to consume two diets each for 21 days. One diet will include the ASL food products found to be palatable in part (a); the second will contain the wheat-based control foods and therefore contain no ASL. The order of the two diets will be randomised and there will be a break of at least 14 days between each dietary period. Blood, faeces and urine samples will be collected before and during each diet so that blood lipids (triglycerides and cholesterols), blood glucose and insulin, sex hormones, faecal chemistry and bowel function can be measured. Subjects will also complete questionnaires to assess the acceptability and effects on satiety (fullness) of the diets.

PROGRESS REPORT

The control and ASL kernel flour product development has now been completed (see Table 1) and the sensory evaluation to these products scheduled for completion by March 2001(*Part a).* This will then allow the dietary studies (*Part b)* to commence.

Table 1. ASL kernel flour and control (wheat flour-based) food products developed for sensory evaluation

Product		Serving size (g edible portion)	Replacement level of wheat by ASL kernel flour (%)	Total dietary fibre content (g/serve)	Permitted dietary fibre claim*
Bread	- Control	60	0	1.83	Source of fibre
	- Lupin	60	15	3.15	High fibre
Pasta	- Control	150	0	2.54	Source of fibre
	- Lupin	150	50	10.5	Very high fibre
American style muffin	- Control	100	0	1.9	Source of fibre
	- Lupin	100	60	7.52	Very high fibre
English muffin	- Control	50	0	1.40	None
	- Lupin	50	30	4.10	High fibre
Focaccia	- Control	100	0	2.56	Source of fibre
	- Lupin	100	40	8.20	Very high fibre
Pizza base	- Control	100	0	2.74	Source of fibre
	- Lupin	100	40	7.74	Very high fibre
Breakfast cereal	- Control	30	0	0.82	None
	- Lupin	30	100	6.00	Very high fibre
Choc-chip biscuits	- Control	30	0	0.76	None
	- Lupin	30	50	3.20	High fibre

* In accordance with the National Food Authority (Now ANZFA) Code of Practice Nutrient Claims in Food Labels and in Advertisements, 1995.

From April 2001-March 2002 the Deakin University researchers will be involved in a GRDC funded study in collaboration with Food Science Australia and food industry partners to investigate the physiological effect of consuming a diet high in fibre purified from ASL. The GRDC funded study will follow a similar methodological approach and will complement the AGWEST/Deakin University study using ASL kernel flour described above. The AGWEST/Deakin University ASL kernel flour dietary intervention study is scheduled to run from April 2002-June 2003.

EXPECTED OUTCOMES

It is expected that this study will identify: (a) a range of approaches for the incorporation of lupin flour into palatable food products; and (b) beneficial physiological effects of consuming lupin. These findings should stimulate the food industry into increasing the utilisation of lupin in commercial food processing. This should benefit growers through catalysing the establishment of a high value human food market for lupin grain both at home and overseas.

GRDC Project No.: SPIRT C00002140

Paper Reviewed by: G. Crosbie, B. Buirchell