Yellow lupin improvement

PROJECT DETAILS

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Summary

Yellow lupins (YLs) have higher protein content and quality than narrow-leafed lupins (NLLs). Small volumes have attracted a $50/tonne premium for processing for the aquaculture feed markets. They are also more suited to very acid soils, areas prone to mild waterlogging, and have excellent brown spot, root rot and cucumber mosaic virus resistance and are reported to have high soil phosphorus use efficiency. Low yields and susceptibility to aphids are the major obstacles to grower adoption.

The project identified why European varieties are unsuccessful in Australia and developed germplasm and breeding lines with better prospects for local adaptation.

An improved variety, Pootallong®, was released but remains short of the level of aphid resistance and yield potential required.

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Conclusions

The significantly higher protein and lower non-starch polysaccharide of the yellow lupin seed still presents a substantial market opportunity for this grain. A conservative estimate from commercial marketers suggests that whole yellow lupins should receive in the order of $50/tonne premium over narrow-leafed lupins.

Given the recent and sustained increase in the price of fishmeal (owing to declining world stocks) and the demonstrated advantages of yellow lupins in aquafeeds, the market potential of the grain would seem assured. Furthermore, there are de-hulling and grinding advantages that yellow lupins have over narrow-leafed lupins which suggest even more profitable value-chains could be possible.

In the 1990s, interest was shown in yellow lupins by growers on the acid sandplain in the eastern wheatbelt and on the south coast where narrow-leafed lupins had not performed well. Since this time, the yields of narrow-leafed lupins have improved significantly and even with the price premium, yellow lupins are less competitive.

Substantially higher yielding varieties are required. It is now believed that this can only come from a fundamental change in the ability to fill pods on the upper branches. Genetic improvement in aphid resistance is clearly the next highest breeding priority.

If there is clear evidence that the current yield ceiling can be lifted and aphid resistance can be achieved, then there can be confidence that a broader range of disease and grain quality traits could be improved based on the evidence obtained and breeding material developed by this project.

Recommendations

1. Australian yellow lupin ideotype/architecture development

Focussed activity is required to assemble a range of genetic material from this project and the genetic resource collection at South Perth to combine earliness with more indeterminacy and ability to set and fill pods on the branches.

Until clear evidence exists that this can be achieved, the current level of investment in yellow lupin breeding cannot be justified.

2. Increase in alkaloid levels to 0.05%

It is now evident that resistance to aphid colonisation may be difficult to achieve with alkaloid levels under 0.02%. Consideration should be given to introducing an alkaloid tolerance of 0.05% for yellow lupins as it is acceptable in Europe and feeding studies with fish, pigs and poultry indicate that it is not a problem. Nevertheless, effort should still continue to search for resistance in lines under 0.02%.

3. New target area
Yellow lupins appear to be less drought tolerant than narrow-leafed lupins. They come from relatively high rainfall areas (<500mm annual rainfall) in the Iberian Peninsula. They are also more frost sensitive than NLLs. As a consequence, greater emphasis needs to be placed on evaluation in higher rainfall areas (which in Western Australia (WA) are also lower frost risk).

**Outcomes**

Potential remains to expand lupin production to areas less suited to narrow-leafed lupins if better adapted and higher yielding yellow lupin varieties can be developed. Like other lupin species, yellow lupins fix substantial quantities of nitrogen as well as providing a disease break for cereal and oilseed crops, while stubbles provide valuable grazing for sheep or cattle. It is expected that the yellow lupin varieties could find niches in a range of environments, not just the low rainfall ‘wodjil soils’ of the eastern wheatbelt of Western Australia as previously considered. Production would be largely in WA and the potential area under cultivation would depend on the extent to which better varieties can compete with narrow-leafed lupins or pasture legumes such as serradella. Earlier estimates of 200,000 ha remain possible but are considered unlikely in the short to medium term.

There has been significant investment in lupin processing in WA with both regionally based small scale operations and a large plant recently commissioned by Australasian Lupin Processing Ltd, a joint venture between Cooperative Bulk Handling Ltd. and George Weston Foods, in Perth. The upswing of interest has been sparked by new opportunities in the aquafeed and food ingredient markets. Yellow lupins have been shown to have significant dehulling advantages, technically and commercially, owing to a different seed structure and higher protein content. Yellow lupin kernel meal has received excellent feedback from the aquafeed sector and significant premiums above narrow-leafed lupins have been paid. Lack of supply is the only obstacle to developing a highly profitable supply chain. Wet processing of lupin kernel meal into protein and fibre fractions is also planned. Yellow lupins have been demonstrated to have some substantial benefits for the production of protein concentrates (Project DAW00069).

This project has contributed knowledge and genetic material that will be necessary to breed better yellow lupin varieties. A new variety, Pootallong, was released but, whilst an improvement over Wodjil, it has not encouraged a significant expansion in production. Pootallong has also been commercialised in the United Kingdom (UK) under license and returns seed royalties to the Department of Agriculture and Food, Western Australia (DAFWA) and GRDC.

**Achievements/Benefits**

Early flowering yellow lupin (YL) varieties from Europe were found to be resistant to Pleiochaeta root rot and brown spot in the 1990s. This, together with their tolerance to aluminium toxicity and efficiency of phosphorus uptake, explained their excellent performance on the ‘wodjil’ soils of the eastern wheatbelt of Western Australia (WA). These results encouraged the release of the first Australian YL variety, Wodjil, in 1997. However, Wodjil proved unpopular with growers due to its extreme susceptibility to aphids. Higher yielding narrow-leafed lupins (NLLs) were subsequently released which made YLs even less attractive.

Yellow lupins have higher protein content and higher sulphur (S) amino acids than narrow-leafed lupins and have obtained a premium grain status in the feed market. When dehulled, the yellow lupin kernel is a very concentrated form of vegetable protein (50%). It has been particularly sought after by the aquaculture feed sector.

The desired outcome of this project was to develop agronomically superior varieties of YL, primarily for WA but with potential for other parts of Australia, to meet the strong demand of premium markets for the nutritionally superior grain. The project aimed to develop breeding lines with enhanced adaptation (yield potential), improved aphid tolerance, herbicide tolerance and disease resistance. It also aimed to explore opportunities to further increase grain quality through protein content and quality and reduced seed coat proportion.

**Aphid tolerance and alkaloid level**

Resistance to aphids in YL is related to alkaloid levels, especially of gramine and possibly lupinine. So far, all lines identified with good aphid resistance have a seed alkaloid content less than 0.02% which is the current Australian standard for NLLs. A field technique to screen against aphids was not reliable and a glasshouse test was developed in 2006. After testing more than 200 lines, 27 lines with 0.02-0.05% alkaloid levels were found moderately tolerant to aphids. These lines are being tested further for confirmation. Moreover, gramine, an indole alkaloid is less toxic than quinolizidine alkaloid found in other...
lupins. An alkaloid level of 0.05% is considered acceptable in YLs in Europe where it is used as a feed for ruminants, poultry and pigs. Feeding studies in Australia with salmonids and prawns have shown that at typical ration inclusion rates, an alkaloid level of 0.05% is not a problem (Brett Glencross, Department of Fisheries, Western Australia).

Anthracnose resistance

At the beginning of the project, there was no known source of resistance to the major fungal disease anthracnose. The project has now identified three different sources of resistance: P28716 (a Portuguese wild type obtained through the United States Department of Agriculture (USDA)), P28865 (a Russian breeding line) and P20856 (an old Hungarian variety). Preliminary results indicated that inter-crossing among resistant lines gives better resistance, suggesting that these are genetically distinct sources. In a short period, 22 crosses have been developed which are at least as resistant to anthracnose as the NLL variety Belara. This level of resistance will be sufficient to grow YL in moderate to low anthracnose risk areas, such as the eastern wheatbelt and southern parts of WA.

Early flowering

Early flowering significantly lifted yields when introduced into NLLs. It was therefore hypothesised that if YLs flowered as early as Belara, grain yields would be improved substantially. This turned out not to be the case with the source of early flowering that was introduced. Early flowering lines from this source matured with lower biomass and limited pod development on the branches and were lower yielding than Wodjil. A newly identified early flowering line (P28176) which flowers at a higher number of internodes appears a more suitable source of earliness to achieve adequate height and biomass. Recent observations indicate that late maturing genotypes are vigorous and tend to produce more pods on the branches. Given that time from flowering to maturity is much shorter in YLs than in NLLs, it is now hypothesised that genotypes flowering even one or two weeks later than Wodjil may not be compromised by terminal drought and may have greater yield potential.

Early vigour

Rapid winter growth is considered important for weed competition and to set up yield potential in a Mediterranean environment. Numerous lines with early flowering and rapid stem elongation were developed, but they were tall, lanky and prone to lodging and had poorer final biomass than more conventional types. There is still an incomplete understanding of the optimum plant type in the seedling stage. There are reports that types with a prolonged rosette stage have greater early tap root development. Genotypes with specific growth habits have been identified and they can be used in the crossing program to direct a population in a desired path.

Larger seed and protein

Larger seed size was postulated as a means to achieve higher yields in a plant type with dominant main stem podding. Larger seeded lines have better emergence at deeper sowing which could be of practical benefit to growers as YLs struggle to emerge when sown deeper than 5 cm. Many lines that have up to 35% bigger seed than Wodjil have been developed, some as big as NLL cv. Danja. In the populations examined, there was a trend for increasing protein content with increasing seed size, with some lines having as much as 43% protein.

Metribuzin tolerance

All YL lines in this breeding program were very sensitive to the post-emergent herbicide, metribuzin, which is used to control wild radish and double gees. Screening of Ethylmethane sulphonate (EMS) induced mutant population of Wodjil yielded several lines with putative tolerance. Subsequent testing confirmed that at least one line (W-99) has tolerance level as good as Mandelup®. Affinity® (carfentrazone®) has also shown good crop safety on YLs.

Reduced shattering

Early experience with Wodjil in WA has shown it to be more prone to pod shattering than NLLs. A broad cross-section of domesticated YL breeding lines from Europe was assessed on standing mature plants and eight lines were found significantly less shattering than Wodjil. These lines are being further evaluated in the 2007 season.

Cucumber Mosaic Virus (CMV) resistance

CMV is controlled by a single dominant gene (Ncm1) in yellow lupins. Each year, F5/F6 lines were screened against the virus
under screenhouse conditions and resistant plants were selected. This meant all the breeding lines were resistant when entering Stage 2 trials. In addition to testing the segregating F5/F6 lines, the parental lines were tested. This avoided screening of progenies against the virus if both parents were resistant.

Defect elimination

A problem believed to be of a physiological nature causing variegation and crinkling of leaves (and sometimes flowers) was found to be linked to genotypes carrying the sulphur-yellow flower colour (e.g. cv. Wodjil). When severe, this variegation and chlorosis could lead to significant yield reduction in plots. It has never been found in genotypes with the gold-orange flower colour (e.g. cv. Pootallong). To eliminate this defect from future varieties, it has been decided to eliminate the sulphur-yellow flowered lines from the program.

Phomopsis tolerance

A set of representative lines (96) from the collection was subject to the YL attacking strain of the *Phomopsis* fungus (*Diaporthe toxica*) and four lines were consistently resistant over two years. These lines are available for crossing if required. It is worth noting that the pathotype causing *Phomopsis* in NLLs is not virulent in YLs and the YL virulent pathotype has not yet been detected in the wheatbelt. Pathotype L is currently confined to orchards and vineyards where YLs were traditionally grown as a green manuring crop.

Seed quality

Lines with lower cadmium accumulation, higher S amino acid content and thinner seed coat have been identified.

Ideotype

Breeding of YLs in northern Europe has progressively favoured the development of an ideotype suited to that environment which is 'self-completing' or determinant. Under WA conditions, these types are reluctant to set pods on the lateral branches and often mature before all the growing season moisture is utilised for pod and grain filling. It is hypothesised that identifying germplasm capable of setting pods on lateral branches is vital if YL is to develop the yield potential of NLL. Most of the grain yield in European bred YLs is contributed by the main stem. By comparison, only about one third of grain yield in NLLs is contributed by the main stem. Lines, such as P28779 and P23291, have been identified in which nearly two-thirds of yield comes from the first order branches. As such, these lines are very late but their ability to produce pods on the branches should be a valuable trait.

Grain yield improvement

A significant improvement in yield over Wodjil (about 10%) is indicated in crop variety trials (CVT). Even greater yield improvements are indicated in Stage 2 trials although there are indications of significant genotype x environment interaction. It should also be cautioned that the past two seasons have been unusually dry and yield potential has been low in trials. However, in general, the rate of yield improvement in YLs is less than has been achieved in NLLs. All the lines tested in CVT and Stage 2 still have the European or Wodjil ideotype. A new yield ceiling is expected with the Australian ideotype which is less determinant and has the capacity to fill more grain on branch pods.

Target environments

In the past, YLs were targeted for the WA eastern wheatbelt because of their ability to tolerate aluminium toxicity in acidic sand, and resistance to brown spot and *Pleiochaeta* root rot. But recent findings indicated that they may also have a niche in the higher rainfall southwest of WA, where moisture is less constrained and aphid feeding damage is less. Higher rainfall, cooler and longer growing season environments in the south are much more similar to habitats in YL’s natural Mediterranean distribution.

Other research

1. The effort to develop a better ideotype for yellow lupins in Australia would be supported by a series of (diverse genotype) x (contrasting environment) trials to better understand the traits associated with adaptation and yield. Such an investigation should include narrow-leafed lupins and pearl lupins as it would enhance understanding of all species.
DAFWA, CSIRO and the University of Western Australia (UWA) have commenced this activity.

2. A plant density and row spacing trial in the high rainfall zone should explore compensating for the poor pod setting ability of yellow lupins on the branches. Crop-topping has been suggested by growers as a means of reducing pod shattering in yellow lupins as it does with blue lupins.

3. Explore the possible registration of the herbicide Affinity® on yellow lupins.

4. Determination of the genetic basis of anthracnose resistance from different sources is desirable to predict the likely success of trying to pyramid resistance through inter-crossing.

5. F8 derived recombinant inbred lines have been developed and will be phenotyped in the summer of 2008. This population can be used to develop molecular markers for CMV resistance.

**Intellectual property summary**

Any varieties forthcoming will be protected by Plant Breeders’ Rights (PBR) and germplasm transferred to a third party will be covered by a Material Transfer Agreement. The IP issues will be managed by DAFWA’s IP office in consultation with the GRDC.

**Additional information**


A link to more recent research is provided at [http://www.lupins.org](http://www.lupins.org)