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Breeding *Phomopsis*-resistant lupins

By John Gladstones, Principal Plant Breeder (Lupins)

The release of Gungurru and Yorrel lupins marks the coming of age of the narrow-leafed lupin as a crop plant. These are the first cultivars of the species to have substantial resistance to *Phomopsis* stem blight, which will make the stubbles much safer for grazing stock. (See “Economic impact of growing *Phomopsis*-resistant lupins” on page 8 of this Journal). Resistance to *Phomopsis*, combined in the case of Gungurru with higher yield and improved field characteristics for medium and high rainfall areas, means that reasonably satisfactory lupin cultivars are now available for most agricultural areas of Western Australia.

This article describes the new lupins, their background, and how they were bred. It also acknowledges the contributions of colleagues who helped in important ways.

Breeding background

The breeding in Western Australia of the first crop cultivars of narrow-leafed lupin (*Lupinus angustifolius*) was described in the Journal of Agriculture in 1982. That issue covered their development up to the release of the cultivars Marri, Illyarrie, Yandee and Chittick, which are resistant to grey leaf spot, and which were bred in collaboration with colleagues in the United States Department of Agriculture.

By the time those cultivars were released, further breeding in Western Australia for resistance to *Phomopsis* stem blight was already well in progress. But the research underlying this breeding started much earlier.

**Phomopsis stem blight and lupinosis**

German research workers in the late 19th century suspected that lupinosis was caused by a toxin produced by a fungus growing in, or on, the lupins; but early attempts there, and later in Australia, failed to identify a causal fungus. By 1966 Dr M.R. Gardiner and A. Bokor, of the Western Australian Department of Agriculture, had narrowed the likely suspects to two: Pleospora and *Phomopsis*. However they, too, were unable to establish a clear link at the time.

The breakthrough came in 1970 when K.T. van Warmelo and colleagues in South Africa, and Gardiner, together with D.S. Petterson and P. McR. Wood in the Western Australian Department of Agriculture, simultaneously proved that the agent is *Phomopsis leptostromiformis*, a fungus which grows mainly in the maturing lupin stems. Research workers knew little about the fungus at the time, but the finding immediately raised the possibility that lupinosis could be avoided by breeding for fungal resistance in the plants.

Studies by Department of Agriculture plant pathologist P. McR. Wood over the next five years progressively built up a picture of the fungus, and of the disease and its epidemiology. By 1976 he was able to devise a practical and consistent method of scoring the amount of disease present. Co-operative studies with Department of Agriculture toxicologist D.S. Petterson, and later with veterinary pathologist J.G. Allen, established a broad relationship between the stem blight score and potential for the stubbles to become toxic.

All commercial lupin cultivars proved to be susceptible and potentially toxic, with the part exception of those of the true white lupin (*L. albus*), of which the cultivar Ultra had been released in Western Australia in 1976.
However, *L. albus* grows best on well drained, fertile soils and this requirement restricts its use in Western Australia.

**Breeding narrow-leafed lupins for resistance**

To breed for resistance to a disease, plant breeders need to have both genetic sources of resistance and reliable methods for scoring infection. Neither was available in 1970. Breeding up to then had been based mainly on a narrow range of mutant selections from existing semi-domesticated lupin cultivars, such as cultivar New Zealand Blue. The likelihood of finding resistance within this material was remote.

I had already collected wild narrow-leafed lupins throughout southern Italy in 1968, with a view to gaining new material for breeding in general. In 1970-72, I crossed and intercrossed a selection of these and of other available wild types with the most advanced Australian breeding lines of the time. Some of the domesticated breeding lines derived from these crosses later proved to have partial resistance to both Phomopsis stem blight and brown leaf spot, as well as some apparent resistance to drought. However several unfavourable characteristics, including unacceptably high trace levels of alkaloids in the seeds, ultimately precluded their commercial release. Their role was therefore confined to that of parents for further breeding.

Gungurru has an erect stiff stem, relatively short branches, dark, rather dull green foliage and pink-tinged flowers. It has an excellent set of stubby, tightly-filled pods, particularly on the primary flower spike, which resist shattering well.

The discovery of the link between Phomopsis and lupinosis in 1970 was one of the factors which spurred further searches for new wild material to use in breeding. In 1973, I undertook a comprehensive collecting trip through Morocco, Tunisia, Spain and Portugal, where (with the exception of Tunisia, as it turned out) narrow-leafed lupins are common on suitable soils as a wild or semi-wild plant. Dr I. Forbes Jr., of the United States Department of Agriculture, accompanied me on the North African part of the trip.

After sorting and screening this material for potentially useful characteristics for breeding (Gladstones and Crosbie, 1979), I crossed 31 diverse wild lines in 1975 with cultivar Marri and with early-generation forebears of cultivar Illyarrie. Gungurru and Yorrel both came directly from these crosses: Gungurru from a cross of Illyarrie with a wild type from southern Spain, and Yorrel from a cross of Illyarrie with a Moroccan wild type.

Yorrel (centre plot) matures normally under drought stress compared with Yandee (left) and Gungurru, both of which dry off while still relatively green.
Selection during the first few years after crossing was necessarily devoted to eliminating unwanted wild characteristics from the progeny, including high alkaloid content, late maturity, shattering pods, hard-seededness, blue flowers and dark-coloured seeds. This entailed screening through large populations to isolate, and then purify, the few individuals and their progeny which combined all the essential characteristics of crop plants. It was not until 1980 that a series of more-or-less true breeding, fully crop-type lines could be assembled.

Throughout this process, and through subsequent field testing for yield and adaptation, I also selected as far as possible for good pod set, erect growth and resistance to lodging, and resistance to aphids and diseases generally. The main criterion of disease resistance was clean stems and pods at maturity, which simultaneously meant potential resistance to grey leaf spot, brown leaf spot and Phomopsis stem blight. Up to 1980, field tests were at the Department of Agriculture's Vegetable Research Station at Medina, where the incidence of these diseases varied from year to year. Phomopsis stem blight was never prominent, so I was unable to tell at the time how much of the apparent resistance was to Phomopsis stem blight.

The first small-plot yield trials of this material at research stations in the main agricultural areas started in 1981. In that year P. McR. Wood, together with Dr J. Hamblin (who had been appointed in 1976 to breed lupins specifically for disease resistance), did detailed ratings of stem blight symptoms on all breeding lines and control cultivars in the trials. Dr W. A. Cowling was appointed to replace Dr Hamblin in 1982, and took over main responsibility for the Phomopsis ratings over the next few years.

These three scientists found that resistance was indeed present in some of the breeding lines, and that there appeared to be good consistency of resistance across environments. Hamblin and Wood had meantime already established, in screening trials at Perth, that resistance was present in some of the wild parents used in the original crossing, and also in some which had not been used. Resistance in the wild types appeared to be no stronger than that in the best crop-type derivatives, if as strong, so it was clear that the wild-type resistance had been fully transferred.

**GUNGURRU** lupin

Gungurru narrow-leafed lupin was bred from a cross between Illyarrie and P22750, a wild type of the species collected in southern Spain in 1973. It was tested under the code names 75A61-3 and 75A:261.

Gungurru is shorter than previous cultivars and has an erect, stiff stem and relatively short branches which turn brown at maturity. The foliage is dark, rather dull green, and the flowers distinctively pink-tinged. It flowers at the same time as Illyarrie, Yandee and Danja, or up to two days earlier.

The cultivar has an excellent set of stubby, tightly-filled pods, particularly on the primary flower spike, which resist shattering well. Because of its erect habit and outstanding resistance to lodging, Gungurru is less affected by spring winds and is easier to harvest than previously released cultivars.

Seeds are round, the same size as Danja (that is, about 10 per cent smaller than Illyarrie and Yandee) and have strong brown markings including a distinctive strong triangular mark just above the seed attachment. Seed protein content averages 1.0 per cent higher than in Illyarrie, Yandee and Danja. Alkaloid content of the seeds is significantly lower (average about 0.013 per cent vs. 0.018-0.020 per cent).

In more than 140 yield trials to 1987, Gungurru has averaged 105 per cent of Danja's yield in the medium and higher rainfall zones (average annual rainfall over 325 mm) but only 95 per cent in the low rainfall zone (less than 325 mm). Observations have suggested that it is more sensitive to drought, but more tolerant of waterlogging.

Gungurru is expected to become the dominant lupin in Western Australia's medium and high rainfall zones over the next few years by virtue of its superior yield, field characteristics, seed quality and moderately strong resistance to Phomopsis stem blight. Its Phomopsis resistance should make the stubbles relatively safe for grazing, which will be a particular advantage in south-west areas where lupinosis has largely precluded lupin growing in the past. However, the resistance is not absolute, and management precautions to avoid lupinosis will still be needed.
Yorrel narrow-leafed lupin came from a cross between Illyarrie and P22872, a wild type of the species collected in Morocco in 1973, and was tested under the code names 75A45-10 and 75A:259.

It is lighter green than previous cultivars, with tall early growth and a rather sprawling habit later. The pods are large, often set irregularly along the spikes. Stems and pods turn bright golden brown at maturity. The seeds are large (about the same as Illyarrie and Yandee) and slightly flattened, with brown markings as in Gungurru but a much weaker triangular marking above the seed attachment.

Yorrel is the earliest-maturing narrow-leafed lupin cultivar yet, flowering and maturing five to six days earlier than Illyarrie, Yandee, Danja and Gungurru. It has superior drought resistance and may mature better than previous cultivars on some medium and heavy soils. Other advantages are good resistance to Phomopsis stem blight, which has less tendency than that of Gungurru to fail under drought stress, and very low seed alkaloid content (average less than 0.010 per cent) which could suit it to specialist human consumption markets and to pig feeding.

Against these factors, Yorrel has three weaknesses.

- It is highly susceptible to aphids, normally escaping them only in the eastern wheatbelt.
- It lodges readily in heavy crops and in high rainfall areas.
- It grows and yields poorly on deep sands or on any soil low in phosphate, where it suffers readily from brown leaf spot.

For these reasons Yorrel is recommended only as a cultivar with good Phomopsis resistance for duplex and medium soils of the eastern wheatbelt (north central, central and south central low rainfall areas). Gungurru is preferable throughout the medium and high rainfall zones and in the northern and southern low rainfall areas. Danja or possibly Gungurru (with an early break of the season) grows better than Yorrel on light sands and low-phosphate soils in the eastern wheatbelt. Yorrel should be replaced by an improved cultivar with more general adaptation for the eastern wheatbelt in about six years.

Collaborative studies between W.A. Cowling, P.McR. Wood (plant pathology) and J.G. Allen (veterinary pathology) have since greatly extended our knowledge of Phomopsis, of plant resistance to it, and of the effects of plant resistance in reducing potential toxicity (Cowling et al., 1986, 1987, 1988).

Other prospective cultivars

A third Phomopsis-resistant line from the 1975 crosses is to be released in South Australia in 1989 under the name Warrah. It has been the highest yielding of the crossbreds in that State, particularly in the long-season areas of the south-east. In Western Australian trials Warrah (code named 75A:260) has approached Gungurru in yield only in high rainfall areas, where it remains under test. Such early release of a regionally adapted cultivar elsewhere in Australia has been made possible by a collaborative programme of interstate testing (Gladstones, 1982). Promising breeding lines from the parent Western Australian programme are supplied to other Departments of Agriculture for evaluation from a relatively early testing stage.

We accelerated the breeding and seed increase of Gungurru, Yorrel and Warrah to allow their early release, two years ahead of the normal breeding schedule. This was done by omitting the normal advanced-generation re-selection of single plants, which produces fully true-breeding progenies. A result, in the cases of Gungurru and Warrah, is that these cultivars contain a small amount of residual variation within the populations, most notably in growth habit. We took a further series of single plants from them, and selected progenies of these are now under Australia-wide trial. Some of the Gungurru reselections have shown promise of surpassing their parent. If this is confirmed, the best will be released about 1991 as a direct replacement for Gungurru.

Further breeding

Lupin breeding in the Western Australian Department of Agriculture now comprises two streams, having different approaches but both incorporating resistance to Phomopsis stem blight as a major selection criterion.

- The continuing 'general' programme (Gladstones). This works mainly within the gene pool created by the 1970-72 and 1975 crosses with wild types, and places primary emphasis on yield and on wider adaptation than that of
previously released cultivars. I am selecting for resistance to disease and aphid attack where these occur naturally in the breeding rows (now at Badgingarra Research Station) and in yield trials. The approach is effective for Phomopsis stem blight because that occurs more or less universally. It is also effective to some extent for brown leaf spot, but less so for other diseases.

- The ‘disease resistance’ programme (Cowling), in which disease resistance is the primary selection criterion and testing for yield and other field characters follows. This programme also seeks an understanding of the inheritance of resistance, quicker and more efficient techniques for selection in the glasshouse and laboratory, and new sources of resistance among the original and more recently collected wild material. The main current emphasis is on Phomopsis stem blight and brown leaf spot (Pleiochaeta setosa), together with Pleiochaeta root rot and Rhizoctonia root and hypocotyl rots. Resistance to cucumber mosaic virus and bean yellow mosaic virus is also being investigated.

These complementary, but interlinking, approaches should between them give the best chance of continued rapid genetic improvement. On present indications we believe there are good prospects for release, by the mid 1990s, of one or more improved, early maturing, Phomopsis-resistant cultivars to replace Yorrel in the eastern wheatbelt, and perhaps of cultivars with enhanced resistance to brown leaf spot and viruses. The genetic material available gives promise of continued improvement in narrow-leaved lupins for many years to come.

Acknowledgements

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References


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Yorrel makes tall early growth and a rather sprawling habit later. Pods are large, long, often set irregularly along the spikes.