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Breeding lupins in Western Australia

By J. S. Gladstones,
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Background to Western Australian breeding

I started studying lupins at the University of Western Australia in 1954 as part of a post-graduate research programme, at the suggestion of the late Mr A. M. Stewart, then Reader in Agriculture and Assistant Director of the Institute of Agriculture at the University. Andrew Stewart was a practical farmer as well as an academic. He had personal experience of lupins and their ability to grow on poor soils. He also had many farming friends on whose properties lupins thrived. He had heard of the new sweet cultivars that had been developed in Germany, and felt sure that some must have potential for growing in Western Australia.

The first studies extended from 1954 to 1958. Although some of the sweet cultivars available grew well, all proved to have serious shortcomings for commercial use.

Of the cultivars of the two species from which true crop lupins had been developed by then, sweet *Lupinus luteus* types were very susceptible to various insect pests. Even if these were controlled, yields were disappointing except, occasionally, in high-rainfall areas. *L. albus* cultivars grew and yielded well on fertile, well-drained loamy soils, given adequate rainfall; but they were hopeless on the sands on which farmers and advisers then wished to grow lupins.

The University released two European cultivars, Weiko III (*L. luteus*) and Borre (*L. angustifolius*) in 1959, but neither had much commercial success. Weiko III was grown on a small scale in the early and mid-1960s to supply poultry feed compounders, but the economics of its cultivation were marginal at best. Borre was used to a small extent for fattening sheep in summer in high-rainfall south-west districts, but suffered because of its pod-shattering and the fact that it was too easily confused with the bitter cultivar New Zealand Blue.

However, early research suggested that *L. angustifolius* was well adapted to many Western Australian soils and climates. And all Western Australians knew already how well *L. consertinii* was adapted to sandy soils in the West Midlands and Geraldton districts... but as yet no genetic improvement of that species had been attempted.

This was the background to the decision, taken in 1960, to undertake a serious breeding programme with these two species.

Building on genetic studies at the Institute of Agriculture during 1954 to '58, the programme continued there throughout 1960 to 1971, and from 1971 onwards in the Western Australian Department of Agriculture. Throughout the University period (1954 to 1971) the programme was supported entirely...
by funds voted by the Wheat Industry Research Committee of Western Australia.

*L. angustifolius*

The immediate requirements for the narrow-leaved lupin were, firstly, to overcome pod-shattering or at least to delay it long enough for mechanical harvesting; and secondly, to breed cultivars early maturing enough for the State’s main cropping areas.

Extensive field screening for non-shattering pods was carried out in December 1960 among commercial stands of the cultivar New Zealand Blue, after all normal plants had fully shed. Two identical healthy plants with pods which had not shattered were found in a 20 ha crop at Kooyonga. Also a single non-shattered plant, looking clearly different, was found in a small planting of New Zealand Blue at the University Field Station, Shenton Park. Both types bred true. In each case, pod shattering was slowed markedly, but not entirely prevented.

Crossing studies showed that each type resulted from a single recessive mutant gene. When combined in the same genotype, they proved to be complementary in action, resulting in pods which were virtually non-shattering.

Commercial crops were screened for early-flowering mutants in the spring of 1961 while they were still at the bud stage. A single plant in a crop of Borre grown by Mr A. E. Henderson at Kulkyne, near Boyup Brook, flowered much earlier than the others. The plant was marked and its seeds collected. Again, it bred true. Earliness was found to be controlled by a single dominant gene which has been named *Ku*. Later studies showed that earliness results from removing the plant’s normal need to be exposed to prolonged winter cold ... a process known as vernalisation ... before flower formation is triggered.

Inter-crossing among these selections and a sweet, white-flowered crossbred which had been developed as part of the preliminary genetic studies led successively to the selection and release of:

- Uniwhite, released in 1967, which was white flowered and seeded, late flowering, and had reduced pod shattering;
- Uniharvest (1971), which was similar but non-shattering; and
- Unicrop (1973), which was similar to Uniharvest but early-flowering.

These were the world’s first true crop cultivars of the narrow-leaved lupin.

Contact with the United States Department of Agriculture group at Tifton, Georgia (see Part 2 of this series) in 1963 launched the second phase of the breeding programme, which, for Western Australia, was designed to incorporate resistance to the diseases grey leaf spot and anthracnose into cultivars otherwise similar to Uniharvest and Unicrop.

At first, neither disease had been recognised in Western Australia. However, in the early and mid 1970s after Uniharvest and Unicrop had been released, grey leaf spot proved indeed to be present and at times extremely serious in near-coastal districts. Anthracnose has not appeared yet as a significant disease under Western Australian conditions, but we cannot discount the possibility of it becoming so.

The double-resistant American cultivar Rancher was crossed with an early-generation forebear of Uniharvest in 1966. The system used was to make the crosses and grow the first and second crossbred generations in Western Australia, selecting only fully non-shattering plants in the second (F2) generation. Immediately after harvest, half the seed of each of the several hundred selected plants was flown to the U.S.A. under quarantine supervision. Glasshouse tests for resistance to the two diseases were carried out there during the northern winter.

Notification of the results came early enough for those lines which were apparently resistant to both diseases to be sown again in Western Australia in May. At the end of the season these were checked for field incidence of locally occurring grey leaf spot and for genetic purity for characters such as non-shattering pods. Then seeds harvested from individual plants from the satisfactory lines were sent back to the U.S.A. for repeat winter screening in the glasshouse.

After further similar checks the following year, the families confirmed as being fully non-shattering and resistant to both diseases were combined and increased to become the cultivar Marri.

Marri was crossed then with Unicrop, and the progeny screened in the same way to produce the resistant early-flowering cultivars Illyarrie and Yandee.

The recently-released grey leaf-spot resistant midseason cultivar Chittick represents a further development of this breeding phase, but this was done entirely in Western Australia. Screening for resistance for grey leaf-spot was carried out under natural epidemic in the field.

A major problem with early-flowering cultivars such as Unicrop, Illyarrie and Yandee is that when sown very early they come into flower too early. Because flower formation does not have to wait for winter’s low temperatures before it is triggered, plants sown in early or mid-April can flower by late May or June, while still quite small. These early flowers are liable to be frosted in cold districts. Even if they escape frosts, the pods they set are deep in the plant canopy where they are strongly shaded. They often develop poorly, and are subject to infection by fungal organisms which cause rotting or staining of the seeds.

Even without fungal infection of the seeds, early-sown early-flowering cultivars can pose problems at harvesting because the lower pods are close to the ground upwards, must be taken in. For this reason some farmers continued to grow the late but much taller-growing Marri in preference to Unicrop or Illyarrie, despite its demonstrably lower yield and a tendency to lodge badly when sown early.

Farmers needed earlier maturing, higher yielding varieties than Marri, still retaining some vernalisation requirements so that early seeding, which lupins need to give the best yields, does not result in excessively early flowering. Also, lodging resistance was needed.
Breeding to meet these objectives started in 1964, using an alternative genetic source of earliness. The earliness gene chosen was efl, present in the line N4229 which seemed the best of a series of artificially-induced early-flowering mutants selected from the progeny of seeds treated by C. M. Francis with the chemical mutagen ethylene imine (EI) in 1961. The efl gene gives a flowering time about half way between those of the established early and late-flowering cultivars. Through a series of crosses made between 1964 and 1972, that gene was incorporated eventually into lines otherwise equivalent to Marri, Illyarrie and Yandee. Lodging resistance was improved also.

Chittick was released in 1982 and outyields Marri substantially in nearly all situations. It is also an equal or near-equal yielding alternative to Illyarrie and Yandee when sown early (before mid-May) in southern and west coastal high-rainfall districts, without having their problems associated with premature flowering.

Early field experience at Badgingarra Research Station has shown that Chittick is easier and quicker to harvest than Illyarrie and other early-flowering cultivars because of its greater concentration of pods in the upper parts of the plant. But outside the high-rainfall areas, and anywhere when sown late, Chittick is lower-yielding than Illyarrie and Yandee and cannot be recommended.

*L. cosentinii*

No breeding had previously been attempted with this species, and because very little natural genetic variability was available, all the required genetic characteristics had to be sought as natural or artificially-induced mutants.
Studies on artificial production of mutants in the sandplain lupin were started in 1954, using the deep-therapy unit at Royal Perth Hospital to deliver varying X-ray doses to seeds of the common bitter variety cv. Chapman. Among the mutants in the 10 kilorontgen treatment selected the following year was one flowering about 10 days earlier than the parent. This was code-named 10-54-1-10, and the recessive mutant gene responsible for early-flowering, xe. Later research suggested that it advances flowering by relaxing the inhibition on bud initiation imposed by long night-length in mid winter, not by reducing the vernalisation requirement.

Also in 1954, Mr H. W. Box found an early-flowering plant in a paddock of sandplain lupins at Northampton. Earliness in 'Box's Early' results from the effects of a dominant gene, Bo, similar to Ku in L. angustifolius in that it eliminates all apparent vernalisation requirement.

Unfortunately the Bo gene causes excessively early flowering, therefore we have concentrated on using the xe gene for earliness in breeding sandplain lupins.

A major search for natural mutants of L. cosentinii with non-shattering pods was undertaken in November 1961, when some 500ha of dense, mature sandplain lupins were screened in detail on the Erregulla Springs property of the late Sir Eric Smart at Mingewen. As with L. angustifolius, two types of true-breeding plants with reduced shattering were found. Again each type proved to be controlled by a recessive mutant gene, which when combined are complementary in their action. The single genes are rather stronger in their effect than in L. angustifolius, while plants of the double mutant type (co, ma) can hold their pods and seeds right through summer without loss.

Sweetness... freedom from alkaloids... was sought both from natural mutation among naturalised L. cosentinii stands, mainly around Perth, and in the progeny of 10-54-1-10 seeds treated with the chemical mutagen ethyl methane sulphonate (EMS) in 1962 and 1963. No sweet plants were found among some 220,000 individually tested in the naturalised groups, but in the mutagen-treated groups we found three separate recessive mutants with almost complete freedom from alkaloids, plus several more with variably reduced alkaloid levels.

Two lines which looked fully normal in their vigor and fertility were chosen for parallel use in further breeding, one fully sweet and the other retaining a small amount of alkaloid—about 10 to 15 per cent of the normal level. This was done as an insurance because, at an early stage, the fully sweet lines were seen to be very susceptible to aphids and red-legged earth mites... presumably because their trace alkaloid contents are even lower than in sweet L. angustifolius or L. albus. Whether insect susceptibility will be a serious limitation to commercial use remains to be proved, but offsetting advantages may exist in their very low seed alkaloid levels, such as for pig feeding or human consumption.

Finally, a range of both naturally-occurring and artificially-induced mutant genes were selected to give various flower, seed and stem colour combinations. The artificially-induced recessive gene ws was chosen as the most satisfactory to use as a marker for fully sweet cultivars. This gene gives white flowers, near-white seeds, and a lack of anthocyanin pigmentation on the stems and leaves.

The final fixed crossbred CB49, combining all these characteristics, has been registered as cultivar Erregulla but has not yet been released commercially. It has all the characteristics required of a crop plant except soft-seededness, needed to ensure immediate germination. There is a possibility that the hard-seededness of Erregulla can be turned to advantage in suitable environments in a system of self-regenerating lupins alternating with cereal crops, provided that weeds in the lupins can be controlled satisfactorily by selective herbicide sprays. Trials are under way in the Geraldton district.

Meanwhile we have sought soft-seededness in L. cosentinii, both from naturalised groups and from new mutants within Erregulla. Extensive screening of naturalised lupins has been unsuccessful so far. However one line selected out of seeds harvested from Erregulla grown at Badgingarra Research Station has proved to be fully soft-seeded. But its permeability results from a fairly gross abnormality in the seed coat, so adverse effects on yield or other agronomic quantities are possible. The line is now being increased for field-scale evaluation. As yet we cannot predict whether it will be commercially useful.

**Future challenges**

Narrow-leaved lupin breeding so far has been concerned with its initial domestication (phase 1), followed in phase 2 by the introduction of resistance to grey leaf spot and anthracnose, cold resistance (USA), and some modification of flowering time. Phase 3 now tackles the far more complex problems of increasing yield capacity as such, widening adaptation, and finding and incorporating resistance to various other diseases. Inevitably, diseases will emerge increasingly as limiting factors as lupins are grown more widely and more intensively in farm rotations.

The main emphasis in the breeding strategy of phase 3 is on crosses with wild narrow-leaved lupin strains collected throughout the species natural Mediterranean habitat, together with some of the green manuring and forage cultivars from the USSR and Poland which are also proving to be a useful genetic source. The introductions are screened initially for their potential contributions to genetic improvement though such characteristics as better pod set; high seed oil or protein contents; different growth habits, such as less branching; better growth under low winter temperatures; new genes for early flowering and maturity to give a wider range of maturity types; adaptation to a wider range of soil types, including heavier and more saline soils; and most importantly, resistance to various diseases including the root and stem rots, brown spot, and especially the fungus Phomopsis leptostromiformis which produces the lupinosis toxin.

Initial indications have been quite promising, especially for improved resistance to Phomopsis. Researchers hope, but have not yet proved, that this will mean a lower risk of toxicity.