Phomopsis-resistant lupins: breakthrough towards the control of lupinosis

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Attempts to control lupinosis in sheep have been thwarted by the unpredictable occurrence of the disease in the field. The complex interaction of the toxin-producing fungus (Phomopsis leptostromiformis) with its host (the lupin plant), together with variable weather and paddock grazing conditions, have made it difficult to predict when stock are in danger of contracting the disease. The risk of lupinosis discourages many farmers from growing lupins, despite the many potential benefits of including them in crop rotations.

A team of Department of Agriculture plant breeders, plant pathologists, and animal scientists set out in the mid 1970s to find resistance to the Phomopsis fungus in lupins. Their goal was to find resistance that prevented the fungus from colonising and producing toxin in lupin stubbles. A decade of work has culminated in the development of lupin breeding lines with low visible symptoms of Phomopsis in the stubble and, most importantly, low stubble toxicity. This article summarises the long-term research programme.

Resistance to stubble colonisation and toxin production

The narrow-leaved lupin (Lupinus angustifolius) was already considered 'resistant' to Phomopsis stem blight, the name by which the disease was known in more susceptible species such as L. luteus. The disease in the narrow-leaved lupin was rarely seen on green healthy plants in the field (Wood and Brown, 1975), and could not be reproduced in the glasshouse unless plants were deliberately wounded (A.G.P. Brown, personal communication).

Symptoms of colonisation by Phomopsis normally appear as purplish-black lesions on stems as plants die at the end of the growing season. Small black fruiting bodies inside these lesions develop at varying rates depending on rainfall and humidity during the summer. P. leptostromiformis causes little damage to the growing lupin plant. Occasionally symptoms are seen on growing plants before they mature, but only if they are predisposed by injury such as frost, drought, or herbicide damage (Cowling et al., 1984).

Unfortunately, this resistance to Phomopsis stem blight in the narrow-leaved lupin was not enough to prevent the fungus colonising stubble and producing toxin. For this reason a higher level of resistance was required. The search began for lupin strains that displayed less Phomopsis stem blight after senescence, and Department of Agriculture plant pathologists developed a visual rating method to assess the severity of Phomopsis symptoms (Wood and Allen, 1980). The level of resistance needed to reduce stubble toxicity was not known at this stage.
search for resistance

The search for resistance to Phomopsis stem blight in the narrow-leaved lupin began with wild relatives of the sweet (low-alkaloid) varieties. More than 250 accessions of wild *L. angustifolius* were available in 1975; most of these were collected by J. S. Gladstones in the western Mediterranean (Gladstones and Crosbie, 1979). Resistance to Phomopsis was one of several characters Gladstones sought when he crossed these wild lupins with cultivated varieties in 1975 and 1976 (Gladstones, 1982).

J. Hamblin joined the lupin breeding group in 1976 and he and P. McR. Wood screened the wild lupin collection for resistance. In 1977, they assessed 254 wild lupin strains for Phomopsis symptoms in early and late summer at two sites. The wild lupins possessed a wide range of resistance, and many were more resistant than existing cultivars (Figure 1). The ratings for Phomopsis symptoms did not change greatly from early to late summer.

The results encouraged the team to assess Phomopsis resistance in the offspring of crosses with these wild lupins.

Many generations of re-selection were needed to extract fully-domesticated lines from the 1975 crosses with wild lupins, and it was not until 1981 that the first of the cross-bred lupins were available for testing in small plots. In that year, more than 230 cross-bred lines and cultivars were rated at two sites for Phomopsis stem symptoms at harvest, and some lines had significantly fewer symptoms than the susceptible cultivars.

These results were verified in 1982 and 1983, when more than 15,000 lupin breeding plots were rated for Phomopsis symptoms by W.A. Cowling, F. O’Donnell and P. McR. Wood. Highly resistant lines maintained their resistance at all sites during the three years, and heritability estimates were high (H = 0.92 to 0.94), indicating strong genetic control of resistance. Some lines expressed less than one-tenth of the Phomopsis symptoms in the susceptible cultivars (Figure 2).

The resistant lines have been assessed at several sites in Western Australia, South Australia, Victoria and New South Wales, with highly consistent results. As the amount of seed available for the Phomopsis-resistant lupins increased, and larger areas were planted, stem symptoms on the resistant lupins decreased relative to the susceptible cultivars. If this trend continues, the value of these lupins in the paddock may be greater than appears from small plot trials.
Testing for toxicity

The consistent and encouraging results prompted an early start to toxicity testing. In 1983 small plots of resistant breeding lines and susceptible cultivars were grown at three sites and the stubble was collected, tested for toxicity and pen fed to sheep by J. G. Allen during early and late summer.

The Phomopsis-resistant lupins had fewer symptoms of Phomopsis at harvest, although symptoms increased during the summer (Figure 3a). Phomopsis was isolated at high frequency from the susceptible lupin stubble and at surprisingly high frequency from resistant stubble (Figure 3b). Despite the presence of the fungus in the stubble of the resistant lupins, and its increasing colonisation of the stubbles during summer, resistant lupins remained significantly less toxic than the susceptible cultivars (Figure 3c).

Toxicity tests repeated during the summer of 1984-85 confirmed that the toxicity of stubble from Phomopsis-resistant lupins was much lower overall than stubble from susceptible cultivars. The first large-scale grazing trials were conducted during the summer of 1985-86. The results suggested that the 'safe grazing period' was extended considerably through the use of Phomopsis-resistant lupins.

Nature of resistance

When the research team set out to select lupins that were less likely to produce lupinosis in grazing livestock, they chose lines with fewer symptoms of Phomopsis, assuming that they would be less toxic. So far this has been true, despite the relatively high frequency of isolation of Phomopsis.
Phomopsis infection in a lupin crop.

A potential new lupin variety which is resistant to Phomopsis.

from resistant lupin stubble. The fungus may be present inside the stems of resistant lupin stubble, but it appears to be restricted and slowed in its colonisation of the stubble.

Nevertheless, the fungus did reproduce in resistant stubbles late in summer. This is encouraging, as it may indicate that the life cycle of the fungus is not seriously interrupted by this new type of resistance. If the processes of infection and reproduction are not interrupted, there should be little natural selection pressure for increased virulence in the fungus.

Studies have started to determine the genetic control of resistance and the effect of resistance on infection and colonisation of lupin plants by Phomopsis. A better understanding of the mode of action of the resistance genes may lead to quicker and easier tests for resistance in cross-bred lupins, and the eventual elimination of lupinosis.

Pod and seed infection by Phomopsis

Preliminary observations on pod and seed infection by Phomopsis in resistant lupins have been promising. Occasionally pod and seed infection was severe in the variety trials, and in all cases, the Phomopsis-resistant lines had fewer pod lesions and less seed discolouration by Phomopsis than the susceptible varieties. Less Phomopsis was isolated from seed of resistant lupins.

In a trial in 1985 to test resistance to pod infection, plots were sprinkler-irrigated late in the growing season to promote the disease. The resistant breeding lines showed fewer symptoms of pod and seed infection than the susceptible controls.

Conclusions

Phomopsis-resistant lupins offer the prospect of extended periods of safe grazing of lupin stubbles in southern Australia. The potential benefits of lupins may in the future be enjoyed by farmers in regions where lupinosis has limited their acceptance in the past. The development of Phomopsis-resistant lupins has been a team effort, and further teamwork is required to confirm the usefulness of resistant lupins in farmers' paddocks, to discover how the resistance works to reduce toxicity in stubbles, and to determine the genetic control of resistance.

References


