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Roger Jones

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Bean Yellow Mosaic Virus in Lupins

Bean yellow mosaic virus (BYMV) is a threat to lupin crops in high rainfall areas of southwestern Australia, particularly in districts where subterranean clover pastures are prevalent. The disease it causes markedly reduces grain yield in all types of lupins. Worldwide it is the most important virus infecting lupins. Roger Jones outlines the symptoms, spread and management of this serious disease.

Occurrence and importance
Bean yellow mosaic virus (BYMV) is a threat to lupin crops in high rainfall agricultural areas of the State (more than 400 millimetres annual rainfall). It also occurs sporadically in medium rainfall regions. The worst affected areas include the south-western corner of the State, the southern half of the wheatbelt including parts of the Katanning, Narrogin and Beverley districts.

BYMV is generally most damaging to lupins in areas where subterranean clover pastures dominate the locality and paddocks are small with large perimeter-to-area ratios. It is especially a problem in years when its aphid vectors arrive early in pastures and are active throughout the growing season, the virus spreading from nearby pastures to lupins.

The causal virus
The BYMV particle can only be seen with an electron microscope. It cannot survive outside a living cell but spreads readily within plants eventually invading the entire infected plant.

Symptoms
Narrow-leaved lupins
When young plants are infected with BYMV by aphids, the virus first causes necrotic streaking of the youngest portion of the shoot, which usually bends over, giving the characteristic 'shepherd's crook' symptom (Photo 2).

The growing tip dies and all leaves become pale, wilt and fall off. Finally, necrosis spreads throughout the plant, blackening the stem and killing the plant. Plants infected early die quickly (Photo 3).

When old plants are infected, the virus can remain localised in some branches producing similar symptoms but without the 'shepherd's crook'. When infection occurs after pod setting, tips of affected shoots die and the pods blacken and fail to fill.

Two other kinds of BYMV symptoms sometimes develop in narrow-leaved lupins. In the first, infection remains restricted to shoot tips, which die off, resulting in stunted growth with already-
formed leaves becoming enlarged, giving them a fleshy appearance (Photo 4).

In the second type, necrotic symptoms do not develop but the plants are stunted with small mottled and deformed tip leaves (Photo 5). Few seeds develop on affected plants with either of these two symptom types.

The ‘non-necrotic’ strain that produces the second type of symptoms was first recognised in 1992 in Western Australia and may be becoming more widespread. Because the plant is not killed it provides a reservoir of infection for further spread by aphids. Thus there is greater potential for current season spread within the crop than with normal necrotic strains.

**Yellow lupins**

Infected yellow lupins show narrowing of leaflets, pallor, vein clearing and faint mosaic on young leaves. The leaflets tend to fold along the midrib and are attached to the petiole at an acute angle giving an ‘upright’ appearance. Early infection sometimes leads to stunted and bunched growth (Photo 6). Mature leaves remain unaffected or develop vein clearing. Infection spreads gradually through the plant causing severe mottle and leaf deformation, decreased leaf size, shedding of leaves and stunting (Photo 7). Early infection results in severe stunting and may kill the plant. Infection reduces seed production greatly.

Seed-borne strains of BYMV have not been found in commercial albus crops in Western Australia.

**Sandplain lupins**

Symptoms of BYMV infection are similar in sandplain lupin to those in albus lupins, but with the growing points developing necrosis in a small proportion of infected plants (Photo 8). Infection reduces seed production greatly. Seed transmission to seedlings has not been recorded in this species.

**Seed-borne strains in lupins**

Seed-borne BYMV strains are a major hazard to yellow lupin production in Europe and lead to the abandonment of the crop in south-eastern USA. Sowing contaminated seed stocks introduces widespread infection within crops, aphids picking up and spreading the virus from plants infected via the seeds.

Such seed-borne strains have been found spreading at lupin breeding sites in Western
Australia. Fortunately, they do not appear to have become established as yet in agricultural areas. As yellow lupins become more widely grown, vigilance is required to avoid this happening through inadvertent release of infected seed stocks.

**Virus spread**

BYMV is endemic in pastures dominated by subterranean clover, especially in high rainfall agricultural areas of Western Australia. The principal source of BYMV for spread to narrow-leaved lupin crops is infected legume plants within these annual pastures.

In late winter or early spring aphids arriving in lupin crops from nearby infected pastures bring the virus with them. They create 'primary infection foci' within the crop. Aphids feeding from these primary foci infect other plants and cause secondary virus spread.

Infection is most pronounced at the edge of a narrow-leaved lupin crop especially at the windward edge, and in thin areas within the crop (Figure 1). Elsewhere infected plants tend to be scattered randomly. Sometimes infection is extensive throughout the crop. Thin crops suffer more from BYMV than dense crops.

Where wide row spacing is used, BYMV infection moves faster along rows rather than across rows.

Similar patterns of BYMV infection are likely in sandplain, albus and yellow lupin crops but with a greater tendency for secondary spread to occur causing expanding infected patches. This is because BYMV does not kill infected plants so they remain as sources for aphids to acquire the virus from and spread it within the crop. With narrow-leaved lupin, these infected source plants are only available for BYMV acquisition by aphids for a brief period between initial infection and plant death.
Persistence outside the growing season

Although not seed-borne in subterranean clover, BYMV is seed-borne at a low level in certain leguminous weeds commonly found in annual pastures, such as cluster, hair's foot and hop clovers and burr medic. It persists over the summer in the soil in their dormant seed. When infected seeds germinate in autumn they give rise to infected plants from which aphids acquire the virus and spread it to healthy plants. During the growing season this results in a gradual build up of infection in subterranean clover and other legumes in the pasture (Photo 9).

Naturalised clovers growing as weeds within lupin crops can also act as sources for spread of BYMV to lupins especially where the field is a former pasture and contains naturalised clovers in which the virus is seed-borne. Subterranean clover weeds that become infected within crops can also act as secondary infection sources for spread to lupins.

Aphid vectors

Aphids need to probe an infected plant for a short time to pick up virus particles and transmit them to a healthy plant when they probe it. They retain the virus for only one or two probes on healthy plants before they lose the ability to transmit it.

The common colonising aphids on clovers in pastures in Western Australia are the bluegreen (Acrithosiphon kondoi) and cowpea (Aphis craccivora) aphids. The spotted clover aphid (Theroaphis trifolii) sometimes also colonises them. Green peach aphids (Myzus persicae) mainly colonise broad-leaved pasture weeds such as capeweed and doublegey rather than clover (Photo 10). Oat (Rhopalosiphum padi) and corn (R. maidis) aphids colonise grasses in pastures. All these species are able to transmit BYMV but green peach aphids are the most efficient.

The aphid species that colonise clovers spread BYMV when they fly from pastures to lupin crops after feeding on BYMV-infected clovers. Species that colonise other plants can also acquire and spread the virus if they probe infected clovers while moving between plants in the pasture and then visit lupin crops next while searching for their preferred hosts.

Green peach, bluegreen and cowpea aphids colonise lupins. These and non-lupin colonising species such as oat and corn aphids that probe lupin plants while in search of their preferred hosts are important for within crop virus spread, especially with yellow, albus and sandplain lupins. Other species that may occasionally play a role in spreading BYMV within lupin crops include two other non-lupin colonising species, turnip aphids (Lipaphis erysimi) flying from wild radish weeds and grain aphids (Sitobion miscanthi) flying from nearby cereals.
Factors influencing virus spread

Available virus source and aphid activity

Spread of BYMV within pastures and from them to adjacent lupin crops is determined mainly by the amount of seed-borne infection in naturalised clovers in the pasture ('primary infection foci'), the earliness of aphid arrival, their numbers, the extent and duration of their activity within the pasture, and the earliness and duration of their flights to adjacent lupin paddocks.

Figure 2: Effect of different plant densities on spread of BYMV into Danja lupin plots. (Site: Avondale). Seeding rates are shown in kilograms per hectare, numbers in brackets are plant densities (plants per square metre).

The time of aphid arrival depends on the climatic conditions during the preceding summer and autumn. Higher than normal summer and autumn rains allow greater numbers of aphids to survive and build up in pastures before spreading to crops while the plants are still young. Dry and hot conditions during the summer and early autumn, decrease aphid survival, resulting in slower virus build up in pastures and later arrival in lupin crops.

Climatic, cultural and environmental factors also affect the establishment of the seed-infected naturalised clover plants within pastures that act as primary sources for spread. These factors also affect aphid landing and occurrence. As a result the extent of BYMV infection varies from site to site and year to year.

Canopy development and plant density

Early development of a canopy of healthy plants within a lupin crop reduces BYMV levels for two reasons:

(i) The presence of continuous ground cover from foliage helps reduce virus spread by altering aphid landing behaviour. Thin and patchy crops are more attractive to incoming aphids, increasing the potential for virus spread.

(ii) Early development of a canopy of healthy lupin plants shades out early BYMV infected plants, thus reducing the numbers of virus sources for secondary spread within the crop.

Early sowing at high seeding rates promotes early canopy development. However, promoting rapid canopy development is less effective in reducing BYMV spread when aphids arrive early in the growing season before a canopy has formed. Significant levels of virus spread may then still occur.

Another method of encouraging early canopy development is sowing lupins at narrow rather than wide row spacing. Our research has shown that BYMV spread is greater with wide than narrow rows. Banding of superphosphate fertiliser below the seed can also promote early growth and canopy development, consequently diminishing virus spread. However, sowing restricted branching lupins, may promote BYMV spread because of their more open growth habit.

In addition to promoting canopy development, sowing at high seeding rates to obtain a high plant density has a dilution effect reducing the level of infection by decreasing the proportion of primary infection foci in relation to total plant numbers (Figure 2). Also, there are more healthy plants in close proximity to early BYMV-infected plants to compete with them and shade them out, thereby tending to remove them as sources for secondary virus spread.

Stubble retention

A ground cover of retained stubble repels aphids and reduces the spread of BYMV in lupins (Figure 3). The amount of stubble present determines the extent of reduction obtained.

The benefit of retained stubble in decreasing the spread of BYMV is most likely to be evident during seasons with early virus spread and when wide row spacing is used. Once canopy closure occurs the effect disappears. As the practice of sowing lupins with wide row spacing continues to be adopted, it is important to maintain a high level of stubble cover with wide row spacing.

Crop perimeter

Because BYMV spreading to lupin crops from adjacent pasture builds up first in the edge of the crop, a greater proportion of the crop is infected with BYMV if the paddock has a large perimeter to area ratio and if it is surrounded by pasture.

A cereal border about 15 metres wide all round the crop reduces BYMV spread because cereals are a non-host of the virus. As incoming aphids probe the cereals in search of their preferred hosts, they lose the virus from their
Table 1. Effect of 15 metres wide cereal versus fallow borders on spread of bean yellow mosaic virus into Danja lupin plots.

<table>
<thead>
<tr>
<th>Border</th>
<th>Narrogin</th>
<th>Avondale</th>
<th>Mt Barker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal</td>
<td>58 *</td>
<td>37</td>
<td>19</td>
</tr>
<tr>
<td>Fallow</td>
<td>119</td>
<td>72</td>
<td>42</td>
</tr>
</tbody>
</table>

* Figures are numbers of BYMV infected plants/plot.

mouthparts before they reach the lupins (Table 1).

**Mixed cropping**

BYMV spread into mixed narrow-leaved lupin and oat plots (1:3:1:5, lupins:oats) was decreased by 76-97% in field experiments at Avondale and Mt Barker. The explanation is that (i) the dense canopy that rapidly formed reduced the numbers of aphids landing, and (ii), when incoming aphids probed the non-host cereal before probing lupins, they lost the virus.

**Insecticides**

Use of insecticides to decrease numbers of aphid vectors has not been tried in Western Australia as a method of control for BYMV in lupins. However, in general, carbamate and organophosphorus insecticides are not very effective in controlling spread of non-persistently aphid-transmitted viruses like BYMV in crops. Also, resistance to organophosphorus, carbamate and pyrethroid chemicals has been identified in green peach aphids on lupins in Western Australia and this species is a key BYMV vector.

Currently we are testing the effectiveness of perimeter spraying with a pyrethroid and imidocloprid (which belongs to a different class of chemical to which green peach aphids have not yet developed resistance) to see if they are worthwhile for growers to use to reduce BYMV spread into narrow-leaved lupins crops.

**Yield losses**

Regardless of stage of growth at which it occurs, infection of narrow-leaved lupin with BYMV almost completely prevents seed production or kills developing seeds. However, when very mature plants become infected, the virus does not spread to all branches or enter fully developed seeds.

By the end of the growing season narrow-leaved lupin crops growing in high BYMV risk areas are usually only partially infected. At low plant density, where compensatory growth of neighbouring healthy plants is minimal, percentage yield loss can sometimes be so severe that it is the same as the percentage of plants infected (Table 2). In contrast, in partially infected crops with high plant densities or where early sowing boosts plant development, compensatory growth by neighbouring healthy plants tends to occupy the space left by plants killed by BYMV resulting in smaller overall losses.

When a high proportion of plants are infected and spread occurs early, grain yield is also markedly decreased in infected albus, yellow and sandplain lupins. Based on overseas work, yellow lupins are particularly liable to have widespread BYMV infection and substantial losses in grain yield caused by the virus.

**Virus resistance**

Different breeding lines and varieties of narrow-leaved lupins vary from being very susceptible to infection with BYMV by aphids through to relatively resistant. Sandplain and yellow lupins tend to be very susceptible but albus lupins are mostly rather resistant.

High levels of resistance to BYMV infection by aphids are being screened for in Western Australia in the national lupin breeding program. Albus lupin cv. Amiga is
Table 2. Effect of BYMV on yield of Gungurru lupins (Site: Badgingarra). The field experiment was sown at low seeding rates to generate low plant densities and thereby promote BYMV spread. Straw mulch groundcover (2 tonnes/ha) was added to half the plots to suppress BYMV spread and create two levels of infection. *

<table>
<thead>
<tr>
<th>Seeding rates in kg/ha</th>
<th>Minus straw, grain yield in tonnes/ha</th>
<th>Plus straw, grain yield in tonnes/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.89 (20%)</td>
<td>1.19 (7%)</td>
</tr>
<tr>
<td>60</td>
<td>1.46 (12%)</td>
<td>1.75 (3%)</td>
</tr>
</tbody>
</table>

* Figures in brackets are levels of BYMV infection recorded at final scoring of the plots.

an example of a line with good resistance of this type.

Genetic engineering for BYMV resistance in narrow-leaved and yellow lupins is underway at the State Agricultural Biotechnology Centre at Murdoch University as part of project within the Cooperative Research Centre for Legumes in Mediterranean Agriculture (CLIMA). This project has already produced transgenic plants of narrow-leaved lupins such as Kalya and Merrit, and yellow lupins such as Teo and Merrit containing synthetic resistance constructs to BYMV.

**Integrated control measures**

Management of BYMV spread in lupin crops requires an integrated approach involving several different measures:

- **Narrow-leaved lupins**
  - Encourage early canopy development

  Obtain a dense canopy as early as possible in the life of the crop by sowing early at high seeding rates. This is the most important control measure. Early sowing at high seeding rates (at least 100 kilograms per hectare) helps to achieve this. Aim for a density of 45 or more plants per square metre. Wherever possible, use narrow row spacing to speed up canopy development or, when wide row spacing is used, band superphosphate below the seed to promote foliage growth.

  - Retain stubble

  When aphids arrive before canopy closure, a ground cover of

  retained stubble helps to deter incoming aphids from landing and spreading BYMV.
  - Plant cereal borders around the crop perimeter

  A cereal border 15 metres or more wide reduces BYMV spread because cereals are a non-host of the virus and infection builds up initially at the edge of the lupin crop.

  - Avoid paddocks with a large perimeter:area ratio.

  If surrounded by pasture, a large perimeter to area ratio will result in a greater proportion of the crop having BYMV infection.

Heavy grazing of adjacent pasture to keep aphid numbers down is not recommended, since this increases BYMV spread by preventing the shading out of infected clover source plants by healthy ones.

Spraying of adjacent pastures with insecticides to decrease aphid numbers is unlikely to be an economic proposition for BYMV control in lupins. Spraying lupins with insecticides to control BYMV spread is not recommended at present but perimeter spraying is under investigation.

Mixed cropping of lupins with cereals such as oats reduces BYMV spread greatly but is rarely likely to be an economic proposition, except for high quality hay production in high BYMV risk zones.

**Broad-leaved lupin species**

With yellow, albus and sandplain lupins, use the same control measures as with narrow-leaved lupins but expect greater BYMV spread within the crop especially with yellow lupins.

In yellow lupin crops keep an eye open for appearance of seedborne BYMV strains. Should there be any evidence of their presence alert Agriculture Western Australia staff. Should they become established in agricultural areas, control measures like those recommended for control of seedborne cucumber mosaic virus in narrow-leaved lupins would be appropriate (see Bwyer et al. 1995)

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**Further Reading**


For further information contact Roger Jones on (08) 9368 3269