Cucumber mosaic virus in lupins

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Cucumber mosaic virus in LUPINS

Cucumber mosaic virus is a threat to lupin crops from Geraldton to Esperance, particularly to those growing in areas receiving more than 400 mm average annual rainfall. The disease markedly decreases grain yield in narrow-leaved and yellow lupins but does not infect albus or sandplain lupins. Worldwide, after bean yellow mosaic virus, cucumber mosaic virus is the second most important virus affecting lupins. Annette Bwye, Roger Jones and Wayne Proudlove outline the symptoms, spread and management of this serious disease.

The virus

Cucumber mosaic virus (CMV) was not recognised as a problem in lupin crops in Western Australia until 1984 when an epidemic of the virus caused heavy yield losses on farms in the coastal region near Geraldton. Subsequently, major epidemic years occurred in 1986, 1988 and 1990, while 1992 was also a bad year in some areas.

The virus is a threat to lupin crops in high rainfall areas of the State (especially those with more than 400 mm average annual rainfall). Low rainfall areas are generally low risk, but the virus causes problems in medium rainfall zones in years when aphids arrive early and are active for the rest of the growing season (see risk areas map based on results from the cucumber mosaic virus seed testing service).
Virus spread

Aphid vectors

Aphids transmit cucumber mosaic virus in a non-persistent manner during feeding. This means that aphids only need to probe a plant for a short time to pick up and transmit virus particles, but they can then only retain the virus for one or two probes on healthy plants before they lose the ability to spread it.

The common colonising aphids on lupins are the green peach (Myzus persicae), bluegreen (Acyrthosiphon kondoi) and cowpea (Aphis craccivora) aphids. All three transmit cucumber mosaic virus, but the green peach and cowpea aphids transmit the virus more efficiently than the bluegreen aphid.

Turnip (Lipaphis erysimi), oat (Rhopalosiphum padi) and corn (R. maidis) aphids do not colonise lupins but are often found in the vicinity of lupin crops. They are all able to transmit the virus and therefore likely to be vectors when probing lupins while searching for appropriate hosts. The dock aphid (Brachycyclus rumexcolens) also often occurs around or in lupin crops but is a poor vector. In southern areas the spotted alfalfa (Theroaphis trifolii) and grain aphids (Sitobion miscanthi) may also play a minor role as cucumber mosaic virus vectors in lupin crops.

Lupins

Cucumber mosaic virus is seed-borne in narrow-leaved and yellow lupins. As they develop, some of the lupin seeds produced on infected plants become infected. Plants growing from infected seeds develop symptoms of ‘seed-borne’ infection. Seed transmission rates in seeds produced on infected plants vary according to variety (Table 1).

Plants that grow from infected seed are the primary source of cucumber mosaic virus for spread within a lupin crop. Aphids that feed on these plants acquire the virus and transmit it to other healthy plants. Plants infected via aphids show symptoms of ‘current-season’ infection with the virus. Winged aphids spread the virus from the initial (primary) sources of infection. Where plants touch and aphids can walk from plant to plant, wingless aphids can also spread the virus.

Current-season cucumber mosaic virus spread is normally concentrated around an infected plant (either a seed-infected plant or a plant infected early by aphids), resulting in a patch of infected lupins. Patches of infected lupins will eventually merge if the level of virus spread is high. Where wide row spacing is used, infection tends to move faster along rows than across rows, but with narrow rows patches tend to be circular.

Weed species

Cucumber mosaic virus is seed-borne at low levels in naturalised burr medic, rufous stonecrop and subterranean clover. Seed of these may occasionally act as a means by which the virus can persist through the dry summer, but all known outbreaks to date have been associated with sowing infected lupin seed.

Weed species such as rufous stonecrop, fumitory, certain wild clovers and volunteer subterranean clover readily become infected with cucumber mosaic virus from infected lupins when growing in the same paddock. They then may contribute to subsequent current-season spread within the lupin crop. The level of virus infection in grazed subterranean clover pastures established from infected clover seed gradually declines over time, so these pastures are unlikely to be an important source for virus spread to adjacent lupin paddocks.
Current-season cucumber mosaic virus symptoms in narrow-leaved lupin (left) showing bunched, downcurled and pale young leaves, with normal-looking lower leaves. The normal lower leaves distinguish current-season from seed-borne infection (right).

Symptoms

Narrow-leaved lupins – seed-borne symptoms

Plants growing from infected seeds are severely stunted and show one or more of the following leaf symptoms: bunching, downcurling, pallor or faint mottling. In a dense crop, these seed-infected plants are often shaded out by the surrounding healthy plants. However, in a sparse crop they persist throughout the growing season, providing a source for cucumber mosaic virus spread.

Narrow-leaved lupins – current-season symptoms

Unless the plants are infected very early, current-season cucumber mosaic virus symptoms are usually only seen in the shoot tips or higher up the plant. Young leaves are bunched, downcurled and pale, while the older, lower leaves have a normal appearance. When very young plants are infected, all the leaves may show symptoms resembling seed-borne infection. Generally, however, the presence of normal lower leaves distinguishes plants infected with cucumber mosaic virus by aphids from those infected through the seed. Late infections with cucumber mosaic virus are often not easy to identify especially when the plants begin to senesce and dry off and symptoms can not be distinguished from normal senescence.

Symptoms of seed-borne infection with cucumber mosaic virus in narrow-leaved lupin seedlings (two plants on the right).

Figure 1. Effect of different levels of infection in the seed sown on the spread of cucumber mosaic virus in Gungurru lupins during a high aphid activity season.

Late current-season infection with cucumber mosaic virus in Illyarrie lupin. Leaves at the growing tips are pale.

Yellow lupins

Symptoms of seed-borne and early current-season cucumber mosaic virus infection in yellow lupins are similar to those in narrow-leaved lupins but more severe. However, symptoms are difficult to see in late-current season infected yellow lupin plants.

Factors influencing virus spread

Level of seed infection in seed sown

Our research has shown that given adequate survival of the seed-infected source plants and substantial aphid activity, the extent of virus spread depends on the original level of infection in the seed sown. As the level of seed infection increases, the level of current-season infection also increases (Figure 1).

Establishment of plants showing seed-borne cucumber mosaic virus symptoms varies according to soil and weather conditions. Moist conditions after seeding favour survival of seed-infected plants. Lower establishment rates of these seed-infected plants have been recorded on heavier soil types compared with the lighter, sandier soils.

Aphid activity

In years when aphids arrive early and remain active throughout the growing season, cucumber mosaic virus spread is substantial and the virus level in harvested seed is greater than in the original seed sown (Table 2).

In contrast, when aphid arrival and activity is late, virus spread does not begin until late in the season and lupin yield is not affected. As a result the level of cucumber mosaic virus in the harvested seed is lower than the initial infection level in the seed sown (Table 3).

The time of aphid arrival depends on the climatic conditions during the preceding summer and
Table 2. Effects of different levels of cucumber mosaic virus infection in Gungurrup lupin seed sown on current-season infection and level of infection in the harvested seed during a season of high aphid activity

<table>
<thead>
<tr>
<th>% CMV infection in seed sown</th>
<th>% CMV current-season symptoms</th>
<th>% CMV infection in harvested seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.7</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>46</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3. Effects of different levels of cucumber mosaic virus infection in Gungurrup lupin seed sown on current-season infection and level of infection in the harvested seed during a season of low aphid activity

<table>
<thead>
<tr>
<th>% CMV infection in seed sown</th>
<th>% CMV current-season symptoms</th>
<th>% CMV infection in harvested seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>1</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
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<td>1.0</td>
<td>0.8</td>
</tr>
<tr>
<td>5</td>
<td>1.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Shading out of a seed-infected plant in a dense Chitick lupin crop.

Illyarrie lupin plots originally sown with 5 per cent cucumber mosaic virus infected (left) seed and healthy seed (right). Note symptoms in the former.

autumn. Higher than normal summer and autumn rains favour general plant growth which allows more aphids to survive (e.g. on weeds) and enter crops while the plants are still young. When weather conditions are dry and hot during the summer, fewer aphids survive, resulting in later arrival in lupin crops.

Seeding rates

Early development of a canopy of healthy lupin plants shades out the less competitive cucumber mosaic virus seed-infected lupins, thus reducing the numbers of virus sources in the crop. Early sowing at high seeding rates promotes early canopy development. Farmers should aim to achieve plant densities above 45 plants/square metre to reduce the survival of seed-infected plants (Figure 2).
Early sowing at high seeding rates is not effective when aphids arrive early in the growing season before a canopy has developed, because the seed-infected plants are not then shaded out even at high plant densities. For example, in an experiment at Wongan Hills in 1990 where 15 per cent infected seed was sown, cucumber mosaic virus spread occurred before canopy closure. By the end of the growing season, at a density of 50 plants/square metre, 75 per cent of the plants showed current-season symptoms.

Another method of encouraging early canopy development is sowing lupins at narrow rather than wide row spacing. In the absence of residual stubble, our research has shown that virus spread is greater with wide than narrow spacing. Banding of superphosphate fertiliser below the seed can also promote early growth and early canopy development, consequently diminishing current-season spread.

The presence of continuous ground cover from foliage also helps reduce virus spread by affecting aphid landing behaviour. Some species of aphids are repelled by a canopy of leaves and attracted when there are areas of bare soil between plants. Sparse and patchy crops therefore tend to be more attractive to aphids, increasing the potential for virus spread.

**Stubble retention**
Experiments have shown that 2 tonnes/hectare or more of retained stubble reduces the spread of cucumber mosaic virus in lupins (Figure 3). In one experiment, current-season virus spread was reduced by up to 50 per cent. This effect is partly due to the aphids being repelled by the stubble ground cover. Also, where there was no stubble cover, the aphids were attracted to plants surrounded by areas of bare soil.

The benefit of retained stubble in decreasing the spread of cucumber mosaic virus is most likely to be evident during growing seasons with early virus spread and when wide row spacing is used. 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 spacing.

**Insecticides**
The use of insecticides to reduce numbers of aphid vectors has been tried as a method of control for cucumber mosaic virus. In an early experiment we found lupin yield increased following foliar application of the carbamate

![Figure 3. Effect of stubble retention on the spread of cucumber mosaic virus in Gungurru lupins](image)

Management of cucumber mosaic virus spread in lupin crops requires an integrated approach:

- **Test a representative sample of lupin seed for cucumber mosaic virus**

Sowing lupin seed with the lowest level of cucumber mosaic virus infection possible is the most important strategy to control the virus. Only retain seed for sowing next season from crops with no visible symptoms of cucumber mosaic virus or at most 2 infected plants per 1000 in spring.

- **Only sow seed with a low (less than 0.5 per cent) or preferably zero cucumber mosaic virus test result**

In high risk areas (see map) use only lupin seed with a negative test result for cucumber mosaic virus, particularly in years when summer-autumn rains favour early aphid build up. In lower risk areas, seed with less than 0.5 per cent infection can be sown without undue risk of yield loss in most years. However, when extensive summer-autumn rains occur, avoid sowing non-zero test result lupin seed even in lower risk areas.

- **Encourage early canopy development**

Obtain a dense canopy and continuous ground cover by sowing early at high seeding rates (more than 100 kg/ha) to shade out the less competitive cucumber mosaic virus seed-infected lupins that provide
control measures

Test representative 1000 seed samples for seed infection. To make seed samples representative, seed should be collected by sampling continuously from the header at harvest or if this is not possible, by thoroughly sampling silos with a spear. If the sampling is not thorough, the sample will not accurately represent the bulk of harvested grain and the test may be misleading. If there is any doubt as to how representative the sample is, only use it to identify seed stocks with dangerously high cucumber mosaic virus levels (above 1 per cent).

- **Retain stubble**
  Ground cover of at least 2t/ha retained stubble also reduces the spread of cucumber mosaic virus by deterring aphids from landing. This is particularly important where wide row spacing is used.

- **Use insecticides to control aphid vectors in seed crops**
  Inspect crops frequently for cucumber mosaic virus symptoms and aphids. Strategic spraying to reduce aphid numbers and subsequent virus spread may be economical for high value seed crops but only in epidemic years. With grain crops, only use insecticides to control aphid feeding damage when aphid numbers are particularly high rather than to control the spread of cucumber mosaic virus.

- **Avoid sowing seed crops next to paddocks sown with untested lupin seed**
  Protect lupin crops by isolating them from other possible sources of cucumber mosaic virus infection. Avoid sowing lupin crops, especially seed crops, next to crops sown with untested seed.

- **Avoid sowing high quality seed crops in high cucumber mosaic virus risk areas**
  Avoid lupin seed production in high risk areas (see map). Growers in such areas should purchase lupin seed from lower risk areas.

Insecticide pirimicarb. In a later experiment, cucumber mosaic virus spread was reduced by foliar application of the organophosphorus insecticide methamidophos. On other occasions, there was no benefit of spraying. In general, these insecticides do not act fast enough to decrease virus spread by aphids.

Further work is in hand to see whether insecticides with a rapid knock down and greater persistence, such as pyrethroids, will provide better control. With non-persistently transmitted viruses like cucumber mosaic virus in other crops, only such fast acting insecticides have been effective in reducing virus spread.

Resistance to organophosphorus and carbamate chemicals has been identified in some populations of green peach aphids in Western Australia. Presently, only methamidophos (a broad spectrum organophosphorus chemical) is recommended for use against these resistant aphids. Other chemicals, including imidocloprid (which belongs to a different class of chemical to which green peach aphids have not yet developed resistance) and triazamates, are being assessed for their effectiveness in reducing cucumber mosaic virus spread.

Yield losses

Losses of up to 53 per cent have been recorded in our experiments where 5 per cent infected seed was sown. However, Table 4 shows a more typical yield loss of 35 per cent. Yield losses have also been recorded (up to 16 per cent) even when 0.5 per cent infected seed was used. However, in seasons...
Table 5. Grain yield reductions caused by early or late cucumber mosaic virus infection in Gungurru lupins

<table>
<thead>
<tr>
<th>Time of infection</th>
<th>% yield reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before flowering</td>
<td>56</td>
</tr>
<tr>
<td>During flowering</td>
<td>73</td>
</tr>
<tr>
<td>After flowering</td>
<td>19</td>
</tr>
</tbody>
</table>

with late aphid arrival there may be no yield loss even when virus infection levels in the seed are high.

Early infection with cucumber mosaic virus causes the greatest reductions in grain yield. Where plants are infected with the virus before or during flowering, yield losses are greater than if infection occurs later (Table 5). Late

infections with the virus may not reduce yield, although unacceptable levels of cucumber mosaic virus may still be present in the harvested seed.

Virus resistance in lupins

Genetically controlled low levels of cucumber mosaic virus seed transmission are being tested for in the narrow-leaved lupin breeding program. The aim is to improve on the low level found in Danja and avoid the release of any new cultivars with levels as high as that in Wandoo (Table 1). In yellow lupins a useful gene for resistance is found in varieties Teo and Motiv. This gene is being exploited in the yellow lupin program.

Genetic engineering for cucumber mosaic virus resistance in narrow-leaved and yellow lupins is under way at the State Agricultural Biotechnology Centre at Murdoch University as part of a project within the Cooperative Research Centre for Legumes in Mediterranean Agriculture (CLIMA). This project should provide good synthetic resistance to the virus in the future.

Acknowledgements

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Further reading


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