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Crop Updates 2000 Cereals - part 3

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Unicorn barley must meet malting specifications to be a viable option
Roslyn Jettner and Blakely Paynter, Agriculture Western Australia

KEY MESSAGES
• Unicorn barley must meet specifications for the malting grade for it to be considered a viable option for growers.
• Particular attention needs to be paid to management to achieve the required grain protein and timeliness of swathing operations.

BACKGROUND
Unicorn is a quick-maturing, large-grained barley variety that was introduced into Western Australia from Japan through a joint project between Kirin Australia and the University of Western Australia. It has quality characteristics that are well suited to the brewing processes used by Kirin Japan. Following the success of domestic malting and overseas brewing trials conducted during 1998 and 1999, Unicorn will be received as a provisional malting barley for the 2000-2001 season by Kirin Australia and The Grain Pool of Western Australia. Unicorn barley is covered by PBR.

Unicorn barley has several advantages over Stirling barley. When sown at the same, Unicorn begins flowering several weeks before Stirling and has completed grain fill when the grains of Stirling are only half-filled (Figure 1). Unicorn has also been shown to be more competitive with ryegrass than has Stirling (Ashley Bacon, pers. comm.).

Due to these characteristics, Unicorn barley may be useful as a cropping tool in integrated weed management (IWM) systems, combining the use of late sowing with quick maturity, several pre-sowing herbicides, crop competition and swathing. Unicorn is being adopted in areas where ryegrass has developed herbicide resistance, because of its quick maturity and suitability for swathing before ryegrass produces viable seed.

Figure 1. Grain filling curves of Unicorn (-------) and Stirling (---) barley sown on 23 June 1997 in the Avon Valley, Western Australia. 100 GDD were equivalent to approximately 8 days duration at the site in September 1997 (Data of Blakely Paynter, AGWEST).

Despite the promotion of Unicorn as a tool for IWM system, much of the information available is speculative as there is little hard data that shows Unicorn can make the malting grade whilst grown in such a system. The limited evidence available suggests that this is not a certainty. Economic analysis indicates that Unicorn must achieve malting specifications for it to be considered a viable
option. For example, to recoup the costs of production, applying herbicides (including 2 knockdowns), swathing and grading the seed, grain yields above 1.4 t/ha of premium malting quality grain need to be achieved. The breakeven yield for feed quality Unicorn barley is 1.9 t/ha, a yield that is higher than the state average barley yield for Western Australia.

Paddock management decisions should therefore be aimed at reducing the risk of Unicorn being downgrading to feed. Results from research trials and grower experience indicate particular attention needs to be paid to management to achieve the required grain protein and timeliness of the swathing operation.

CROP MANAGEMENT FOR MALTING GRADE

The following suggestions for managing the Unicorn barley crop are based on trials conducted in weed free situations along with observations by farmers and agronomists. Little hard data is available on the ability of Unicorn to achieve the malting grade under high weed burdens. It is anticipated that high weed burdens will reduce yield, may increase protein, and involve an extra cost in grading the grain to reduce weed seed contamination.

Rainfall zones and sowing dates

Being a short season variety, Unicorn is best adapted to low and medium rainfall areas and, as such, has been promoted for late sowing opportunities. The suggested sowing date for Unicorn is late June, where weed management is maximised, the grain yield of Unicorn is similar to Stirling and where there is a higher probability of Unicorn achieving the malting specifications relative to Stirling, particularly for grain size (Figure 2). But how late is too late before grain quality begins to be eroded? Growers are interested in sowing Unicorn as an opportunistic spring crop in high rainfall areas or as a salvage crop following waterlogging or crop failure. In these situations, sowing Unicorn in July is possible. However, this may be risky as there is no supportive evidence to indicate that malting specifications can be achieved.

Late May and early June sowing of Unicorn is also possible, crops are higher yielding and have a greater probability of achieving the malting grade than later sowings. However, there may be a yield penalty on some soil types when compared to Stirling. On the sandier soils of the eastern wheatbelt (Wongan Hills, Tammin and Merredin), the grain yield of Unicorn is significantly lower than Stirling (AGWEST data). On the loamy soils of the Avon Valley however, yields of Unicorn appear to be competitive with Stirling (AGWEST and UWA data).

A disadvantage of late May sowing is a reduced chance of managing weeds pre-sowing and early swathing may allow for the re-growth of ryegrass. A May sowing also puts Unicorn at a higher risk from frost. In the Merredin area for example, there is greater than a 20% chance of 1 to 2 frosts in mid to late August, the time when a late May sown Unicorn crop will be flowering (Craig White, pers.

![Graphs showing screenings and grain protein](image-url)
Figure 2. Relationship between Stirling and Unicorn Barley in a weed-free situation in the M1, M2, M3, M4 and L3 cropping zones of Western Australia for: (a) screenings (% < 2.5 mm); and (b) grain protein (%) across a range of sowing dates, soil types, rates of applied N and plant densities (Data of Blakely Paynter, Frances Hoyle and CVT, AGWEST).
Rotation and nitrogen application

Managing grain protein to meet the specification required by the maltster and brewer will need to be a priority for growers. When sown in June in a weed free situation, protein levels in Unicorn can be up to 1% greater than for Stirling (Figure 2).

It is important that nitrogen fertiliser is applied at or close to seeding. This is because the length of the period between emergence and stem elongation for Unicorn is one week shorter than for Stirling. Applying more nitrogen fertiliser than is required to satisfy tiller requirements is likely to raise grain protein above the required level. Waterlogged conditions or later sowings may also increase the risk of high protein.

The Kirin Malthouse in Perth will be more flexible next season in their protein receival standards for Unicorn. This is because they anticipate a high proportion of the deliveries to be above 11% protein during the first couple of seasons of Unicorn’s release. This flexibility is only possible because Unicorn is able to produce a high level of malt extract (fermentable sugars) at higher protein levels. This is not a characteristic of Stirling barley.

Seeding rate

A plant density of 150 plants/m² (approx. 80 kg/ha) is currently recommended for Unicorn. Seeding rate trials by AGWEST have shown no major increase in grain yield or screenings of Unicorn when plant establishment is above 100 plants/m² (weed free). However, the higher establishment rate is recommended to help smother weeds, particularly in IWM systems.

Disease management

Unicorn is very susceptible to scald and the use of an appropriate seed dressing for its control in high risk areas is recommended.

Head-loss and harvesting

Unicorn is susceptible to head loss prior to harvest. For example, a hot easterly in October can cause up to 20% head loss in 1 day. Timely swathing is essential to achieve maximum yield and quality of the crop.

To delay swathing increases the risk of head loss. To swath too early, before maximum grain-fill, will increase small grain and, in some situations, immature green grains that will be rejected as unsuitable for malting. Uneven ripening of the crop and the development of late tillers with September rains may exacerbate the problem of sappy green kernels in the sample.

Grain filling studies have shown that maximum grain weight is reached when all green tissue has gone from the flag leaf and the stem immediately below the head. Swathing can begin when grain has reached the late dough stage and the grain moisture content is up to 35%.

Unicorn has no inherent grain dormancy and this suggests it would be susceptible to sprouting. Swathed barley may still be susceptible to sprouting if the swath becomes wet.

At this stage, the use of desiccants with Unicorn barley in an IWM system will be not allowed on deliveries of grain made to either the Grain Pool of Western Australia or Kirin Australia. This situation may change closer to harvest, but should be checked when signing a delivery contract.

ACKNOWLEDGEMENTS

Dr Rodger Boyd from University of Western Australia and AGWEST Agronomists for providing trial data. Hamish Mines (SGB) and Barrett Sinclair (IAMA) for comments on farmer experiences with Unicorn barley. Grains Research and Development Corporation support AGWEST agronomic trials.
KEY MESSAGES

- Each set of environmental conditions results in a different optimum seed rate for each variety. For example, where weed infestation is high, seed rates of up to 150 kg/ha (or 375 plants/m²) are recommended, especially for the dwarf variety Dalyup.
- Optimum seed rate is dependant on variety. Rates of 75 to 110 kg/ha (or 185 to 275 plants/m²) for non-dwarf varieties and 100 kg/ha (or 250 plants/m²) for dwarf varieties should be used.
- Increasing seed rates had minimal effect on hectolitre weight. Variation between sites, and potentially BYDV infection, resulted in a larger effect on hectolitre weight.

BACKGROUND

Previous oat research indicated that optimum seed rates for the varieties tested were approximately 60-70 kg/ha (Anderson and McLean, 1989). With increased agronomic and varietal knowledge, the current project has shown that these rates require reviewing. Apart from yield, hectolitre (HL) weight in oats is probably the most important characteristic to growers. The current challenge to many oat growers is to produce high yielding oat crops with sufficient HL weight to meet strict receival standards. Oats below this standard are deemed unacceptable to most oat buyers.

METHOD

Trials were sown with between 120 and 150 kg/ha Agras CuZnMo. All 1998 and 1999 trials had at least one application of synthetic pyrethroid (SP) insecticide spray at 5-6 weeks to control barley yellow dwarf virus (BYDV). Most trials had a second spray at 9-10 weeks. The 1997 trials were not sprayed with a SP. Environmental factors for each site are listed in Table 1.

Table 1. Factors affecting results from trial sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dongolocking</td>
<td>Medium rainfall zone</td>
</tr>
<tr>
<td>Doodlakine</td>
<td>Low rainfall zone, more rain than normal, high grass weed infestation</td>
</tr>
<tr>
<td>Mayanup</td>
<td>High rainfall zone</td>
</tr>
<tr>
<td>Narrogin</td>
<td>Medium rainfall zone, relatively low rainfall through winter</td>
</tr>
<tr>
<td>Punchmirup</td>
<td>Medium rainfall zone, dry start and finish to season, high grass weed infestation</td>
</tr>
<tr>
<td>South Stirling</td>
<td>High Rainfall zone, longer season than normal, high levels of rust</td>
</tr>
<tr>
<td>South Stirling</td>
<td>High rainfall zone, waterlogging during winter, some rust infection</td>
</tr>
<tr>
<td>Williams</td>
<td>High rainfall zone</td>
</tr>
</tbody>
</table>

The optimum seed rate is calculated as where a 30 kg/ha increase in the sowing rate caused an increase in yield of 0.15 t/ha (i.e. 1 kg seed increased yield by at least 5 kg/ha).
RESULTS AND CONCLUSIONS

- The optimum seed rate for each variety depended on the environmental stresses imposed (Table 2). For example where grass weed competition was high and finishing rains were poor (Punchmirup), the optimum seed rate for Mortlock was higher than where either environmental stress were not present (Narrogin and Doodlakine).
- To reach the optimum yield response the dwarf varieties needed higher seed rates than the non-dwarf varieties.
- No relationship was observed between optimum seed rate and the environment except for the Punchmirup location. At this site the high weed infestation, coupled with only 6 mm of rain during grain filling, contributed to the highest optimum seed rate. Growers should increase seed rates where high weed densities and/or a dry finish to the season is predicted.

<table>
<thead>
<tr>
<th>Site</th>
<th>Non-dwarf Varieties</th>
<th>Dwarf Varieties</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortlock</td>
<td>Hotham</td>
<td>Coomallo</td>
</tr>
<tr>
<td>Dongolocking</td>
<td>99</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Doodlakine</td>
<td>99</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>Mayanup</td>
<td>98</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Narrogin</td>
<td>97</td>
<td>60</td>
<td>--</td>
</tr>
<tr>
<td>Punchmirup</td>
<td>97</td>
<td>150</td>
<td>--</td>
</tr>
<tr>
<td>South Stirling</td>
<td>97</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>South Stirling</td>
<td>98</td>
<td>90</td>
<td>60</td>
</tr>
<tr>
<td>Williams</td>
<td>98</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Average</td>
<td>86</td>
<td>78</td>
<td>110</td>
</tr>
</tbody>
</table>

- Hectolitre weight is dependant on both the site and crop growing conditions. Sites with higher rainfall had lower hectolitre weights. Examples of this are the high rainfall site Mayanup (GSRF = 483 mm) and the low rainfall site Narrogin (GSRF = 237 mm) which had average hectolitre weights of 50.5 kg and 55.2 kg respectively.
- Dalyup had a lower hectolitre weight than Mortlock at all sites sown in 1997, without the addition of SP insecticide. Where SP insecticides were applied the hectolitre weight of Dalyup was greater or equal to that of the non-dwarf variety Mortlock and other dwarf varieties, Needilup and Wandering.

<table>
<thead>
<tr>
<th>Site</th>
<th>Non-dwarf Varieties</th>
<th>Dwarf Varieties</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mortlock</td>
<td>Hotham</td>
<td>Coomallo</td>
</tr>
<tr>
<td>Dongolocking</td>
<td>99</td>
<td>51.0</td>
<td>52.9</td>
</tr>
<tr>
<td>Doodlakine</td>
<td>99</td>
<td>50.7</td>
<td>52.6</td>
</tr>
<tr>
<td>Mayanup</td>
<td>98</td>
<td>50.2</td>
<td>51.4</td>
</tr>
<tr>
<td>Narrogin</td>
<td>97</td>
<td>56.9</td>
<td>--</td>
</tr>
<tr>
<td>Punchmirup</td>
<td>97</td>
<td>56.1</td>
<td>--</td>
</tr>
</tbody>
</table>
South Stirling 97  50.6  --  51.3  45.9  --  --  49.3
South Stirling 98  48.7  47.8*  --  49.1  49.1  --  48.7
Williams 98  52.5  52.3  --  52.9  --  51.8  52.4
Average 52.1  51.4  53.9  45.6  50.1  51.4  44.4

ACKNOWLEDGEMENTS

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REFERENCES


GRDC Project No.: DAW497
Paper reviewed by: N. Littlewood
OPTIMISING AGRONOMIC INPUTS

Varieties

- Trials were conducted in the New Norcia, Yerecoin area and at Williams.
- Trials were cut in early October to suit early maturing varieties and late October to suit the later types.
- At the early cut, Winjardie averaged 10.1 t/ha (5 sites). Bettong was the only superior variety. Mortlock was very variable in performance. Carrolup, Euro and Marloo data are only from 1999.
- At the later cut Vasse averaged 12.1 t/ha (5 sites). Yield of Vasse relative to Winjardie increased greatly between the early and late cut.
- Winjardie, Bettong and Carrolup are readily accepted by exporters. Euro, Esk, Glider and Vasse are also likely to be acceptable.
- Carrolup is very susceptible to crown rust. Bettong, Euro, Glider and Vasse showed good resistance. Glider, Bettong and Vasse were also quite good for Septoria avenae.

<table>
<thead>
<tr>
<th>Early assessment (early October)</th>
<th>Late assessment (late October)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winjardie 10.1 t/ha</td>
<td>Vasse 12.1 t/ha</td>
</tr>
<tr>
<td>Bettong 110% (5)</td>
<td>Bettong 96% (2)</td>
</tr>
<tr>
<td>Carrolup 94 (2)</td>
<td>Esk 85 (4)</td>
</tr>
<tr>
<td>Esk 86 (5)</td>
<td>Glider 84 (4)</td>
</tr>
<tr>
<td>Euro 99 (2)</td>
<td>Swan 94 (3)</td>
</tr>
<tr>
<td>Glider 90 (3)</td>
<td>Winjardie 88 (2)</td>
</tr>
<tr>
<td>Marloo 93 (1)</td>
<td></td>
</tr>
<tr>
<td>Mortlock 100 (4)</td>
<td></td>
</tr>
<tr>
<td>Swan 98 (5)</td>
<td></td>
</tr>
<tr>
<td>Vasse 93 (4)</td>
<td></td>
</tr>
</tbody>
</table>

Nutrition

- Trials have been conducted on sites that have been either very fertile or very responsive.
- On responsive sites economic yield responses were obtained at up to 160 kg/ha N and 100 kg/ha K (soil test ~ 60 ppm).
- On fertile sites economic yield responses were obtained at up to 50-80 kg/ha N and nil K (soil test ~ 300 ppm).
- Industry experience suggests lower hay quality from highly fertile paddocks. Experimental data does not clearly support this.
• At high N rates, there were weak trends to lower in-vitro digestibility and water soluble carbohydrates.
• At high K rates, there was a weak trend to higher in-vitro digestibility.
• There was no clear effect on shear energy with either nutrient.

Research funded by GRC and Gilmac (WA) Pty Ltd
RYEGRASS COMPETITION STUDIES

Crop competition site at New Norcia was seeded on 14.6.99. Paired 1m squared plots were established. Ryegrass plants were counted in the weedy plots and the clean plots were hand-weeded on 11.7.99. Plots were harvested on 26.10.99.

Figure below shows the percent yield loss in oat hay when infested with varying levels of ryegrass. Ryegrass density ranged from 153-2,500/sqm. The curve shows that at lower densities (200-600 ryegrass/sqm), losses were quite variable. At higher levels (1,200-2,400/sqm), losses were more predictable. The fitted curve suggests that the presence of 200 ryegrass plants/sqm resulted in 10% yield loss in oat hay with nearly 50% loss at 1000 ryegrass plants/sqm.

Export hay standards require no more than 5% contamination from ryegrass. Trial work conducted in 1998 as part of this project showed that mixtures of ryegrass plus oats achieved approximately 110% of the production of oats alone and that as ryegrass number increased, the relative proportion of each species altered. This suggests that with a 10% yield loss in oats, a mix of oats and ryegrass would be

90 oats: 20 rye
OR
82 oats: 18 rye

which is in excess of the acceptable limit.

Full summaries are available on fievez@q-net.net.au~fievez/index/html

GRDC Project No.: PFA9
Climatology of Frost in Southern Western Australia
Ian Foster, Agriculture Western Australia

KEY MESSAGE
The prevailing winter weather systems over southern Western Australia mean that frost risk occurs virtually every year over southern and eastern agricultural regions. Actual occurrence of frost is determined by location and landscape factors as well as the climate. Low cost electronic temperature recorders offer farmers the ability to respond with greater certainty to frost events.

AIMS
Widespread and severe frosts in 1998 and 1999 have heightened awareness of its impact on crops. This paper aims to show why southern Western Australia is climatologically predisposed to frosts in winter and spring. Also, historical temperature records will demonstrate that frost is an annual event in many parts of the agricultural regions.

METHODS
Daily minimum temperature data for a number of locations were obtained from the Commonwealth Bureau of Meteorology. Over 30 years of data from the mid 1960s to the end of 1998 were available. The measurements were taken with mercury-in-glass thermometers housed in standard Stevenson screens, and represent the minimum temperature recorded until 0900 hours each day. The frequency of occurrence of days of minimum temperature of less than 2°C and 0°C was used as an indicator of the likelihood of frosts or damaging low temperatures. They are not observations of frost on the ground. The thermometers are almost always located in towns, and depending upon the topography and presence of buildings may record a different temperature to surrounding farmland. They are, however, suitable for defining the seasonal and geographical distribution of low temperatures across the State.

RESULTS
Figure 1 shows the number of days per year at Lake Grace where the minimum temperature was at or below 2°C for 1964 to 1998. In most years there are five or more potential frost events.

Figure 1. Number of Days Below 2°C for Lake Grace

<table>
<thead>
<tr>
<th>Year</th>
<th>No Days &lt; 2°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td></td>
</tr>
<tr>
<td>1973</td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td></td>
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<tr>
<td>1988</td>
<td></td>
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<tr>
<td>1991</td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td></td>
</tr>
</tbody>
</table>
There is a clear geographical distribution in the frequency of frosts as shown in Table 1.

### Table 1. Number of days below 2°C and 0°C for selected locations

<table>
<thead>
<tr>
<th>Location</th>
<th>No. days below 2°C</th>
<th>No. days below 0°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morawa</td>
<td>4.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Wongan Hills</td>
<td>3.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Merredin</td>
<td>19.7</td>
<td>4.6</td>
</tr>
<tr>
<td>Corrigin</td>
<td>29.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Lake Grace</td>
<td>11.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Esperance Downs RS</td>
<td>1.9</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The sequence of weather events that generate frosts is composed of the passage of a cold front, followed by cold southerly winds and the establishment of a ridge of high pressure. This results in cool daytime temperatures, light winds and clear skies overnight. Such events occur commonly during winter and spring.

The actual occurrence of frost under these conditions then depends upon a complex interaction with landscape factors such as topography, soil type and vegetation cover.

There is now available a range of electronic temperature recorders which can be applied to monitor temperatures at several sites on any farm. Their measurements can be used to define the severity and duration of low temperatures, permitting a more accurate assessment of frost impact and a more timely response to damage.

### CONCLUSIONS

The prevailing climatology of southern Western Australia in winter and spring mean that frost is an annual risk for much of the agricultural region. Long term temperature records allow the risk to be quantified. The development of electronic temperature recorders allows on-farm monitoring and rapid assessment and response.

### KEY WORDS

frost, climatology

**Paper reviewed by:** David Stephens
# Flowering calculator

**David Tennant,** Agriculture Western Australia

The choice of sowing date and variety is the key to maximising yield potential. Earlier sowing should mean better water use efficiencies and higher yields. Successful adoption of this strategy hinges on matching variety to sowing time to maximise growth and minimise the likelihood of frost after flowering yet avoid the incidence of high temperature events and terminal drought during grain fill. Many options are now available when making this choice. The FLOWERING CALCULATOR is a tool that enables the user to compare flowering outcomes relative to risks of frost and high temperature events and the likelihood of experiencing optimum conditions during grain development.

**KEY FEATURES**

- The FLOWERING CALCULATOR provides procedure to calculate flowering time using average daily temperature and day length data.
- The user can interrogate daily temperature data records to provide information on incidence of frost and critical mean temperature events after flowering, high temperature events towards the end of grain filling and variation in flowering time.
- Outcomes from variety selections can be assessed relative to user defined flowering windows and end of season dates, for any date of sowing.
- The user can define frost, critical temperature and high temperature events in terms of severity (temperature) and duration (consecutive days).
- The user can select one or more years of temperature record to calculate year specific flowering times and identify occurrence of frost, critical temperature, and high temperature events in those years.
- A visual ‘Frost Identification’ guide is included.

Parameter data are supplied to enable flowering time to be calculated for a selection of varieties for each of several crop species using a range of phenological models. The models were selected on the basis of (i) enabling easy generation of parameters as new varieties come to hand using sowing date, flowering date, and daily temperature and site latitude data, and (ii) accessing existing and developing parameter data bases.
Some options for managing the risk of frost damage

Wal Anderson, Agriculture Western Australia

KEY MESSAGE
Frost prone areas in the lower parts of the landscape can be identified and managed differently to the rest of the farm. The main options, once the frost prone areas have been identified, are sowing crop varieties slightly after their optimum times and using wide rows (35-45 cm). Some salvage operations on frosted crops can have long term effects that should be considered when decisions are made.

The problem
Severe frost damage in some crops in the last two years has created considerable debate about possible means to reduce losses. There has been some reluctance to identify frost prone areas on farms and to consider if they can be managed so as to reduce the risks. Unfortunately there have been few techniques available that are considered to be likely to make an economic contribution to the problem. This paper discusses some of these options using data from experiments and measurements made on frosted crops by Craig White.

METHODS
1. Replicated plots were harvested at lower, mid and upper slope positions in the landscape of nine frosted paddocks in the Lakes area in 1998. Samples of the whole plants were taken alongside each harvested plot and analysed for frost damage. The grain was assessed for protein, test weight and screenings as well as yield.
2. Farmer-scale plots were sown at three frost-prone sites using narrow (18-23 cm) and wide (35-45 cm) rows spacings. Temperatures in the ears in the spring were measured. Grain yield and delivery standards were also recorded.
3. An experiment was conducted in 1999 to test various salvage options on the residue of a wheat crop frosted in 1998. Treatments were assessed for weed numbers, and grain yield of the following wheat crop.

RESULTS AND DISCUSSION
1. In every case studied grain yields were less in the lower landscape than in the mid- or upper slopes. Grain protein was higher in the samples from the lower slope positions in every case. Small grain screenings were also greater from the lower slope samples in all but one case where screenings were very high in all samples and there appears to have been some other over-riding cause. There was no clear trend of hectolitre weight with position in the landscape. Assessments of frost damage on the plant samples (both stem and head damage) taken at each landscape position were clearly related to yield losses in some cases but less so in others. A clearer method for assessing damage is required.
2. Temperatures in the ears of wheat plants grown in wide rows were 1-2°C higher than ears in narrow rows. Only one of the three sites suffered frost damage but the yield of the wide spaced rows at that site was greater than yield of the narrow row plots. The difference between the treatments at the other two sites was very small. It could be assumed that grain yield in wider rows will not be less, and losses may be reduced, by using wider rows if frost is a problem.
3. Options for a frosted crop could include harvesting as normal, slashing, hay cutting, burning, cultivation or some combinations of these. In the Newdegate experiment the grain yield of wheat following frosted wheat that was cut for hay was greater and weeds under the crop (largely ryegrass) were less than any other salvage option. Weed numbers after the rake and
burn treatment were the largest by far. This observation is contrary to data from earlier experiments but it highlights the advisability of considering the longer-term consequences of any salvage options as well as the immediate financial implications.

<table>
<thead>
<tr>
<th>Salvage option</th>
<th>Weeds/m²</th>
<th>Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvest</td>
<td>20</td>
<td>2.72</td>
</tr>
<tr>
<td>Cut hay</td>
<td>4</td>
<td>3.02</td>
</tr>
<tr>
<td>Rake and burn</td>
<td>244</td>
<td>2.61</td>
</tr>
<tr>
<td>Slash</td>
<td>80</td>
<td>2.50</td>
</tr>
<tr>
<td>Slash/plough</td>
<td>28</td>
<td>2.28</td>
</tr>
<tr>
<td>Plough/offset</td>
<td>77</td>
<td>2.82</td>
</tr>
</tbody>
</table>

**A possible strategy**

In frost prone locations the lower parts of the landscape will be the most susceptible. [Light coloured soils and areas of impeded cold air drainage may be minor exceptions.] In these areas the soils are often deeper and the yield penalty for late sowing in deeper soils is less than in poorer soils. The crop can thus be deliberately sown slightly after its optimum time in the lower landscape so that it will flower when the risk of frost is less. This will allow time for extra weed control operations before sowing, with minimal risk of reduced yield. If the risk is considered especially high in the areas identified as frost prone then wide rows (block every second run) could be used as a further insurance.

When considering the options for salvaging frosted crops the longer-term consequences for future weed, and possibly disease management, should be factored in.

**ACKNOWLEDGEMENTS**

Steve Crook and Ross Ramm at Newdegate Research Station assisted with the experiments and many farmers freely gave their land and resources to assist in this work.

**GRDC Project No.:** DAW493  
**Project reviewed by:** Alex Edward
TIMERITE® Control of redlegged earth mite in southwestern Australia with a spring spray in pastures

James Ridsdill-Smith and Celia Pavri, CSIRO Entomology, University of Western Australia

KEY MESSAGE
At demonstration sites on farms through southern Australia a package TIMERITE® is being tested to control redlegged earth mite with a single spray at a critical time in spring. With this spring spray mites are also controlled in the following autumn. Subterranean clover density in pastures increases when mites are controlled.

AIMS
Research on factors affecting RLEM abundance showed that a greater benefit would be achieved if mites were controlled in spring rather than autumn. It would prevent the production of the oversummering generation and thus also control mites in autumn. Chemical sprays will kill active mites but not their eggs. Therefore it is important to spray when most of the population are present in an active stage. RLEM feed on pastures for 6 months of the year from May till October. They survive the hot dry summer as protected eggs inside the dead cadavers of the adult female mites. These diapause eggs are produced in spring while the mites are still running around. The optimum time to spray in spring is after mites have stopped laying normal winter eggs on pasture, and just before the diapause eggs are produced. Following six years of detailed study we have developed a package called TIMERITE® which predicts the onset of diapause, and it is recommended to spray exactly two weeks before this date. The aim of this study is to test the accuracy of the model and to demonstrate the benefits of mite control on 40 farms across southern Australia.

METHODS
At each of 40 sites in WA, SA, Vic and NSW an area of at least four hectares was selected and on the predicted date the farmer used a single spray of an organophosphate chemical. Bayer Australia supplied one litre of Le-mat® free to collaborating farmers. The abundance of mites was calculated just before spraying (prespray) and following the break of season in the following autumn, using a vacuum suction sampler. At 10 sites weekly samples were taken around the time of onset of diapause and mites dissected so that the actual proportion of diapause eggs could be plotted against time. At 28 of the other sites one sample was collected at the predicted time of diapause to check if the mites did indeed contain at least 90% diapause eggs, and sites were resampled weekly if the proportion was too low. Increase in pasture legume density was taken as a measure of increased productivity. Subterranean clover seed yield was sampled in early summer (December/January) from soil cores, and the density of pasture legumes was measured at the break of season (June/July) by counting seedling density in soil cores.

RESULTS

Model
At the 10 sites in southern Australia where weekly sampling was carried out on each side of the predicted date of 90% diapause, the actual date occurred on average 0.2 days earlier than the predicted date. At the 28 other sites with a single sample the actual date was on average 1.2 days later. At six sites, extra samples were needed to estimate the date of 90% diapause, and the worst fits were where the model was 10 days late.

RLEM abundance
In Western Australia the RLEM population in unsprayed pastures has been averaging around 29,000 mites/m² when counted in spring 1998, autumn and spring 1999 (these are periods of peak populations). A single spray in spring 1998 at the recommended date resulted in 97% control in
autumn 1999 eight months later (Table 1). Thus the spring spray was successful in preventing RLEM from oversummering. In the autumn only one of these farms had populations greater than 5000 mites/m², the assumed threshold for damage (there were 6104 mites/m² in the sprayed area but 118,048 mites/m² in the control area). Mite populations were followed through the winter season, and 12 months after the single spray in 1998 there was still detectable (46%) control (Table 1), although these populations would probably require to be sprayed again.

Table 1. Average RLEM control from 20 sites in south western Australia from a single spring spray in 1998. The assumed damage threshold is around 5,000/m²

<table>
<thead>
<tr>
<th>Season</th>
<th>Year</th>
<th>Timing</th>
<th>No. mites/m²</th>
<th>% control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Control</td>
<td>Sprayed</td>
</tr>
<tr>
<td>Spring</td>
<td>1998</td>
<td>Prespray</td>
<td>33144</td>
<td>(20669)</td>
</tr>
<tr>
<td>Autumn</td>
<td>1999</td>
<td>8 months after spray</td>
<td>29669</td>
<td>845</td>
</tr>
<tr>
<td>Spring</td>
<td>1999</td>
<td>12 months after spray</td>
<td>23369</td>
<td>12708*</td>
</tr>
</tbody>
</table>

* Data for 14 sites carried through since the previous spring.

Blue oat mite abundance

Blue oat mite (BOM) populations were also monitored at these sites. There was an average of 705 mites/m² in the control areas. Control of BOM was not as good as for RLEM. The single spring spray resulted in a 76% reduction in the autumn eight months later, and there was a 34% reduction still evident 12 months later.

Pasture legume density

For the 20 farms in western Australia, the single spring spray in 1998 resulted in a 34% increase in subterranean clover seed yield in summer, and a 107% increase in subterranean clover seedling numbers in autumn 1999 (Table 2). The increase in seedling numbers is greater than that of seed yield, because the seedlings that did emerge were attacked less by the lower number of mites present.

Table 2. Average increase in subterranean clover yields in 1999 from 21 sites in south western Australia from a single spring spray in 1998

<table>
<thead>
<tr>
<th>Measure</th>
<th>Season</th>
<th>Control</th>
<th>Sprayed</th>
<th>Benefit</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed yield (kg/ha)</td>
<td>Summer</td>
<td>508</td>
<td>678</td>
<td>170</td>
<td>34</td>
</tr>
<tr>
<td>Seedlings (numbers/m²)</td>
<td>Autumn</td>
<td>829</td>
<td>1729</td>
<td>890</td>
<td>107</td>
</tr>
</tbody>
</table>

CONCLUSIONS

- The model gave a good prediction of the onset of diapause in both 1998 and 1999 across southern Australia
- A single spray at the critical time in spring prevented the production of oversummering eggs with 97% RLEM control in autumn eight months later. The reduction in mite numbers was still evident after 12 months, but it was not sufficient to avoid the need for further control.
- BOM were present at all sites but were relatively minor pests representing only 3% of the ‘red legged mites’ in pastures in Western Australia. The spring spray was not as effective in controlling BOM as RLEM.
- The benefits of a spring spray in terms of seed yield and seedling density were large and would be economically significant.
Farmers can obtain the package TIMERITE® which gives information about spring spraying of RLEM, and a date for each individual farm, from the Kondinin Group: call 1800 63 00 11. This is being sold for $50 (members) or $60, to cover the cost of producing the package.
ACKNOWLEDGEMENTS
This project is supported by the Woolmark Company, and by Bayer Australia Ltd. We are grateful for advice and help from members of Woolpro, AgWest and CLIMA, and from the numerous farmers involved at these demonstration sites.

KEY WORDS
redlegged earth mite, control, spring, pastures

REVIEWED BY
Owain Edwards
The pattern of seed softening in subterranean clover in relation to predicted false break risk

Ross Chapman and Senthold Asseng, CSIRO Plant Industry, Centre for Mediterranean Agricultural Research

KEY MESSAGE
False breaks occur in 67% of years, with the greatest risk arising over early to mid-autumn. Early cessation of seed softening makes subterranean clover particularly sensitive to these events. Including legume species with seed softening patterns that extend later into the autumn could reduce the negative impact of false breaks on pasture composition.

AIMS
Many pastures in the Mediterranean climatic region of Western Australia are characterised by sub-optimal legume contents. A study was carried out to determine the role that false breaks have in suppressing legume content of pastures and to identify possible techniques for improving the resilience of the pasture legume base.

METHOD
A computer program and historical weather data were used to identify past false break events. This information was used to quantify the proportion of years in which false breaks occurred and how the risk of false break events changed over summer and autumn. False breaks were recognised once two conditions had been met: a rainfall event of sufficient magnitude to initiate major germination activity and a subsequent drought of sufficient duration to induce substantial death among the establishing seedlings. The quantity of rainfall required for germination was varied across the summer and autumn period to account for variations in potential evapotranspiration. Thus, no significant germination was anticipated to occur in January until at least 24 mm of rain had fallen over a period of three days. This figure was reduced to 20 mm in February, 16 mm in March, 12 mm in April and 8 mm in May. Field observations revealed that seedlings rarely survived rain-free periods of more than two weeks at any time over summer and early autumn. Substantial seedling death was therefore presumed to have occurred after any drought period of 14 days or more.

Insufficient field data exist to validate the assumptions about seed germination and death. Instead, the frequency and timing of false break events identified using the parameters cited above were compared with those predicted from a range of alternative rainfall and drought conditions. This demonstrated that changing the conditions required to induce germination or seedling death had negligible impact on the prediction of false breaks unless extreme and biologically unreasonable conditions were adopted. The parameters adopted in this exercise will therefore give a reliable and robust estimate of false break events in the Mediterranean region of Western Australia.

Changes in the germinable seed pool over summer and autumn were used to describe the pattern of seed softening in a field population of subterranean clover. The ability of the seed softening process to protect this species from the effects of false breaks was then assessed.

RESULTS
The use of this computer program indicated that false breaks occurred in 67% of years. The risk of a false break occurring varied considerably over summer and autumn (Figure 1). These events occurred in less than 4% of years in the first two weeks in January. However, the frequency of false breaks increased as the summer and autumn seasons progressed, reaching a peak over late March and April. The risk then declined sharply over late April and May.
Clover seed softening did not commence until after the December sampling, then proceeded at a near linear rate until March (Figure 2). No further seed softening was observed to occur after mid March. This indicates that seed softening in subterranean clover is completed prior to the onset of the period of the greatest risk from false breaks.

CONCLUSION
This analysis has demonstrated that false breaks occur with great regularity in the Mediterranean region of Western Australia. Furthermore, it was revealed that seed softening was terminated in subterranean clover before the risk of a false break event reached its maximum. The high frequency of false breaks and inappropriate pattern of seed softening in subterranean clover explains why subterranean clover tends to be so poorly represented in many annual pasture communities. These findings suggest that the stability and resilience of the pasture’s legume component can be improved by including species that extend seed softening into late autumn, such as gland or arrow-leaf clover.

KEY WORDS
false breaks, subterranean clover
Paper reviewed by:  Senthold Asseng
Charano serradella - a viable option for 1:1 cropping
Steve Carr and Brad Nutt
IAMA Agri-Services Western Australia and Centre for Legumes in Mediterranean Agriculture, University of Western Australia

KEY MESSAGES
Charano yellow serradella used in a 1:1 pasture/crop rotation offers a viable alternative to rotations with grain legumes on sandplain soils in low and medium rainfall areas. It has a number of attributes that are highly desirable in a pasture legume suited to the ley farming system. Some of these include: adaptation to infertile, acidic soils, early maturity, high seed yield and high hard seed levels. With recent technological advances in processing yellow serradella pod to produce highly germinable seed, the disease limitations imposed on lupin crops (e.g. anthracnose) and the onset of herbicide resistant weeds, the use of Charano serradella is expected to rapidly increase.

BACKGROUND
In the last 10 years economic conditions have strongly favoured extended cropping sequences. Agronomic advances and improved genetics have contributed to profitable cropping systems with grain legumes. However, the long-term sustainability of these systems is being challenged. Herbicide resistance, recent outbreaks of disease such as anthracnose and depressed lupin prices have all contributed to a renewed interest in pasture legumes, even for the most ardent continual croppers.
Fortunately the foresight of pasture scientists several years ago, has provided a number of exciting new pasture species to meet this demand. Yellow serradella (*Ornithopus compressus*) has long been recognised as a pasture legume capable of significantly improving agricultural production on the acidic, sandy textured soils in Western Australia (Revell, Nutt and Ewing 1998). Unfortunately a number of minor issues have restricted farmer confidence and subsequent uptake of serradella, with the capacity to sow germinable seed the main limitation. The release of Cadiz French serradella in 1996 provided an alternative, in the form of an easily harvested, soft seeded species that could also grow on the acidic soils of the wheatbelt. The main role for Cadiz was to provide a phase species that could be economically resown after a cropping sequence. The lack of hard seed and the slightly later maturity does restrict the usefulness of Cadiz in the lower rainfall regions, particularly in 1:1 pasture/crop rotation.

Recent research mainly from CLIMA and innovation from seed processors such as Satinwood Pty Ltd and Ballard Seeds have provided solutions on seed germinability and the yellow serradella industry is now destined to expand dramatically. It is now possible to purchase dehulled or naked yellow serradella seed, which can have in excess of 80% germination. This is a vast contrast to the situation five years ago, when the only form of seed in the market place was serradella pod, containing seed (approximately 35% seed by weight), that at best may have had a germination rate of 5%.

AIMS
The performance of yellow serradella compared to existing pasture alternatives is being assessed at a number of sites throughout the wheatbelt. Some preliminary data from a pasture trial initiated in 1998 in the Goodlands region of the northern wheatbelt of Western Australia are reported here. The aim is to use this as a case study outlining the role of yellow serradella in wheatbelt cropping rotations.
METHODS
Charano yellow serradella (7 kg/ha), Cadiz French serradella (15 kg/ha), and Nungarin subterranean clover (15 kg/ha) were sown in a randomised block design on 4 June 1998. The site was on Max Hudson’s property near Goodlands Western Australia, on a deep yellow sandplain soil with the following soil analyses measured on the top 10 cm soil sample: pH (CaCl$_2$) 4.2, P 9 ppm and S 7 ppm, Org C 0.77% and EC 0.04 dS/m. Plot dimensions were 20 m by 2 m, with rates of superphosphate (0, 50, 100, 200 and 400 kg/ha applied). Plots were split to evaluate the effect of potassium treatment (0 or 100 kg/ha KCl) which was top dressed six weeks after sowing.

RESULTS AND DISCUSSION

Herbage yield
There was no effect of additional potassium on either herbage yield or seed yield of any variety. Data for the highest rate of potassium are presented here. Charano yielded between 0.9 and 1.1 t/ha by 11 August which was intermediate between Cadiz French serradella (1.2 to 2.0 t/ha) and Nungarin subterranean (0.2 to 0.5 t/ha) respectively (Table 1). Increasing levels of superphosphate increased herbage production of Nungarin to a greater extent than that of the serradellas. Time limitations restricted the opportunity to sample subsequently, although visual assessments later in the spring indicated these differences were less pronounced.

Table 1. Herbage yield (t/ha) of Charano yellow serradella, Cadiz French serradella, and Nungarin subclover sampled 11th August 1998 (12 weeks after sowing) and seed yields (kg/ha) measured in December 1998 (highest rate of potassium)

<table>
<thead>
<tr>
<th>Species/variety</th>
<th>Charano</th>
<th>Cadiz</th>
<th>Nungarin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superphosphate (kg/ha)</td>
<td>Dry Matter (t/ha)</td>
<td>Seed Yield (kg/ha)</td>
<td>Dry Matter (t/ha)</td>
</tr>
<tr>
<td>0</td>
<td>0.88</td>
<td>434</td>
<td>1.27</td>
</tr>
<tr>
<td>50</td>
<td>1.10</td>
<td>439</td>
<td>1.96</td>
</tr>
<tr>
<td>100</td>
<td>1.13</td>
<td>407</td>
<td>1.41</td>
</tr>
<tr>
<td>200</td>
<td>0.88</td>
<td>444</td>
<td>1.21</td>
</tr>
<tr>
<td>400</td>
<td>0.94</td>
<td>307</td>
<td>1.73</td>
</tr>
</tbody>
</table>

Seed yield
In the year of establishment, Charano yielded between 307 and 444 kg/ha of clean seed per hectare (Table 1). By contrast, Cadiz French serradella yielded between 9 and 22 kg/ha and Nungarin subterranean clover between 76 and 121 kg/ha. These differences between Cadiz and Charano serradella can be largely attributed to their differing maturity, with Charano flowering approximately 20 days earlier than Cadiz. There is ample evidence in the literature which shows that the productivity and success of ley farming systems is highly correlated to the capacity of the pasture legume to set seed yield (Rossiter 1966). Spraying non-selective herbicides to eliminate seed set of ryegrass is a common practice for wheatbelt farmers, and the capacity of Charano to flower and set seed earlier than Cadiz is a major advantage in low rainfall environments.

Hard seed levels were not determined in this trial, although past experience would indicate that the relativities between the three species are: Charano (99% hard after the first summer), Cadiz (0% hard after the first summer) and Nungarin (40%) (B Nutt and A Loi, unpublished data). Clearly, this is where Charano gains a massive advantage in terms of a variety capable of surviving through a cropping regime. Cadiz is unsuitable for this system, and although it may produce high herbage yields in low rainfall environments, it must be resown following a crop. Another major advantage of Charano compared with Nungarin subterranean clover is the germination pattern following the commencement of winter rainfall (data not shown). Like most varieties of yellow serradella,
Charano germinates over an extended period. This attribute vastly reduces the likelihood of low plant densities following ‘false breaks’ which frequently devastate subterranean clover pastures in the Western Australian wheatbelt.
CONCLUSIONS

Charano yellow serradella offers an exciting prospect for pasture crop rotations in the low and medium rainfall wheatbelt. It has a number of attributes which should allow it to persist through the cropping phase and maintain a reasonably stable legume content between years. Its lower initial productivity compared to Cadiz serradella is more than compensated for by its capacity to produce a high and persistent seed bank.

REFERENCES


GRDC Project No.: UWA255
Paper reviewed by: Clinton Revell
Alfalfa mosaic virus in alternative annual pasture and forage legumes

Lindrea Latham and Roger Jones

Crop Improvement Institute, Agriculture Western Australia and Centre for Legumes in Mediterranean Agriculture, University of Western Australia

KEY MESSAGES

• All 17 alternative pasture and forage legumes species tested were infected with AMV to varying extents.
• The species most susceptible to AMV infection were French serradella, rose clover, crimson clover, purple clover and Persian clover.
• AMV was seed-borne in 15 species with highest rates of seed transmission in Trigonella, purple clover and bladder clover.
• AMV infection has important implications for the health of seed stocks of pasture legume improvement programmes and commercial seed.

BACKGROUND

Alfalfa mosaic virus (AMV) is spread by aphids in a non-persistent manner, infects over 150 legume species and is readily seed-borne. Annual medics are the most important pasture legume hosts in which the virus is seed-borne and able to carry over outside the growing season in the Western Australian wheatbelt. In pastures AMV decreases herbage and seed yields and increases the content of less desirable species such as capeweed. The symptoms caused by AMV in pasture legumes are often confused with those of nutrient deficiencies, physiological disorders and herbicide damage, etc. and as a result the importance of the virus is often underestimated.

METHODS

A screening experiment was sown at Medina Research Station in June 1998 to determine the AMV susceptibility (= % plant infection) and sensitivity (= extent of damage) of a collection of 18 different pasture and forage legumes. Approximately 50 plants of each species were grown in single row plots (3 replicates). AMV-infected medic plants were transplanted at either end of each test row to act as virus infection sources. Natural aphid movement was relied on to spread AMV from the infector plants to the plants in the test rows. Plants were examined for virus symptoms regularly over a 10 week period and percentage AMV infection determined for each row. Representative leaf samples were collected and tested by ELISA to confirm AMV infection levels assessed by visual symptoms. Seeds from test rows were collected and germinated in rolls of moist absorbent paper and kept at 25°C in an incubator for up to 7 days. Seedlings (minus the seed coat) were tested by ELISA in grouped samples of 10. Percentage virus transmission to seedlings was estimated from the grouped sample test results.

RESULTS

The symptom types and severities due to AMV infection recorded are shown in Table 1. Infection was first observed in helmet and arrowleaf clover in mid September and by early November it reached high levels in many species. Highest susceptibilities were in French Serradella, rose clover, crimson clover, purple clover and Persian clover. Most of the clover species tested had between 25 and 75% final infection levels and symptoms ranged from a mild in Balansa clover cv. Paradana to severe in crimson clover cv. Caprera. French serradella cv. Cadiz was highly susceptible to AMV and had severe symptoms and produced no viable seed. In contrast, yellow serradella cv. Santorini was ranked as resistant and its symptom...
severity was only moderate. Although *Biserrula pelecinus* cv. Casbah was classed as moderately resistant it was sensitive because when plants became infected symptoms were severe. None of the species tested were ranked as highly resistant (= no AMV infection) but Trigonella SA5045 and sea clover 36881 were resistant as they had less than 10% infection at the end of the growing season. Symptoms were only moderate in both of them.

Seed transmission was found in all of the 15 species tested with between 0.07% (helmet clover) and 7% (Trigonella) infection (Table 2). The greatest risk of high seed infection is therefore in Trigonella, purple clover and bladder clover.

**Table 1. Symptoms caused by AMV in pasture and forage legumes species**

<table>
<thead>
<tr>
<th>Common name</th>
<th>Species</th>
<th>Sensitivity</th>
<th>Severity</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>French Serradella</td>
<td><em>Ornithopus sativus</em></td>
<td>HS</td>
<td>5</td>
<td>MM, CS, LDC, TD, TN, S</td>
</tr>
<tr>
<td>Rose Clover</td>
<td><em>Trifolium hirtum</em></td>
<td>S</td>
<td>5</td>
<td>M, RL, LN, TD, S</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td><em>Trifolium incarnatum</em></td>
<td>S</td>
<td>6</td>
<td>M, VC, LN, S, D</td>
</tr>
<tr>
<td>Purple Clover</td>
<td><em>Trifolium purpureum</em></td>
<td>S</td>
<td>5</td>
<td>M, NSS, TN, S</td>
</tr>
<tr>
<td>Persian Clover</td>
<td><em>Trifolium resupinatum</em></td>
<td>S</td>
<td>4</td>
<td>M, S</td>
</tr>
<tr>
<td>Subterranean Clover</td>
<td><em>Trifolium subterraneum</em></td>
<td>S</td>
<td>5</td>
<td>VC, LMN, S</td>
</tr>
<tr>
<td>Biserrula</td>
<td><em>Biserrula pelecinus</em></td>
<td>MR</td>
<td>7</td>
<td>SC, TD, TN, S, D</td>
</tr>
<tr>
<td>Cupped Clover</td>
<td><em>Trifolium cherleri</em></td>
<td>MR</td>
<td>4</td>
<td>VC, S</td>
</tr>
<tr>
<td>Helmet Clover</td>
<td><em>Trifolium clypeatum</em></td>
<td>MR</td>
<td>5</td>
<td>M, RLM, TD</td>
</tr>
<tr>
<td></td>
<td><em>Trifolium dasyurum</em></td>
<td>MR</td>
<td>3</td>
<td>MM</td>
</tr>
<tr>
<td>Gland Clover</td>
<td><em>Trifolium glanduliferum</em></td>
<td>MR</td>
<td>4</td>
<td>M</td>
</tr>
<tr>
<td>Moroccan Clover</td>
<td><em>Trifolium isthmocarpum</em></td>
<td>MR</td>
<td>4</td>
<td>M, TD</td>
</tr>
<tr>
<td>Balansa Clover</td>
<td><em>Trifolium michelianum</em></td>
<td>MR</td>
<td>3</td>
<td>VC</td>
</tr>
<tr>
<td>Bladder Clover</td>
<td><em>Trifolium spumosum</em></td>
<td>MR</td>
<td>4</td>
<td>M, RL, LN, TD, S</td>
</tr>
<tr>
<td>Arrowleaf Clover</td>
<td><em>Trifolium vesiculosum</em></td>
<td>MR</td>
<td>4</td>
<td>VC, TD, LMN</td>
</tr>
<tr>
<td>Yellow Serradella</td>
<td><em>Ornithopus compressus</em></td>
<td>R</td>
<td>4</td>
<td>MM, CS, LDC, TD, TN, S</td>
</tr>
<tr>
<td>Sea Clover</td>
<td><em>Trifolium squarrosum</em></td>
<td>R</td>
<td>4</td>
<td>VC</td>
</tr>
<tr>
<td>Trigonella</td>
<td><em>Trigonella balansae</em></td>
<td>R</td>
<td>4</td>
<td>MM</td>
</tr>
</tbody>
</table>

**Sensitivity:**
- HR = 0% infection, R = 1-25%, MR = 25-50%, S = 50-75%, HS = 75-100%

**Severity:**
- 1 = symptomless, 2 = very mild, 3 = mild, 4 = moderate, 5 = severe, 6 = very severe, 7 = plant death

**Symptoms:**
- CS = chlorosis in new shoots, SC = severe plant chlorosis, MM = mild mottle, M = mottle, VC = vein clearing, SVC = severe vein clearing, LDC = shoot tip and leaflet down curling, RLM = reddening of leaf margins, LMN = leaf margin necrosis, RL = red leaves, NSS = systemic necrotic spots and streaking on leaves, RRS = systemic red ring spots, LRI = leaves rolling inwards, AS = axillary shoot production, LN = necrosis of new and or old leaves, TD = shoot tip distortion, TN = shoot tip necrosis, MS = mild stunting, S = stunting, SS = severe stunting, D = plant death, R = recovery from early infection.

**Table 2. Seed transmission of AMV to pasture and forage legume species**

<table>
<thead>
<tr>
<th>Common name</th>
<th>No. seeds tested</th>
<th>% Seed infection</th>
</tr>
</thead>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Susceptibility</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigonella</td>
<td>980</td>
<td>7</td>
</tr>
<tr>
<td>Purple Clover</td>
<td>2000</td>
<td>5</td>
</tr>
<tr>
<td>Bladder Clover</td>
<td>2050</td>
<td>3</td>
</tr>
<tr>
<td>Yellow Serradella</td>
<td>2010</td>
<td>1</td>
</tr>
<tr>
<td>Sea Clover</td>
<td>2000</td>
<td>0.9</td>
</tr>
<tr>
<td>Arrowleaf Clover</td>
<td>2030</td>
<td>0.9</td>
</tr>
<tr>
<td>Moroccan Clover</td>
<td>2000</td>
<td>0.8</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>2030</td>
<td>0.6</td>
</tr>
<tr>
<td>Biserrula</td>
<td>2210</td>
<td>0.5</td>
</tr>
<tr>
<td>Cupped Clover</td>
<td>2000</td>
<td>0.5</td>
</tr>
<tr>
<td>Persian Clover</td>
<td>2000</td>
<td>0.2</td>
</tr>
<tr>
<td>Gland Clover</td>
<td>2000</td>
<td>0.1</td>
</tr>
<tr>
<td>Rose Clover</td>
<td>2040</td>
<td>0.07</td>
</tr>
<tr>
<td>Balansa Clover</td>
<td>4080</td>
<td>0.05</td>
</tr>
<tr>
<td>Helmet Clover</td>
<td>2040</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Highest susceptibilities and therefore risk of spread were in French Serradella, and rose, crimson, purple and Persian clovers. Highest seed transmission rates were in Trigonella, purple clover and bladder clover raising concerns over distribution of infected seed stocks and losses arising from sowing infected seed. ‘Duty of care’ responsibilities involve ensuring that varieties are not released that are highly susceptible to already established viruses like AMV and that seed is not seriously contaminated by them.

We thank plant virology technical staff at Agriculture Western Australia for assistance with this work.

**Paper reviewed by:** Roger Jones
Pasture mixture performs better than single-species-based pastures-1999

Anyou Liu, Clinton Revell and David Ferris

Centre for Cropping Systems, Agriculture Western Australia, Northam

KEY MESSAGE

A mixture of different legume pasture species could be the solution to declining legume contents in pastures. A project primarily funded by GRDC has recently been started with AGWEST to exploit the potential benefits that may arise from this approach. In 1999, the sown pasture mixture performed better than pure subclover pasture with a higher production (6.3 t/ha cf. 4.1 t/ha, an increase of 54%) and a higher legume percentage (93% cf. 77% of biomass). Performance of regenerating pasture mixtures after one year of crop will be monitored in the following years.

BACKGROUND

Ley farming has long been a default practice in the Western Australian wheatbelt, in which crop rotates with pastures regularly and the pasture will self regenerate after each crop phase. Traditional systems are based on single sown species such as subterranean clover and annual medics. Despite the benefits pasture can bring to the farming system, there are often problems in maintaining a high legume content in pastures, especially in the face of false breaks of season. Recent work has shown that environmental influences can have a greater impact on pasture production than farm management practices.

The use of pasture mixtures using recently developed alternative legume species may offer a solution to maintain the stability of the legume component.

Compared to single legume species based pastures, the potential benefits of using pasture mixtures are:

- Species with different patterns of growth will utilise the environmental resources more efficiently and, therefore be more productive.
- High seed production with variable hardseededness will increase the seed bank size, and result in a high and stable legume content in the pastures in following years.
- Greater tolerance of pests and diseases.
- Higher legume content will improve the pasture quality.
- Higher legume content will reduce weeds and, therefore reduce the reliance on the use of herbicide.
- Higher legume content will fix more nitrogen, leave more organic matter in the soil and improve performance of subsequent crops.
- The right mixtures may also reduce groundwater recharge and associated salinity problems.

PROJECT ADDRESSING THIS OPPORTUNITY

Project: ‘Developing pasture species mixtures to ensure a high and stable legume content for the benefit of subsequent crops’.

The main approaches of this project will be the use of a key site for in-depth studies to get a better understanding of how species mixtures can better cope with variations in season and management. To achieve this, extensive collaboration with other scientists at the Centre for Cropping Systems, Northam and CSIRO will be undertaken. To demonstrate findings from this trial under different environmental conditions and to enable more farmers to judge the success of this new technology,
the ‘participatory research’ approach will be used to conduct demonstration trials on farmer’s properties at different sites throughout the wheatbelt.

**METHODS**

The trial is being conducted at Jennacubine (the key site) with a sandy surfaced loam duplex soil. The long term annual rainfall of the nearby town is 368 mm (Goomalling). The actual rainfall of the site in 1999 was 476 mm. The previous phase before this trial was a wheat crop after two years of subclover-based pasture. The pasture treatments in 1999 were as follows:

<table>
<thead>
<tr>
<th>Pasture mixture (16.3 kg/ha with equal weight of the following)</th>
<th>Subclover (15 kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Trifolium subterraneum</em> (subclover) cv Dalkeith</td>
<td><em>T. subterraneum</em> (subclover) cv Dalkeith</td>
</tr>
<tr>
<td><em>T. vesiculosum</em> (arrow leaf clover) cv Cefalu</td>
<td></td>
</tr>
<tr>
<td><em>T. glanduliferum</em> (gland clover)</td>
<td></td>
</tr>
<tr>
<td><em>Ornithopus sativus</em> (French serradella) cv Cadiz</td>
<td></td>
</tr>
<tr>
<td><em>Ornithopus compressus</em> (yellow serradella) cv Santorini</td>
<td></td>
</tr>
<tr>
<td><em>Biserrula pelecinus</em> (biserrula) cv Casbah</td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS AND DISCUSSION**

The pastures were ungrazed in this establishment phase. The pasture mixture produced significantly more biomass than the subclover pasture at flowering time. This indicates a potential ability to support a higher grazing rate and therefore higher wool and meat production. The pasture mixture treatment also had a higher legume content and a lower grass content than the subclover-based pasture (Figure 1). This could indicate better pasture quality for grazing animals, better weed control for subsequent crops, and possibly more nitrogen fixation.

![Figure 1. Biomass production and composition of pastures sown to species mixture and subclover (1999).](image)

**ACKNOWLEDGMENTS**
We thank Peter Newton and Christiaan Valentine for technical support and Murray Siegert for allowing this trial on his property at Jennacubine. The project is funded by GRDC.

**GRDC Project No.:** DAW 634  
**Paper reviewed by:** Clinton Revell
Better pasture management improves performance of following crops-1999

Anyou Liu, Clinton Revell and David Ferris

Centre for Cropping Systems, Agriculture Western Australia, Northam

KEY MESSAGE

Better pasture management including the resowing of a well-adapted legume species and grass and insect control improved subsequent crop performance.

BACKGROUND

In a ley farming system, one of the major benefits from a good legume pasture is improved performance of subsequent crops resulting from increased nitrogen fixation and reduced weed and disease problems by the legume components in the pasture. However, traditional management systems are usually not able to maintain a high and stable legume content and therefore can not take full advantage of such system. Development, evaluation and adoption of appropriate management strategies for pastures in the ley farm system are central to increase legume content and important to enhance the grain industry’s capacity to produce wheat of a consistent quality and yield over a long period.

METHODS

A long-term pasture/crop rotation experiment is being conducted at Cunderdin and commenced in 1995. The site has a red-brown clay soil with a long-term annual rainfall of 366 mm (Cunderdin). The actual rainfall of the site in 1999 was 434 mm. The experiment is managed in a 1:1 pasture/crop rotation with different pasture management strategies (Table 1). The pasture is based on Santiago burr medic (Medicago polymorpha). For 1999 crops, the wheat variety Carnamah was sown at a rate of 60 kg/ha plus 120 kg/ha super on 10 June. The response of the crop to additional nitrogen application was also tested on plots with different pasture management strategies (data not yet available).

RESULTS

At Cunderdin in 1998, optimum pasture management resulted in higher pasture production and a higher medic content than the control management (Figure 1). In 1999, crop after pasture with optimum management produced significantly higher grain yield (4.5 t/ha) than crop following pasture with control management (2.96 t/ha) (Figure 2). The result indicates that, differences in previous pasture performance can have a significant effect on performance of following crops. However, the response in wheat production was much greater in 1999 than in previous years. This is due in part to the instability of the medic component between years (e.g. effects of season, disease etc.), which may possibly be overcome by the introduction of other legume species as a mixture.

ACKNOWLEDGMENTS

We thank Peter Newton and Christiaan Valentine for technical support and James Stokes for allowing this study on his property. The project is funded by GRDC.
Table 1. Details of the two pasture management strategies

<table>
<thead>
<tr>
<th>Management</th>
<th>Weed control</th>
<th>Insect control</th>
<th>Grazing management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum</td>
<td>Selective grass herbicide</td>
<td>Control when required</td>
<td>Low intensity during flowering and stop grazing of burrs over summer when &lt; 400 kg/ha.</td>
</tr>
<tr>
<td>Control</td>
<td>Spraytopping only</td>
<td>No inputs</td>
<td>District practice</td>
</tr>
</tbody>
</table>

ACKNOWLEDGMENTS

We thank Peter Newton and Christiaan Valentine for technical support and James Stokes for allowing this study on his property. The project is funded by GRDC.

GRDC Project No.: DAW 361 and DAW 634

Paper reviewed by: Clinton Revell
Lucerne Benefits Crop Production

Roy Latta¹, Lisa-Jane Blacklow², Chris Matthews¹

¹ Agriculture Western Australia
² University of Western Australia

KEY MESSAGES

A rotation of three or more years of lucerne followed by several years of crop will increase the water use of south-western Australian grain-producing farm systems and so limit ground water recharge. This has profound implications in a region where 1% of the land surface is lost annually to salinity and where rising water tables and salinity threaten some 6 million hectares. Phase farming with lucerne offers perhaps the most attractive option for farmers wishing to continue grain production in a sustainable manner.

Results from research that has compared a five-year lucerne based pasture-crop rotation (LLLWC) to an annual legume based (AAAWC) pasture-crop rotation has shown that lucerne:

- Maintained a drier soil profile through years 2 to 5.
- Fixed 30 kg/ha more nitrogen in the pasture phase.
- Produced quality fodder over the summer and autumn period.
- Increased average wheat yield by 10% and grain protein by 1% in year 4.
- Increased average canola yield by 7% while maintaining oil content in year 5.
- Reduced the crop weed component.
- Provided a profit increase of $0–$40/ha/annum compared to the next most profitable rotation (MIDAS Model pers comm Bathgate/Blennerhasset).

AIMS

To extend research results that provide evidence that phase farming with the deep-rooted perennial lucerne is an effective means of improving productivity while addressing encroaching salinisation in the wheatbelt of Western Australia.

METHODS

The experiments were conducted at Borden on a sand over gravel, pHCa 5.0 and at Pingrup on a grey clay soil, pHCa 5.8. Experiments were sown to lucerne and sub-clover cv. Dalkeith (Borden) and annual medic cvs. Serena and Santiago (Pingrup) in June 1995. In the autumn of 1998 lucerne was removed. Both sites were sprayed with glyphosate (450 g/L a.i.) at 2 L/ha and Estercide800® (2.4-D 800 g/L a.i.) at 2.8 L/ha. Wheat (cv. Cunderdin) was sown at 78 kg/ha on 28 and 29 May 1998 at Borden and Pingrup respectively with 140 kg/ha of 3:1 SuperPotash (CSBP). In 1999 both sites were sprayed pre-seeding with 2 L/ha of Atrazine (500 g/L a.i.) and 1 L/ha of glyphosate (450 g/L a.i.). A further 2 L/ha of Atrazine (500 g/L a.i.) was applied to the Borden site post-emergent on 23 May. Canola was sown on 12 May 1999 (Borden) and 21 May 1999 (Pingrup) at 4 kg/ha to cvs. Pinnacle and Karoo respectively.

RESULTS

Rain

Table 1. Annual rainfall (mm/yr) between 1996 and 1999 and the long term average annual rainfall (mm/yr) for Borden and Pingrup

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Borden</td>
<td>341</td>
<td>369</td>
<td>576</td>
<td>395</td>
<td>400</td>
</tr>
<tr>
<td>Pingrup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Soil water content

At Borden there was no difference in water stored in the 10-150 cm profile in the spring (October) of 1996. However, at least 40 mm less water was stored under the lucerne pasture than subterranean clover from January 1997 until May 1998 with a maximum deficit of 99 mm in January 1998. This deficit was erased in August 1998 following the removal of the lucerne in April 1998. The difference in stored soil water following the wheat and canola was extended to 40 mm and 50 mm respectively. At Pingrup, the difference in total stored water in the 10-150 cm soil profile was maintained at 20 to 30 mm until the second summer (January 1998) when 63 mm less water was measured under the lucerne treatment. This decreased to 20 mm following the lucerne removal in 1998. The difference in soil water between the annual and perennial treatments had increased to 47 mm following wheat in December 1998, partly due to ‘rogue’ lucerne escapees. This deficit had been erased by June 1999 but returned to a 27 mm deficit by December 1999.

Crop yield and quality

At Borden the wheat yield after the lucerne treatment (4.7 t/ha) was greater than after subterranean clover treatment (4.0 t/ha). The lucerne treatment had no effect on grain protein levels. At Pingrup there was no effect of previous pasture species on grain yields but the lucerne treatment retained an average of 8 lucerne plants/m² which survived the pre-seeding removal. Grain protein levels after lucerne were higher than after annual medic.

| Table 2. Wheat yields (t/ha) and grain proteins (%) in 1998, canola yields (t/ha) and oil contents (%) in 1999 in response to lucerne and annual legume pasture treatments at Borden and Pingrup |
|-----------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Wheat yield and (grain protein)               | Canola yield and (oil content) |
| Borden                                        | Pingrup         | Borden          | Pingrup         |
| Lucerne                                      | 4.7 (9.3)       | 2.1 (13.3)      | 2.1 (46.1)      | 1.5 (40.1)      |
| Annual legume                                | 4.0 (9.3)       | 2.0 (12.0)      | 2.1 (46.1)      | 1.3 (40.1)      |
| l.s.d. (P = 0.05)                            | 0.58 (n.s.d.)   | n.s.d. (0.7)    | n.s.d. (n.s.d.) | 0.7 (n.s.d.)    |

DISCUSSION

The beneficial effects of lucerne on wheat yield (Borden) and quality (Pingrup) in 1998 and canola yield (Pingrup) in 1999 may be attributed to higher nitrogen accretion and increased depth of access to the stored soil water. Although at Pingrup any beneficial effects of the lucerne treatment on wheat grain yield were most likely nullified by competition for water and nutrients from ‘rogue’ lucerne plants during the drier than average spring. The wheat yield increase with similar grain protein levels at following lucerne compared to a sub-clover pasture indicate increased nitrogen availability Borden. In 1999 a ‘dry’ season at Borden resulted in a similar canola yield. A higher yield at Pingrup resulted in response to the ‘wet’ season. This indicates increased depth of soil profile access by the canola. The increasing stored soil water deficit during the spring in the previous lucerne treatments supports this contention.

The opportunity to use more water and address rising saline water tables with pasture has wide appeal through the 300-400 mm wheat belt and is strongly supported by the draft Salinity Action Plan in Western Australia. Pasture that provides high quality fodder for 12 months to an integrated cereal/livestock system will reduce the need for costly fodder conservation and purchasing requirements. However, the wider uptake of lucerne will rely on other economic and management issues: effective establishment and management packages; adaptation to acid soils; ability to
produce economic benefits through increased nitrogen inputs; and more efficient weed control options leading to increased quantity and quality of grain crops.
ACKNOWLEDGMENTS

The Grains Research and Development Corporation (GRDC) have funded this project. The experiments were conducted on land generously donated by Richard and Nan Sounness of Borden and Brian and Del Smith of Pingrup. Their valuable counsel and assistance is gratefully acknowledged.

GRDC Project No.: GRDC UWA149
Paper reviewed by: R. Latta and L.-J. Blacklow
Does size count? Determining optimum release number of red apion for biocontrol of doublegee

Tim Woodburn and Paul Yeoh, CSIRO Entomology/CRC Weed Management Systems, Perth

KEY MESSAGE

Release numbers of red apion need to be about 300 to ensure that numbers will increase sufficiently to allow for high mortality that occurs during Western Australia’s hot, dry summers. However, this will allow fewer releases to be made in a season than if smaller numbers were released.

AIMS

The South African plant doublegee is a major weed of cereal-growing areas of Western Australia and costs the industry many millions of dollars annually. Although it is readily controlled by herbicides, there are concerns about continued reliance on chemicals in agriculture. Biological control offers an environmentally safe means of reducing this troublesome weed problem. A weevil, Apion minimatum (red apion), was approved for release in Australia several years ago. Establishing biological control agents is often difficult and many programs fail at this stage. There can be many reasons for this, but a prime one is that initial release numbers are too low. During the last doublegee season releases of red apion were made across Western Australia to study optimum release size.

METHODS

Releases were made on growers’ properties from Geraldton to Esperance during autumn 1999. The insects had been mass reared in tunnel houses at Floreat in 1998, and oversummered in the laboratory. The following autumn, when they were sexually mature, mated and ready to oviposit, they were released onto dense stands of doublegee within growers’ properties. Release numbers were 60, 120, 240, 480, 960 or 1,920 insects/site. Figure 1 shows their distribution across south-west Western Australia. Given the numbers involved, the insects were not sexed before released. However, the sex ratio is 50:50 and it was assumed that equal numbers of males and females were released. Grower commitment to the project was that they would either fence off the release area, or keep stock out of that part of their property. There was also a commitment that insecticides/herbicides would not be sprayed in the immediate vicinity of the release site. Each site was revisited at the beginning of summer at about the time of doublegee senescence. Assessments were made at the release site and at increasing distances towards the four compass points, moving away from the release site until no further evidence of attack was seen. Measurements were made of the doublegee density and plants were dissected in the field to estimate the number of red apion per plant.

RESULTS

Three releases failed outright due to growers’ either spraying out the doublegee, or allowing stock to crash graze it. The most easterly site was not assessed. Six of the 33 remaining sites showed very poor breeding (defined here as a rate of increase less than five offspring per insect). Although there were more sites with poor breeding where low numbers of insects were released, one occurred at a 480 site (Figure 1). They were however all from releases that were made in coastal areas. Twenty releases had a rate of increase that was greater than 20, 18 of which were inland. As would be expected there were increasing numbers of insects estimated from sites with increased release size (Figure 2).

The oversummering period is when mortality of red apion is expected to be highest: the insect has to survive this hot dry period without recourse to its host plant, doublegee. It is unknown where oversummering occurs, but the most likely place is sheltering underneath tree bark. Hence, to counter-balance this expected high mortality, it is imperative that large populations of insects enter the oversummering phase. Previous experiments indicate that 3,500 insects are insufficient to see evidence of establishment in the following autumn. In this series of releases greater than 3,500
insects were reared in 11, 44, 75, 80, 100 and 100% of the 60, 120, 240, 480, 960, and 1,920 releases respectively.
Figure 1. Release sites and corresponding reproductive success of individuals.

Figure 2. Number red apion reared per release site.

\[ \log_{10}(y) = 1.01 \log_{10}(x) + 1.18 \]

\( R^2 = 0.84 \)
CONCLUSIONS
The results indicate that releases of between 240 and 480 insects/site will lead to successful breeding in a high proportion of cases, and will also produce oversummering populations well in excess of 8,000 insects. Obviously with larger release numbers, fewer sites are possible. However, even releases of this magnitude are not all guaranteed of success, as is evident from the results above. The reasons remain unknown for these failures, as there was an adequate population of doublegee at each site, and the growers undertook all that we required them to do. Releases in the immediate future will not occur in the southern, more temperate parts of Western Australia, given the uniformly poor success rates there, or in coastal areas to the north. Rather we will concentrate our efforts in inland regions in an attempt to build large insect populations that can act as nursery sites for future redistribution of this promising biological control agent. Whether establishment results from any of these releases will not be known until the break of season when red apion will reappear from their oversummering sites.

ACKNOWLEDGMENTS
We would like to thank the many growers who have allowed us access to their properties, too many to mention individually. This work is jointly funded by the GRDC and the Australian Government.

GRDC Project No.: CSE132
Paper reviewed by: Owain Edwards
Herbicide tolerance of some new cultivars of annual pasture legumes

Clinton Revell and Ian Rose
Centre for Cropping Systems, Agriculture Western Australia, Northam

KEY MESSAGES

- Herbicide reactions vary widely between species.
- Frontier balansa clover was broadly tolerant of a range of herbicides including post-emergent gramoxone and Tigrex®.
- Serradella and biserrula were tolerant of bromoxynil which may offer another alternative for broadleaf weed control in these species.
- Persian clover and arrowleaf clover showed particular sensitivity to simazine.
- Most species were tolerant of Broadstrike® except biserrula.

BACKGROUND

Herbicides can play an important role in pasture management but there is considerable variation amongst species in their tolerance to herbicides. Progress has been made towards quantifying the reactions of new pasture legume species to some of the more commonly used herbicides.

METHODS

A replicated experiment was established at Goomalling, Western Australia in 1999 on a sandy loam pH (CaCl₂) 4.8. Pasture legume species included subterranean clover (Dalkeith), burr medic (Santiago), French serradella (Cadiz), persian clover (Prolific), balansa clover (Frontier, Paradana), arrowleaf clover (Cefalu), biserrula (Casbah) and gland clover. The pastures were sown after a knockdown herbicide on 10 June and maintained in a weed-free condition to avoid confounding weed competition with herbicide reaction. Herbicide treatments included pre-emergent applications of Treflan® and post-emergent applications (3 August - 6 leaf stage) of Broadstrike®, Jaguar®, MCPA, Tigrex®, 2,4-DB, Spinnaker®, Simazine and Gramoxone. Gramoxone was also applied as a spraytopping treatment on 23 September. Plots were visually rated in August and September for effects on herbage production and seed yields were measured in December. Seed yield data is still being processed.

Reactions to herbicides varied widely between species. Treflan resulted in some thinning of plant numbers (particularly the clover species) but had no serious impact in any species. Glyphosate severely reduced herbage production in the clover species (except Dalkeith), serradellas and biserrula but favourable conditions in spring allowed seed production to be maintained at high levels. Gramoxone was more severe than glyphosate in burr medic and was particularly damaging to biserrula and gland clover. The balansa clovers showed a strong capacity to recover after mid-winter gramoxone application but seed yields appear to be considerably reduced with its use as a spraytopping treatment. The effectiveness of simazine on this loam soil type was difficult to quantify but persian clover and arrowleaf clover showed particular sensitivity. All species were highly sensitive to MCPA except Dalkeith subterranean clover and gland clover.

Burr medic and most of the clover species showed a substantial reduction in herbage production following either bromoxynil or Jaguar (especially persian clover and arrowleaf clover). Tigrex generally had less impact on herbage growth, with Dalkeith subterranean clover and the balansa clovers showing particularly strong recovery. The serradellas and biserrula were sensitive to both Jaguar and Tigrex but were considerably more tolerant of bromoxynil. Bromoxynil may provide a useful alternative in these species for broadleaf weed control, especially where capeweed is a
problem or where an alternative to Group B herbicides is required. Broadstrike and Spinnaker were generally safe across all species except biserrula. Mixtures of Diuron and 2,4-DB caused moderate levels of damage, particularly in biserrula and the clover species. It also appeared to have a greater effect on seed production than herbage production.
RESULTS AND DISCUSSION

Table 1.  Percentage reduction in herbage production of selected legume pasture cultivars at two times during the growing season (August and September) following herbicide application (Pre = pre-sowing, PE = post emergent, ST = spraytopping).  Seed yields (SY) where available are expressed as a percentage of un sprayed yields.  Days to 10% flower given in parenthesis

<table>
<thead>
<tr>
<th>Herbicide (Rate/ha)</th>
<th>Species</th>
<th>Yellow serradella</th>
<th>French serradella</th>
<th>Balansa clover</th>
<th>Balansa clover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Charano (89)</td>
<td>Cadiz (97)</td>
<td>Parada (108)</td>
<td>Frontier (78)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aug</td>
<td>Sept</td>
<td>SY</td>
<td>Aug</td>
</tr>
<tr>
<td>Pre 1.5 L Treflan</td>
<td></td>
<td>13</td>
<td>23</td>
<td>111</td>
<td>6</td>
</tr>
<tr>
<td>PE 400 ml Glyphosate</td>
<td></td>
<td>52</td>
<td>86</td>
<td>90</td>
<td>52</td>
</tr>
<tr>
<td>PE 500 ml Gramoxone</td>
<td></td>
<td>44</td>
<td>38</td>
<td>103</td>
<td>51</td>
</tr>
<tr>
<td>PE 750 ml Simazine</td>
<td></td>
<td>8</td>
<td>28</td>
<td>99</td>
<td>6</td>
</tr>
<tr>
<td>PE 1 L MCPA</td>
<td></td>
<td>42</td>
<td>82</td>
<td>65</td>
<td>28</td>
</tr>
<tr>
<td>PE 1.5 L Bromoxynil</td>
<td></td>
<td>13</td>
<td>23</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>PE 500 ml Jaguar</td>
<td></td>
<td>28</td>
<td>58</td>
<td>95</td>
<td>27</td>
</tr>
<tr>
<td>PE 400 ml Tigrex</td>
<td></td>
<td>26</td>
<td>69</td>
<td>78</td>
<td>30</td>
</tr>
<tr>
<td>PE 25 g Broadstrike</td>
<td></td>
<td>10</td>
<td>15</td>
<td>118</td>
<td>9</td>
</tr>
<tr>
<td>PE 250 ml Spinnaker</td>
<td></td>
<td>16</td>
<td>23</td>
<td>116</td>
<td>7</td>
</tr>
<tr>
<td>PE 200 Diuron+400 24DB</td>
<td>15</td>
<td>28</td>
<td>77</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>ST 500 ml Gramoxone</td>
<td></td>
<td>89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter (t/ha) or seed yield (kg/ha) - Unsprayed</td>
<td>1.7</td>
<td>5.9</td>
<td>880</td>
<td>2.1</td>
<td>6.1</td>
</tr>
</tbody>
</table>

The effect of spraytopping on seed production will be influenced by the stage of maturity of the pasture. Santiago, Dalkeith and Frontier balansa clover had begun to flower four to five weeks before spraying. Charano, Cadiz, Prolific, Casbah and gland clover had been flowering for one to two weeks before spraying. Paradana and Cefalu had yet to flower. Given its early maturity, the substantial reduction in seed yield of Frontier after spraytopping is surprising, but may have been a consequence of a reduced capacity for regrowth after spraying.

Table 2.  Percentage reduction in herbage production of selected legume pasture cultivars at two times during the growing season (August and September) following herbicide application (Pre = pre-sowing, PE = post emergent).  Days to 10% flower given in parenthesis

<table>
<thead>
<tr>
<th>Herbicide (Rate/ha)</th>
<th>Species</th>
<th>Burr medic</th>
<th>Subterranean clover</th>
<th>Biserrula</th>
<th>Persian clover</th>
<th>Gland clover</th>
<th>Arrowleaf clover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Santiago (67)</td>
<td>Dalkeith (86)</td>
<td>Casbah (102)</td>
<td>Prolific (99)</td>
<td>(95)</td>
<td>Cefalu (120)</td>
</tr>
<tr>
<td>Pre 1.5 L Treflan</td>
<td></td>
<td>12</td>
<td>52</td>
<td>20</td>
<td>24</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>PE 400 mL Glyphosate</td>
<td></td>
<td>33</td>
<td>49</td>
<td>40</td>
<td>54</td>
<td>79</td>
<td>86</td>
</tr>
<tr>
<td>PE 500 mL Gramoxone</td>
<td></td>
<td>80</td>
<td>64</td>
<td>55</td>
<td>53</td>
<td>94</td>
<td>97</td>
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<tr>
<td>PE 750 mL Simazine</td>
<td></td>
<td>2</td>
<td>21</td>
<td>8</td>
<td>18</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>PE 1 L MCPA</td>
<td></td>
<td>38</td>
<td>74</td>
<td>25</td>
<td>39</td>
<td>39</td>
<td>77</td>
</tr>
<tr>
<td>PE 1.5 L Bromoxynil</td>
<td></td>
<td>85</td>
<td>71</td>
<td>34</td>
<td>48</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>PE 500 mL Jaguar</td>
<td></td>
<td>67</td>
<td>71</td>
<td>32</td>
<td>47</td>
<td>31</td>
<td>49</td>
</tr>
<tr>
<td>PE 400 mL Tigrex</td>
<td></td>
<td>33</td>
<td>52</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>PE 25 g Broadstrike</td>
<td></td>
<td>12</td>
<td>20</td>
<td>7</td>
<td>12</td>
<td>44</td>
<td>93</td>
</tr>
<tr>
<td>PE 250 mL Spinnaker</td>
<td></td>
<td>18</td>
<td>38</td>
<td>8</td>
<td>9</td>
<td>35</td>
<td>51</td>
</tr>
<tr>
<td>PE 200 Diuron+400 24DB</td>
<td>15</td>
<td>45</td>
<td>18</td>
<td>38</td>
<td>23</td>
<td>62</td>
<td>48</td>
</tr>
</tbody>
</table>
**CONCLUSIONS**

There is considerable variation amongst new pasture legume species in their tolerance to commonly used herbicides. This variation can be exploited with most species appearing to have several options which can be used with safety. Seed yields do not always reflect the substantial reductions in herbage production. The high seed yields measured in this experiment are probably a consequence of conserved soil water, no defoliation and favourable conditions in spring. The work needs to be continued to account for soil type and seasonal variation as well as the timing of herbicide application, grazing and the use of herbicide mixtures.

_We thank Steve Bell, Chris Roberts and Sue Donald for excellent technical assistance with this work._

**GRDC Project No.:** UWA 269  
**Paper reviewed by:** Terry Piper
Lucerne - crop rotations in the Esperance region

Anita Lyons¹, Roy Latta² and Chris Matthews², Agriculture Western Australia

¹ Esperance
² Katanning

KEY MESSAGE

Early results from several rotation experiments in the Esperance region indicate that lucerne can be incorporated into productive cropping systems. Lucerne can dry out the soil profile to a greater degree than annual pastures, although this effect is not apparent until the second year of the lucerne phase. Lucerne can also reduce the prevalence of undesirable weeds.

BACKGROUND

The need to take action to limit the spread of dryland salinity in the agricultural regions of Western Australia is now widely recognised. Past clearing of perennial vegetation for agricultural purposes has led to rising water tables and the spread of salinity through much of the wheatbelt. It is now clear that in order to prevent the further spread of salinity large areas of land must be replanted to perennial vegetation. Lucerne is a deep-rooted perennial that has been shown to be well adapted to the southern and central cropping zones of Western Australia.

AIM

The aim of this work is to evaluate the performance of lucerne in cropping systems of the southern wheatbelt. The study continues the work of Roy Latta and Lisa Blacklow, which compared lucerne and annual pasture systems over a five year pasture/crop rotation at sites near Borden and Pingrup.

METHODS

Two long-term experimental sites contrasting annual pasture and lucerne systems were established near Esperance in 1998. One site is at Wittenoom Hills (average annual rainfall 350 mm) and soil pH (CaCl₂) 5.4, the other is at Cascades (average annual rainfall 372 mm) and soil pH (CaCl₂) 5.3. Treatments include varying lengths of lucerne phases followed by crop, deferred defoliation and weed control strategies. The annual legume treatment is based on subterranean clover. Grazing is simulated by six weekly mowing cycles. Soil water is measured monthly in neutron access tubes located in each plot. Only the first two years of this five-year research program have been completed and these preliminary data are presented here. The first cereal crops will be sown in 2000.

RESULTS AND DISCUSSION

Lucerne densities in excess of 40 plants/m² were achieved at both sites in 1998. Soil water at the end of 1998 was similar for both lucerne and annual pasture treatments. In January 1999 there was unusually high rainfall (in excess of 100 mm) at both sites (Figure 1), which increased soil water levels (Figure 2). From January to May 1999 soil water declined at both sites, being significantly lower under lucerne at Cascades (Figure 2). Soil water increased during winter but was still lowest under lucerne although this again was only significant at Cascades. At this site lucerne used about 25 mm more water.

Cumulative herbage production during 1999 is shown in Figure 3. Considering both sites together, lucerne produced an average of 3000 kg/ha of herbage compared to 2500 kg/ha for the annual legume. There was also much less weed invasion in the lucerne plots compared with the annual pasture.
Figure 1. Monthly rainfall (mm) recorded at the Wittenoom Hills and Cascades experimental sites.

Figure 2. Soil water storage (mm) to a depth of 150 cm measured at Wittenoom Hills (WH) and Cascades (C) experimental sites.

Figure 3. Cumulative herbage production (kg/ha) measured at the Wittenoom Hills (WH) and Cascades (C) experimental sites.
CONCLUSIONS

After two years this study appears to support the findings of previous experiments in other parts of the state that lucerne based crop rotations are a productive option and can dry out the soil profile to a greater degree than annual pasture systems. Effects on soil water, however, do not occur until the second year of the lucerne phase.

GRDC Project No.: DAW 562
Paper reviewed by: Clinton Revell
Assessing the results of on-farm experiments using yield monitors
Simon Cook and Matthew Adams, CSIRO Land and Water, Perth

BACKGROUND: USING YIELD MONITORS TO EXPERIMENT OVER WHOLE PADDOCKS
Experimentation seems to come naturally to farmers. Farmers with yield mapping capability can experiment over whole paddocks. These experiments can be more meaningful than small plot trials and in some ways easier to install. We have been helping growers design, install and analyse whole-paddock experiments since 1996 and in this short paper we review some case studies.

METHOD: HOW TO CONDUCT A WHOLE-PADDOCK EXPERIMENT
The principles of whole-paddock experiments have been described in previous Crop Updates and detailed in a GRDC Manual entitled: ‘Designing your own on-farm experiments: How precision agriculture can help’ (Bramley et al. 1999).

The process comprises five basic steps:

1. Select a paddock or paddocks and decide with which controllable input(s) you want to experiment (e.g. N, P, K, seed, spray, crop variety). It is normally advisable to vary only one or two inputs.

2. Choose a design to suit your operations. For the majority of growers without variable rate equipment (VRT) this normally boils down to varying rates as strips, blocks, or the so-called ‘donut’. VRT allows better replication.

3. Install treatments as per plan. Make sure to record what went where (VRT does this automatically) – it will be used to create a treatment map for analysis later.

4. Harvest as normal and generate the yield map.

5. Analyse the yield map with respect to the treatment map. Other information about the paddock will help interpret these results (for example, yield maps from previous seasons, TOPCROP observations through the season, soil or tissue test data, soil map).

CASE STUDIES

Case study 1: Wyalkatchem: Identification of poor responsiveness to N
Doug Maitland’s 1996 checkerboard experiment at Wyalkatchem was the first in Australia to use VRT. The results indicated that the response of wheat (after wheat) to urea was very patchy –despite demand overall. Much of the paddock did not respond to urea, some parts responded strongly. Uniform application was unprofitable; optimum application significantly more profitable ($25/ha). By comparing the results with other information we have since interpreted the result more fully. Weeds were obviously a problem that year, but so too was haying off, K deficiency and low pH. The results have helped Doug decide that if N is to pay, more attention has to be given to other limitations such as weeds.

Case Study 2: Improved targeting of K fertiliser using estimates of yield potential
This experiment was installed meticulously without VRT by Richard Barrett and Precision Farming Australia at Corrigin. The results also showed that wide variation of response to fertiliser (this time, K). The weak response overall was again caused by poor or negative response in some areas.
Comparison of the K response against soil test data, soil map and prior yield indicated a strong correlation with soil variation but not soil test value. This could be explained by variable demand for K. The conclusion appears to be that fertilising to variable demand (yield potential, indicated by soil type) would have been more effective than fertilising to variable K supply (as indicated by soil testing).

**Case study 3: Wyalkatchem: Identification of areas of poor response to P**

This experiment was one of many conducted by Doug Maitland in 1997 and 98 using VRT. This one looked at the crop response to variations in P and seed rate. The results showed again that the response varied widely within the paddock, a small overall positive response masking large unresponsive areas.

Comparison of the P response with soil and tissue test data suggested reasons for variable response. Over the eastern part, soil P and tissue P are already quite high. Low Zn was more likely to be a limitation. The central area responded well in places. Zn is higher here, but the potentially stronger crop response was held back by weeds, which were probably there in the 96 lupin crop and persisted through 97 and 98.

**Summary of case studies:**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Basic result</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Checkerboard’ N on wheat</td>
<td>Small average response to N concealed wide variation.</td>
<td>$25/ha difference between returns from uniform and ‘optimum’ variable application.</td>
</tr>
<tr>
<td>Strip trial of K on wheat</td>
<td>Small average response concealed wide variation. K response varied with soil type.</td>
<td>Small positive return could have been increased by about $9/ha by targeting to soil type.</td>
</tr>
<tr>
<td>‘Eggbox’ P on wheat</td>
<td>Weak average response to P concealed wide variation. Non-response linked to low Zn, high P and weeds.</td>
<td>P may be less critical than other yield limitations.</td>
</tr>
</tbody>
</table>

**REVIEW: WHAT HAVE WE LEARNED?**

- Whole-paddock experiments can be easy to install, providing the details are all worked out beforehand and the technology performs well.
- The results almost always show substantial opportunity for improvement. But the causes of variable response are often quite complex and may challenge ‘accepted’ scientific wisdom.
- The results are highly relevant to growers because they are specific to their farm and because they look at paddocks, not plots.
- In some cases, it may be possible to define ‘management zones’ within paddocks, but greater benefit may be achieved in the short-term simply by using the results to manage whole paddocks better.
- Consultants with the GIS skills necessary to analyse this data are few and far between. A toolbox of standard methods will help. To date this is rudimentary.
REFERENCES
This booklet is an abridged version of: Bramley, R.G.V., Cook, S.E., Adams, M.L. and Corner, R.J. 1999. On-farm Experimentation: A farmer guide to the design of farm-scale experiments using precision agriculture technologies. Grains Research and Development Corporation, Canberra. (Both are available in hard copy form, or on CD as part of the GRDC Australian grains field research manual 1999).

GRDC Project No.: CSO 179
Paper reviewed by: Robert Corner
Achiever: A GIS based achievable yield and fertiliser recommendation system for precision agriculture

Robert J. Corner, Matthew L. Adams, Precision Agriculture Research Group
CSIRO Land and Water

KEY MESSAGE
Grain growers throughout Australia are collecting yield maps which show the variability of production within paddocks. These maps contain information about the productive capacity or achievable yield within those paddocks. In order to make full use of the information contained in these maps they need to be analysed using a Geographic Information System (GIS). Such systems are complex and can be daunting for new users. The CSIRO Precision Agriculture Research Group has produced software, called Achiever, which customises a commercially available GIS to enable consultants and individual growers to estimate spatially variable achievable yields and to calculate appropriate fertiliser recommendations. These recommendations may be fed to Variable Rate Technology (VRT) fertiliser application equipment. This work has been supported by a grant from GRDC

THE SOFTWARE
The software, named Achiever, is an extension to the ArcView™ GIS marketed by ESRI. ArcView™ is a powerful desktop GIS which contains all of the tools needed to analyse yield data, soil tests, satellite imagery and other data sources. The spatial data processes relevant to precision agriculture have been simplified and collected into functional menu and dialogue driven commands in the Achiever extension, so that the individual consultant does not need to become a GIS expert. The other, more complex features of ArcView™ are disabled, but access to them can be enabled if required.
The core functions of Achiever were designed in consultation with a number of agribusiness consultants. The software provides a functional toolbox which will enable consultants to start advising clients about spatial variability as quickly as possible.

Achiver concept

Figure 1. A conceptual representation of Achiever.

WHAT IT DOES
The software has been designed with digital data analysis and output in mind. However, in a simpler form, it may be used either just to create yield maps or as a visual representation tool. For example, it may be used to examine the variability in productive capacity within a paddock and to compare it to
variations in soil tests. Further levels of complexity allow recommended management zones to be
delineated or to output VRT maps ready for uploading into VRT systems.
The main features of the software are as follows:

- Yield map generation.
- Read and subset standard remotely sensed image products (e.g. SPOT/TM/DMSV).
- Normalise yield maps and other data.
- Synthesise maps of yield potential (achievable yield).
- Input soil test data.
- Generate maps of the required fertiliser application needed to generate a particular outcome.
- Output maps in digital form for input to VRT controllers.

**Yield Map generation**

The software can read input from a variety of yield monitors and create surfaces from the raw data.
The user can select a range of grid cell sizes and the data may be clipped within user defined
boundaries as required.

**Using remotely sensed imagery**

In the absence of yield monitor information, remote sensing products such as Normalised Difference
Vegetation Index (NDVI) imagery may be used as an indicator of relative productive capability.
Achiever can subset paddock sized data sets from larger images to enable them to be analysed with
yield maps.

**Normalising yield maps and other data**

By normalising (converting to standard scores) spatial data we are better able to compare the basic
potential of land management units between paddocks and between different crops in a rotation. This
procedure provides a relative measure of productive capacity.

**Synthesise maps of yield potential (achievable yield)**

Maps of estimated achievable yield are developed from any one of three possible inputs: farmer
estimates, historical yield maps or historical NDVI imagery.

**Input soil test data**

Soil test data in a variety of tabular formats may be loaded in and converted to analytical surfaces
representing nutrient status within the paddock.

**Generate fertiliser application maps for input to VRT controllers**

Application maps for K fertiliser and top dressed N may be generated using spatial implementations of
standard fertiliser recommendation techniques. These maps may then be used as input to VRT
controllers. Although the fertiliser recommendation maps are produced as continuous surfaces these
may be broken down into a number of steps to suit individual controllers.

**CONCLUSION**

The development of the Achiever software provides agricultural consultants with a means of providing
GIS based advice to their clients without the need to become experts in Geographic Information
technology.

**GRDC Project No.:** CSO179
**Paper reviewed by:** Matthew L. Adams