Crop Updates 2002 - Farming Systems

Peter Metcalf
*Department of Agriculture*

Mike Ewing
*Department of Agriculture*

Roy Latta
*Department of Agriculture*

Keith Devenish
*Department of Agriculture*

Diana Fedorenko
*Department of Agriculture*

See next page for additional authors

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Authors

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Introduction

FUTURE FARMING SYSTEMS SESSION FOR CROP UPDATES 2002

The purpose of this session is to:

- identify some of the external issues that could impact upon farming systems in the future;
- assist agribusiness in identifying and exploring options to deal with some of these potential changes to the system;
- aid in establishing priorities for managing information relating to future farming systems.

The following is a brief overview of how the future farming systems session could function.

It’s a concurrent that does not involve any choice. Each participant will be allocated to a room in which the associated topic will be discussed.

Ten rooms with a facilitator and recorder in each. At the end of the session the facilitator and recorder will enter the information generated from the session into a ‘laptop’ computer and all the information will be compiled, printed overnight and available to all participants the next morning.

A summary of the outcomes will be presented to all participants on the second day of Crop Updates.

The topics include:

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<td>Mike O’Connell and Richard Olive</td>
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- The session will open up with a general discussion about what are some of the changes that people might see happen in the future in these areas.
- Then move on to identifying the new skills that growers will need to access and or develop to take advantage of these possible changes.
- Please place priorities on the skills in terms of importance to success in conducting a future farming business.

Peter Metcalfe
FARMING SYSTEMS SUBPROGRAM MANAGER
GRAINS PROGRAM
ACKNOWLEDGMENTS

I would like to thank Mike Ewing, Walter Milsteed, Alan Peggs, Richard Quinlan, Clinton Revell, Roger States and Cameron Weeks for their advice on the program.

Also the cooperation of contributors in meeting tight deadlines is highly appreciated, as are the efforts of Chiquita Butler in formatting the booklet.

Richard Olive
FARMING SYSTEMS CONVENOR
# FARMING SYSTEMS FOR SUSTAINABILITY
## UPDATES, 2002

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Perennial pastures in annual cropping systems: lucerne and beyond, the ‘Big Picture’

Mike Ewing, Deputy CEO CRC for Plant-based Management of Dryland Salinity

KEY MESSAGE
Perennial pastures can play a critical role in reducing the threat of increased salinity. However, demonstrating their ability to use more water than other components of the land use sequence will not be enough to ensure wide scale adoption. For this to occur, the perennial pasture will need to be as profitable as other components of the system as well as conferring positive advantages to other phases of the rotation. These advantages will take the form of direct short-term advantages such as N fixation by perennial legumes that benefit subsequent crops. Important additional benefits will take the form of indirect benefits such as reduced salinity expression resulting from reduced recharge of groundwater systems.

BACKGROUND
Perennial pastures have played a minimal historical role on wheatbelt farms. The explanation for this revolves around the lack of well adapted perennial plants as well as farming systems and rotational arrangements that have been developed around annuals.

While much of the native vegetation in the wheatbelt was dominated by perennial species, very few of these plants were agriculturally useful. This gave rise to the replacement of native perennials with exotic annuals and the development of extensive, low input farming systems.

A key aspect of the extensive system was the development of annual legume based pastures capable of self regeneration between years and after cereal crops. The concepts behind this system which involved low level and infrequent investment in pasture establishment sat very poorly with any form of perennial component to the pasture. Cropping would require the removal of the perennial pasture to allow cropping and then re-sowing the following year to re-establish this pasture. This appeared to introduce expensive and unnecessary complications.

The development of long crop sequences often involving cereals, crop legumes and oilseeds has changed farming system assumptions. In this setting re-sowing of annual pastures after crop phases becomes an option so why not substitute a perennial? There would be even greater incentive if the perennial pasture was more profitable for livestock, fitted better into the crop rotation (complimentary benefits) and had sustainability advantages, such as substantial potential for recharge control.

Once the incentive to explore new systems emerged, the driving question became what perennial plants might be available to fit into evolving systems. The best known perennial pasture is lucerne and initial research and producer experience provides optimism that it can have a role in our farming systems (see Latta et al., part B of this presentation). Experience to date indicates that lucerne is unlikely to be universally applicable so we need to consider what else is required and what seems possible.

TYPES OF PERENNIAL PASTURE FOR THE WHEATBELT
As our experience with perennial pastures increases it seems likely that we will be able to identify a number of specific roles that such pastures might play. The diversity of these roles is influenced by the range of soils, climates and economic influences that we recognise across the cropping zones.

Phase pastures
A period of perennial based pasture followed by a period of cropping appears to be the most likely role for perennial pastures for the cropping zone (termed phase pastures). However, within this category there is great scope for pasture diversity based on such matters as:

- Length of the pasture phase.
- Functional form of the perennial (herbaceous or woody).
- If herbaceous, the nature of the perennial introduced (legume, grass or herb).
- Role and management of sown or volunteer annuals.

In general perennial phase pastures are likely to run for several years. This reflects the fact that perennials initially invest in plant structures that provide persistence and productivity in the longer term such as deep roots and reserves of carbohydrate. In addition, the financial costs involved in
establishment encourage this investment to be amortised over several years. A perennial phase following annual crops is also likely to obtain a productivity advantage based in part on access to water stored deeper in the soil profile than can be accessed by annuals. The optimum length of perennial pasture phase before cropping is resumed will depend on a composite of these factors.

Herbaceous perennials (as opposed to woody perennials) offer advantages when used in phase systems. The lack of woody material reduces complications when moving between the pasture and crop phase. The choice of herbaceous perennial will depend on the adaptation of alternatives to the soil and rainfall zone as well as the availability of complementary annual species. In general perennial legumes such as lucerne have advantages in providing positive inputs to the crop phase (N fixation, disease suppression, soil structure improvement and weed control).

**Companion perennials**

An alternative to re-sowing the perennial component of a pasture after each crop sequence is to choose a plant that can persist with the crop, become active out of the growing season period and be a productive element of the pasture in years when crops are not sown. This has the advantage of decreasing the likely frequency of sowing and provides a mechanism of use of out-of-season rain in all years, not just in the non-crop years as is the case for phase perennial systems.

Few companion perennial systems currently exist and they are more likely to be useful in high rainfall zones where water moves beyond the root zone of annual crops in most years. Plant characteristics likely to be important include:

- Winter dormancy and summer activity.
- A prostrate growth habit to avoid competition and contamination of crops.
- Resistance to physical damage during crop establishment (buried crown).
- Insensitivity to herbicides used in the crop.

Legumes fitting this specification would be desirable for companion systems but other function groups such as highly summer active grasses could play a role. The natural variability that exists within lucerne might allow the development of quite different cultivars to fit such systems. Systems of minimal disturbance crop establishment are a requirement.

**Permanent pastures**

On many wheatbelt farms there are parts of the landscape that are contributing little to farm profit when used in cropping systems. Typically infertile and acidic areas high in the landscape fit this model. The use of perennial based pastures as a low input but stable land use has many advantages for such areas.

Uncropped areas allow a wide choice of perennial component. The use of a woody element has few drawbacks and non-legumes can be used because they can be complemented with annual legumes which are often well established technology. The use of alley systems in such circumstances is an option.

**NEW DEVELOPMENTS**

Breeding and selection activities to provide the new genotypes that producers will need to put together the systems outlined above have been commenced. Targets for this work include both exotic species as well as Australian native perennials to take account of the diversity of soils and climates in the cropping zones. Initial selection has identified genera such as *Lotus* and *Dorycnium* that deserve highly focussed plant improvement activities. Success will require a ‘perennial pasture decade’ of committed effort and investment to get the ‘tools’ flowing through to producers.

**ACKNOWLEDGMENTS**

GRDC is supporting the activities of the West Australian Department of Agriculture and CRC for Plant-based Management of Dryland Salinity in the development of new perennial legumes for the wheatbelt through DAW 562, DAW 659 and 660 (lucerne) UWA 337 (alternatives to lucerne).

**KEY WORDS**

perennial, lucerne, phase pasture, farming systems

**Paper reviewed by:** Bill Porter
Perennial pastures in annual cropping systems:
lucerne and beyond

Roy Latta and Keith Devenish, Department of Agriculture

KEY MESSAGE

Compared to annual pastures lucerne uses more water, provides a summer-autumn fodder source and can improve subsequent crop yields through better weed control options and nitrogen supply. However, slow establishment, sandy acidic soils, extended dry summers and grazing can reduce productive stand life to 1-2 years. In dry seasons following the lucerne phase it may also be responsible for lower crop yields due to soil water deficits. The performance of lucerne is greatly enhanced with summer-autumn rainfall. Cover-cropping establishment techniques provide viability to short duration lucerne-crop phases. Spring removal of lucerne was shown to be an effective method to remove lucerne and allow some replenishment of soil water in preparation for the cropping phase.

BACKGROUND

Numerous farmers throughout the agricultural zone are evaluating lucerne as forage and for inclusion in cropping rotations. Previous research has shown it to be productive and persistent in the higher rainfall southern and coastal regions with a likelihood of summer rain. However, lucerne is currently recommended throughout the agricultural zone (300-600 mm) with only waterlogged-saline and very acidic soil types not considered suitable. This paper presents results from the medium to low rainfall central and northern wheatbelt to help establish the validity of the recommendation. Minimum performance criteria was considered the persistence of an adequate plant density to increase water use over a pasture phase (2-4 years) and produce comparable forage and subsequent crop yields as an annual pasture phase.

AIMS AND METHODS

To report the comparative performance of lucerne and annual legume pastures in rotation with field crops through water-use, forage production and crop yields. Results are presented from 2 research sites in the central wheatbelt (Quairading) supported by 9 commercial evaluation sites from the central/northern wheatbelt. All sites were within the 300-450 mm rainfall zone over a range of soil types and soil acidity levels; shallow duplex, acidic sands, gravels, loams and clay, pH 4.4-6.0 CaCl₂. The pastures on the research sites were mown on a regular basis and not grazed, the commercial sites were grazed. Results are reported from the period 1998 to 2001.

RESULTS

Rainfall


Persistence

All sites established more than 30 lucerne plants/m². Plant losses from these sites were most apparent over the 2000-2001 summer when no significant rainfall events occurred from October to April. The average plant numbers/m² on the ungrazed research sites declined from 35 to 7. The mean plant density decline on the 9 commercial sites was 46 to 9. Grazing had no major impact on plant numbers.

Pasture production

In the establishment phase lucerne produced less than an annual pasture. The biomass production of established lucerne was higher in autumn/winter than annual pasture, less during spring and greater over summer, up to 2 t/ha following the 1999/2000 summer rain.

Table 1. Comparative pasture production (lucerne biomass as a % of annual pasture biomass)

<table>
<thead>
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<th></th>
<th>Establishment year</th>
<th>Autumn/Winter</th>
<th>Spring</th>
</tr>
</thead>
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<tr>
<td>Lucerne</td>
<td>60</td>
<td>140</td>
<td>55</td>
</tr>
<tr>
<td>Annual pasture</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
**Soil water**

The maximum soil water deficit in comparison to the sub. clover pasture was achieved in the second summer on both soil types. The lucerne\(^{[A]}\) plant density after the 2000/01 summer (7/m\(^2\)) was not as effective as the wheat\(^{[B]}\) crop following lucerne in maintaining the soil water deficit.

### Table 2. Soil water deficit (mm H\(_2\)O/150 cm soil profile) under lucerne compared to annual pasture during both spring and autumn of a 4 year lucerne/wheat-rotation

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spring</td>
<td>Autumn</td>
<td>Spring</td>
<td>Autumn</td>
</tr>
<tr>
<td>Clay - Lucerne</td>
<td>12</td>
<td>39</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Clay - Wheat</td>
<td>52(^{[B]})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand - Lucerne</td>
<td>+10</td>
<td>10</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>Sand - Wheat</td>
<td>29(^{[B]})</td>
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**Grain yields**

Low yields harvested were an indication of the dry seasons of 2000 and 2001. The soil water deficit maintained under the clay based soil following lucerne reduced grain yield. The improved grain yield on the sand following lucerne was in response to lower weed numbers and a lower soil water deficit than the heavier clay based soil type in the lucerne-annual pasture comparison.

### Table 3. Wheat yields (t/ha) following 2 and 3 years of lucerne and sub. clover pastures

<table>
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<th>Soil type</th>
<th>Pasture treatment</th>
<th>2000</th>
<th>2001</th>
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<tr>
<td>Clay</td>
<td>Lucerne</td>
<td>0.5</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Sub. clover</td>
<td>0.7</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Lucerne</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cadiz</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>Lucerne</td>
<td></td>
<td></td>
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**CONCLUSIONS**

The outcomes of this four-year study show that lucerne can be successfully established in the central/northern wheatbelt. It will use more water and provide valuable out of season forage for livestock. However, opposing the recommendation of lucerne for the central/northern wheatbelt the study has shown it to be more productive for only 1 or 2 years of a 3-year pasture 1-year crop rotation. The establishment year was negative as it used less water and produced less pasture than the annual pasture. The 3\(^{rd}\) year pasture maintained a dry soil profile, which produced no more biomass than an annual pasture, and impacted on 4\(^{th}\) year grain yields. A loss in grain crop production following the lucerne phase was measured in one case although this was offset by better weed control at the second site. The benefits of reducing recharge are not included in discussion.

To recommend lucerne in this environment several establishment and management strategies should be included. Sow at 2 kg/ha in alternate rows with a companion field crop to compensate for the low production establishment year. Remove lucerne in the spring of the year prior to returning to crop to allow for some available soil nitrogen and soil water to accumulate. Further research into the use of low-density stands is also required to help overcome the limitations imposed by soil type and rainfall patterns in the central/northern wheatbelt.

**ACKNOWLEDGMENTS**

The Grains Research and Development Corporation provided the funding. Bill and Neil Fraser provided the land and enthusiasm at Quairading. Nine farming families provided the land and managed the commercial sites.

**KEY WORDS**

lucerne, rotations, dryland, production

**GRDC Project Nos:** DAW 562 DAW 593

**Paper reviewed by:** Alex Douglas
Establishing lucerne with a cover crop

Diana Fedorenko¹, Clayton Butterly¹, Chantelle Butterly¹, Kim and Neil Diamond², Stuart McAlpine², Bill Bowden¹, Jessica Johns³, ¹Centre for Cropping Systems, Northam, ²Farmer, Buntine, ³Department of Agriculture, Three Springs

KEY MESSAGE
Crop yield and yield components decreased when sown with lucerne. Lucerne plant density and production were lower when established with a cover crop.

BACKGROUND AND AIMS
High costs, lack of forage production and forgone income from an annual crop are issues farmers are confronted with when deciding to grow lucerne. Seeding lucerne with a cover crop is a practice that lucerne specialists have investigated and found profitable. Some farmers have readily adopted this technology and are experimenting with ways to adapt it to their own socioeconomic circumstances. There are others that are being more cautious, choosing to establish lucerne as monoculture and recover the costs later in the rotation.

Researchers and farmers have shown that sowing the pasture and the cereal in alternate rows is a good practice to establish both crops. This is because the chances of competition between the lucerne and the crop are reduced facilitating the establishment and survival of lucerne. This paper addresses two experiments on covercropping where the effects of the crop on lucerne establishment and the effect of lucerne on crop yield were measured.

METHOD
On 27 June 2001 Neil Diamond established this experiment on a duplex soil (sand over gravel). Plots measured 9.2 x 336 m and a satellite navigation system was used. Treatments shown in Table 1 were randomised in two blocks.

Table 1. Covercropping treatments

<table>
<thead>
<tr>
<th>Crop</th>
<th>Row sequence</th>
<th>Lucerne</th>
<th>Cereal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seeding rate (kg/ha)</td>
<td>Row spacing (m)</td>
</tr>
<tr>
<td>Lucerne</td>
<td>LLLLLLLLL</td>
<td>4</td>
<td>0.225</td>
</tr>
<tr>
<td>Barley</td>
<td>BBBBBBBBBB</td>
<td>-</td>
<td>60</td>
</tr>
<tr>
<td>Lucerne and barley</td>
<td>LBLBLBLBLB</td>
<td>3</td>
<td>0.45</td>
</tr>
<tr>
<td>Lucerne and barley</td>
<td>LBBBLBBBLB</td>
<td>3</td>
<td>0.675</td>
</tr>
<tr>
<td>Oats</td>
<td>OOOO OOOO</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>Lucerne and oats</td>
<td>LOLOLOLOLOLO</td>
<td>3</td>
<td>0.45</td>
</tr>
<tr>
<td>Lucerne and oats</td>
<td>LOOLOOLLOOL</td>
<td>3</td>
<td>0.675</td>
</tr>
<tr>
<td>Wheat</td>
<td>WWWW WWWW</td>
<td>-</td>
<td>80</td>
</tr>
<tr>
<td>Lucerne and wheat</td>
<td>LWLWLWLWLW</td>
<td>3</td>
<td>0.45</td>
</tr>
<tr>
<td>Lucerne and wheat</td>
<td>LWLWWLWWL</td>
<td>3</td>
<td>0.675</td>
</tr>
</tbody>
</table>

RESULTS
The analyses of variance for all lucerne and cereal parameters showed significant differences (P < 0.001). The results are presented in Table 2.
Table 2. Average of lucerne and cereal yield components

<table>
<thead>
<tr>
<th></th>
<th>LLLL</th>
<th>BBBB</th>
<th>LBLB</th>
<th>LBBL</th>
<th>OOOO</th>
<th>LOLO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lucerne</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant density</td>
<td>83</td>
<td>10</td>
<td>13</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total dry matter</td>
<td>9.8</td>
<td>1.3</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cereal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant density</td>
<td>90</td>
<td>57</td>
<td>54</td>
<td>60</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Total dry matter</td>
<td>372</td>
<td>350</td>
<td>310</td>
<td>466</td>
<td>359</td>
<td></td>
</tr>
<tr>
<td>Heads</td>
<td>248</td>
<td>197</td>
<td>157</td>
<td>174</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Grain yield</td>
<td>92</td>
<td>80</td>
<td>57</td>
<td>147</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Grain weight</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>42</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>LOOL</th>
<th>WWWW</th>
<th>LWLW</th>
<th>LWWL</th>
<th>LSD (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lucerne</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant density</td>
<td>8</td>
<td>12</td>
<td>14</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total dry matter</td>
<td>0.8</td>
<td>1.8</td>
<td>1.6</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td><strong>Cereal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant density</td>
<td>43</td>
<td>66</td>
<td>38</td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td>Total dry matter</td>
<td>371</td>
<td>364</td>
<td>313</td>
<td>307</td>
<td>24</td>
</tr>
<tr>
<td>Heads</td>
<td>118</td>
<td>119</td>
<td>77</td>
<td>78</td>
<td>20</td>
</tr>
<tr>
<td>Grain yield</td>
<td>95</td>
<td>85</td>
<td>61</td>
<td>57</td>
<td>12</td>
</tr>
<tr>
<td>Grain weight</td>
<td>41</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Quality parameters for wheat varied as follows: 81-85 kg/hL, protein 12.3-14.4%, screenings 1.3-3.8%.

DISCUSSION

The yields of both the cereals and lucerne were low across all treatments. The combination of erratic rainfall distribution and late seeding could help explain these results. However, the yields of both lucerne and the cereals were higher when sown as monocultures, compared to the yields when they were sown in alternate rows. Quality parameters are between expected ranges. An analysis of the economic feasibility of the different treatments in the context of the season and of the farm will help in further interpretation of these data.

This research is part of the Low Recharge Cropping Systems Project funded by GRDC, Land and Water Australia and the Department of Agriculture.

KEY WORDS

covercropping, lucerne, cereals, establishment

GRDC Project No.: DAW 659

Paper reviewed by: Richard Olive
Overcropping: Chemical suppression of lucerne

Terry Piper¹, Diana Fedorenko¹, Clayton Butterly¹, Chantelle Butterly¹, Stuart McAlpine², Jessica Johns³, ¹Centre for Cropping Systems, Northam, ²Farmer, Buntine, ³Department of Agriculture, Three Springs

KEY MESSAGE

- Tordon® and 2,4-D Ester 80 showed potential to remove lucerne and 2,4-D amine, Lontrel® and Kamba® to suppress it.
- Higher wheat yields were associated with lower lucerne densities.

BACKGROUND AND AIMS

Overcropping is a practice that farmers and researchers are experimenting with to develop cropping systems with lower recharge. This is, systems that combine annual crops and perennial pastures that farmers can manage opportunistically fitting in with seasons, market opportunities, and personal preferences while maintaining the watertable low.

Since lucerne has the potential to compete with the companion crop, it would be desirable to suppress it if a single cropping year was to be inserted into an otherwise long-term lucerne phase. On the other hand, if a long-term lucerne phase were to be converted to several years of cropping it would be necessary to kill or remove lucerne. Research has shown that the best time to remove lucerne is in the spring before initiating the cropping phase. However, it is still necessary to determine what chemicals, rates and times of application would be the most effective and economic to suppress lucerne for as long as necessary to get the benefits of the crop, and recover lucerne after harvest.

The aim of this experiment was to study the effects of different chemicals and rates used to suppress or kill lucerne on lucerne survival and on the crop.

METHOD

The experiment was established on a lucerne pasture in the second year of growth overcropped with wheat in 2001. Five of the 10 treatments evaluated in this trial had the potential to suppress the lucerne: Ally @ 3, 5 and 7 g/ha, 2,4-D amine @ 1.2 L/ha and 2,4-D ester 80 @ 700 mL/ha. These treatments were rated on lucerne suppression and crop yield, and lucerne recovery is being evaluated over summer.

The second five treatments have the potential to kill the lucerne: Kamba® 500 @ 280 mL/ha, Lontrel® @ 200 and 300 mL/ha, Tordon® 75D @ 350 and 500 mL/ha. The experimental plot was 21 x 2.5 m and each treatment was replicated three times. Chemicals were applied 12 weeks after seeding the crop. At harvest plots were subdivided in two sections (east and west) in an attempt to separate what we believed were visual effects of salinity, which became apparent across plots after the beginning of the experiment. However, soil samples taken in the top 0-20 cm did not show contrasting differences in chemical properties between these sections. The interaction section x treatment was not significant hence data were averaged within plots. Suppression and kill treatments were analysed separately.

RESULTS AND DISCUSSION

Wheat yield was low across the experiment very likely because lucerne was suppressed late in the season. Grain quality parameters were all within expected ranges. However, herbicides applied to suppress or kill lucerne affected significantly lucerne survival as well as wheat yield and quality (Table 1).

Tordon® and 2,4-D Ester 80 killed most lucerne plants and those left at the end of the season were severely damaged (Table 1). These effects are associated with the highest grain yields. Lontrel®, Kamba® 500 and 2,4-D amine suppressed lucerne growth and maintained plant density.

With the benefit of these initial results, there is likely to be some interchange of ‘suppression’ and ‘killing’ herbicides in future trials. The time of application of the chemicals also needs to be done at the...
beginning of the season to reduce yield loss. Economic analyses should be included to interpret results in the context of the season and of the whole rotation.

Table 1. Effects of herbicides on lucerne survival and on wheat yield and quality

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Lucerne plants/m²</th>
<th>*Lucerne condition</th>
<th>Grain yield t/ha</th>
<th>Kernel wt mg</th>
<th>Hectolitre wt kg</th>
<th>Protein %</th>
<th>Screenings %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suppress</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,4-D Amine</td>
<td>14</td>
<td>3</td>
<td>0.74</td>
<td>36</td>
<td>80</td>
<td>7.9</td>
<td>6.3</td>
</tr>
<tr>
<td>2,4-D Ester 80</td>
<td>3</td>
<td>2</td>
<td>0.93</td>
<td>37</td>
<td>81</td>
<td>8.7</td>
<td>8.0</td>
</tr>
<tr>
<td>Ally® 3</td>
<td>11</td>
<td>4</td>
<td>0.64</td>
<td>33</td>
<td>79</td>
<td>8.2</td>
<td>7.3</td>
</tr>
<tr>
<td>Ally® 5</td>
<td>12</td>
<td>4</td>
<td>0.59</td>
<td>32</td>
<td>79</td>
<td>8.4</td>
<td>8.7</td>
</tr>
<tr>
<td>Ally® 7</td>
<td>11</td>
<td>4</td>
<td>0.59</td>
<td>33</td>
<td>79</td>
<td>8.2</td>
<td>8.0</td>
</tr>
<tr>
<td>Untreated</td>
<td>15</td>
<td>5</td>
<td>0.54</td>
<td>33</td>
<td>79</td>
<td>8.3</td>
<td>8.3</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>4</td>
<td></td>
<td>0.21</td>
<td>1</td>
<td>0.4</td>
<td>0.4</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Kill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamba® 500</td>
<td>16</td>
<td>4</td>
<td>0.61</td>
<td>35</td>
<td>81</td>
<td>8.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Lontrel® 200</td>
<td>15</td>
<td>3</td>
<td>0.60</td>
<td>34</td>
<td>80</td>
<td>8.5</td>
<td>5.3</td>
</tr>
<tr>
<td>Lontrel® 300</td>
<td>10</td>
<td>3</td>
<td>0.72</td>
<td>35</td>
<td>81</td>
<td>8.5</td>
<td>5.3</td>
</tr>
<tr>
<td>Tordon® 350</td>
<td>6</td>
<td>2</td>
<td>0.81</td>
<td>37</td>
<td>81</td>
<td>9.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Tordon® 500</td>
<td>4</td>
<td>2</td>
<td>0.84</td>
<td>37</td>
<td>81</td>
<td>9.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Untreated</td>
<td>16</td>
<td>4</td>
<td>0.37</td>
<td>31</td>
<td>79</td>
<td>9.5</td>
<td>6.7</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>4</td>
<td></td>
<td>0.15</td>
<td>1</td>
<td>0.7</td>
<td>0.7</td>
<td>0.9</td>
</tr>
</tbody>
</table>

* 1 = dead, 5 = unaffected.

This research is part of the Low Recharge Cropping Systems Project funded by GRDC, Land and Water Australia and the Department of Agriculture.

**KEY WORDS**

overcropping, lucerne, suppression, removal

**GRDC Project No.:** DAW 659

**Paper reviewed by:** Richard Olive
Overcropping: Effect of lucerne density on crop yield

Diana Fedorenko¹, Bill Bowden¹, Clayton Butterly¹, Chantelle Butterly¹, Stuart McAlpine², Terry Piper¹, ¹Centre for Cropping Systems, Department of Agriculture, Northam, ²Farmer, Buntine

KEY MESSAGE

When growing a crop on an established lucerne pasture grain yield is higher at lower lucerne densities and vice versa.

BACKGROUND AND AIMS

Overcropping (growing a crop on an established perennial pasture) is a practice that farmers and researchers are currently studying as an option to increase water use and profitability of farming systems. After observing on two lucerne paddocks overcropped with wheat that variation on wheat condition within each paddock appeared to be related to lucerne plant density, we took this opportunity to make preliminary measurements of the effects of lucerne density on grain yield and yield components. We expect these results will serve as a reference to plan further experiments to determine at what point the impact of lucerne density on the companion crop and of that crop on lucerne persistence will be most profitable and sustainable in different farming systems.

METHOD

In 2001, Stuart McAlpine grew wheat on two paddocks with sandy loam soil. One paddock had been on lucerne in the previous three years. Prior to crop establishment, Glyphosate @ 1 L/ha and Logran® @ 30 g/ha were applied to suppress the lucerne. On 19 November 2001, 30 quadrats were harvested. On another paddock with a lucerne pasture in the second year of growth, Stuart direct-drilled wheat on 30 April 2001, initially intending to produce pasture. However, as the crop was performing better than expected, he applied Tigrex® @ 500 mL/ha + Ally® @ 2.5 g/ha to suppress the lucerne 10 weeks after sowing the crop. On 8 November 2001, 40 quadrats were harvested. Quadrats used on both paddocks consisted of five 1 m wheat rows each. Lucerne plant density and dry matter, and wheat plant density, total dry matter, number of heads, grain yield and grain weight were determined for each quadrat. Also paired 10 cm depth soil cores were taken inside and outside the quadrats to look for any soil factors that could be influencing the variation observed in lucerne density and grain yield.

RESULTS

Table 1 shows the relationship between lucerne plant density and wheat traits. Similar relationships were obtained between lucerne dry matter and wheat.

Table 1. Correlation coefficients (r) showing the relationship between lucerne plant density and wheat yield in two paddocks with different management

<table>
<thead>
<tr>
<th>Wheat traits</th>
<th>Units</th>
<th>Lucerne suppressed before seeding wheat</th>
<th>Lucerne suppressed 10 weeks after seeding wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant density</td>
<td>plants/m²</td>
<td>0.388</td>
<td>ns</td>
</tr>
<tr>
<td>Total dry matter</td>
<td>g/m²</td>
<td>-0.696</td>
<td>*</td>
</tr>
<tr>
<td>Heads</td>
<td>number/m²</td>
<td>-0.156</td>
<td>ns</td>
</tr>
<tr>
<td>Grain yield</td>
<td>g/m²</td>
<td>-0.688</td>
<td>*</td>
</tr>
<tr>
<td>Grain weight</td>
<td>mg</td>
<td>-0.041</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns = no significant; * significant (P ≤ 0.01).
Significant negative values in Table 1 indicate that an increase on lucerne density is related to a decrease on those wheat traits.

**Figure 1.** Observed (symbols) and fitted data (lines) of the relationship between lucerne density and wheat yield.

There was a decrease in total dry matter (Table 1) and grain yield (Table 1, Figure 1) of wheat as lucerne plant density increased. Models fitted to sets of data A and B of Figure 1 were all significant (P < 0.001) and they explain 50-60% of the variance.

**DISCUSSION**

A low correlation coefficient between lucerne and wheat plant densities (Table 1) suggests that wheat establishment was not affected by lucerne plant density. Correlation between lucerne plant density and number of heads on both paddocks (Table 1) indicates that there are beneficial effects on tillering associated with early suppression of lucerne and detrimental effects with late suppression. Removal or suppression of lucerne tops (using chemicals or grazing) immediately before direct drilling the crop into the pasture provides open spaces and minimises the chances of competition at early stages of development of the crop.

To define the model that accurately explains the decrease on grain yield as an effect of increasing lucerne plant density is not critical at this stage. The point is that data indicate that competition between crops can occur later in the season. It is expected that competition would take place as lucerne plants recover after the initial suppression and data suggest that the higher the number of lucerne plants the more severe the drop on wheat production. Then, what lucerne density is the most appropriate for overcropping conditions? We do not know yet, but we know that to determine this is not easy. The effects of lucerne density on yield and its components will vary in terms of the season in which they were observed and will be determined largely by the times at which environmental stresses occurred during the development of the crop.

**KEY WORDS**

overcropping, lucerne density, wheat yield

**GRDC Project No.:** DAW 659

**Paper reviewed by:** Richard Olive
Residual effects of weed management in the third year of lucerne on the following wheat crop

Diana Fedorenko\(^1\), Clayton Butterfly\(^1\), Chantelle Butterfly\(^1\), Stuart McAlpine\(^2\), Terry Piper\(^1\), David Bowran\(^1\), Jessica Johns\(^3\), \(^1\)Centre for Cropping Systems, Northam, \(^2\)Farmer, Buntine, \(^3\)Department of Agriculture, Three Springs

KEY MESSAGE
Herbicides applied on lucerne in the last year of a 3-year pasture phase or before the beginning of the cropping phase did not affect significantly wheat grain yield or quality.

BACKGROUND AND AIMS
Depletion of weed reserves in soil seed bank is important goal that farmers have throughout the pasture phase. In the last pasture year, it is particularly important to think about the effects that herbicides used on pastures could have on the establishment, production and quality of the following crop. Initial results on the effects of weed management practices on lucerne survival and capeweed control were measured in 2000 and reported in this publication in 2001. Having continued this experiment during the growing season 2001, this paper presents the residual effects of those practices on a wheat crop. In addition, it shows the effects of three chemical treatments to suppress lucerne before establishing the crop.

METHOD
In 2000 ten chemical treatments to control mainly high populations of capeweed were applied before and after the break of season on a lucerne pasture in the third year of growth. Three spring control treatments were also applied across all herbicides. Taking advantage of no differences found between spring control practices, the same subplots were used in 2001 to apply three herbicide treatments aiming to cause low damage, suppression or removal of lucerne before the farmer established wheat cv. Westonia in the first week of June. The experimental design was split-split plots in three randomised blocks and the size of the smallest plot was 5 x 21 m. Lucerne plant density was measured at the beginning and the end of the experiment. Wheat was harvested on 28 November 2001 and grain yield and quality determined.

RESULTS
Table 1. Lucerne and wheat parameters observed in 2001 on plots treated with herbicides to control capeweed in the third year of a lucerne pasture (2000)

<table>
<thead>
<tr>
<th>Herbicides applied in 2000</th>
<th>Rate/ha</th>
<th>Lucerne Plants/m(^2)</th>
<th>Wheat Grain yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basta® 20 L</td>
<td>1.5 L</td>
<td>5</td>
<td>93</td>
</tr>
<tr>
<td>Dicuron</td>
<td>1.0 L</td>
<td>5</td>
<td>107</td>
</tr>
<tr>
<td>Propicon®</td>
<td>3.0 kg</td>
<td>6</td>
<td>91</td>
</tr>
<tr>
<td>Roundup®</td>
<td>0.4 L</td>
<td>8</td>
<td>108</td>
</tr>
<tr>
<td>Roundup®</td>
<td>0.6 L</td>
<td>6</td>
<td>103</td>
</tr>
<tr>
<td>Roundup®</td>
<td>1.0 L</td>
<td>8</td>
<td>110</td>
</tr>
<tr>
<td>Simazine</td>
<td>1.1 kg</td>
<td>6</td>
<td>102</td>
</tr>
<tr>
<td>Spinnaker®</td>
<td>0.3 L</td>
<td>4</td>
<td>86</td>
</tr>
<tr>
<td>Spray.Seed®</td>
<td>1.0 L</td>
<td>7</td>
<td>103</td>
</tr>
<tr>
<td>Surflan®</td>
<td>0.5 L</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>Velpar®</td>
<td>3.5 kg</td>
<td>7</td>
<td>92</td>
</tr>
<tr>
<td>No herbicide</td>
<td>-</td>
<td>7</td>
<td>103</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>N/A</td>
<td>26</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Table 2. Lucerne and wheat parameters observed in 2001 on plots treated with herbicides to cause low damage, growth suppression or removal of lucerne plants before establishing wheat in the first year of the cropping phase

<table>
<thead>
<tr>
<th>Herbicides applied in 2001</th>
<th>Rate/ha</th>
<th>Plants/m²</th>
<th>Grain yield t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundup® (low damage)</td>
<td>0.4 L</td>
<td>8</td>
<td>87</td>
</tr>
<tr>
<td>Roundup® (suppress)</td>
<td>1.0 L</td>
<td>8</td>
<td>99</td>
</tr>
<tr>
<td>Roundup® + Logran® (remove)</td>
<td>1.0 L + 35 g</td>
<td>3</td>
<td>114</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>N/A</td>
<td>38</td>
<td>0.16</td>
</tr>
</tbody>
</table>

In most treatments no differences on wheat development were observed in 2001, except for those plots treated with Spinnaker® @ 0.3 L/ha in 2000, which appeared to have poorer performance. One clear visual observation on these plots was a slightly darker colour of the crop. An analysis of variance of wheat plant density and yield has shown no significant differences between times of application, herbicides applied in the third year of lucerne (2000) (Table 1) or between treatments applied on lucerne before seeding (2001) (Table 2). Quality parameters ranged as follows: kernel weight 48-50 mg, hectolitre weight 80-81 kg, protein at 11% moisture 11.3-11.9%, screenings 7-9%.

DISCUSSION

The most important findings from this experiment over the last two seasons were: 1) In 2000 Roundup® applied @ 0.6 and 1 L/ha reduced the target population of capeweed to < 10% and lucerne plants recovered completely after suffering severe damage. 2) Basta® 20 L @ 1.5 L/ha was also effective controlling capeweed. 3) The rest of the herbicides did not damage lucerne nor controlled capeweed. 4) In 2001, wheat yield was satisfactory under a particularly uncertain season. 5) Spinnaker® is the only chemical that appears to have a detrimental effect on wheat. This fact could be a matter of further investigation.

This research is part of the Low Recharge Cropping Systems Project funded by GRDC, Land and Water and the Department of Agriculture.

KEY WORDS

herbicides, residual effects, lucerne, capeweed, wheat

GRDC Project No.: DAW 659
Paper reviewed by: Richard Olive
Production of lucerne and serradella in four soil types

Diana Fedorenko\(^1\) Clayton Butterly\(^1\), Chantelle Butterly\(^1\), Robert Beard\(^2\)

\(^1\)Centre for Cropping Systems, Department of Agriculture, Northam, \(^2\)Farmer, Cunderdin

KEY MESSAGE

Production of lucerne and serradella varies in different soil types. A dry season contributed to emphasise these differences due to variation in water holding properties between soils.

BACKGROUND AND AIMS

Because of their ability to use water throughout the year perennial pastures have the potential to lower recharge of aquifers and prevent soil salinisation. This is one of the reasons why the area of lucerne (\textit{Medicago sativa} L.) in phase farming systems has increased in recent years. Some farmers have succeeded in establishing and growing lucerne while others have failed. In some cases, failure has been related to inadequate agronomic practices, but unsuitable environmental conditions, e.g. soil acidity, salinity, waterlogging, low calcium carbonate or hostile sub-soils, have also been associated with poor establishment, production and persistence of lucerne.

This experiment is part of a series of studies aiming to explore the range of adaptation and the potential production of lucerne in some parts of the wheatbelt of Western Australia. Lucerne is being sown with a best-bet species for each particular environment. The best-bet could be another deep-rooted perennial or annual, legume or grass, with the potential to lower recharge and/or fix nitrogen in areas that limit lucerne production and persistence.

METHOD

This experiment was established and run in collaboration with Robert Beard on a paddock in the first year of the pasture phase. Four soil types were identified: duplex, white sand, yellow sand and gravel. Soil samples were taken to describe the different soil profiles. Soil pH only is shown in Table 1. Electric conductivity in most samples was less than 4 mS/m.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Duplex</th>
<th>White sand</th>
<th>Yellow sand</th>
<th>Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>4.9</td>
<td>5.9</td>
<td>5.7</td>
<td>5.0</td>
</tr>
<tr>
<td>10-20</td>
<td>4.7</td>
<td>4.3</td>
<td>4.4</td>
<td>4.6</td>
</tr>
<tr>
<td>20-30</td>
<td>4.3</td>
<td>4.6</td>
<td>4.5</td>
<td>4.8</td>
</tr>
<tr>
<td>40-50</td>
<td>4.2</td>
<td>4.6</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>4.7</td>
<td>4.8</td>
<td>6.0</td>
<td>-</td>
</tr>
</tbody>
</table>

Plot size was 61 x 50 m. Two lucerne plots and two serradella plots were located on the sandy and the duplex soils. One plot of each species was fertilised with potassium at 40 kg/ha. On the gravelly soil there was only one plot of each species with no potassium. A total of 24 access tubes were installed to measure changes in soil water. These data are not available yet since calibration of moisture measurements is lacking. Pink serradella cv. Cadiz and lucerne cv. Sceptre were sown on 7 June 2001. Plant traits were measured on 10 quadrats within each plot. Student t-tests were performed to compare pairs of plots. Pod and seed yields of serradella are still to be determined.
RESULTS

Table 2. Comparison of average dry matter production (t/ha) between soil types within species and potash level

<table>
<thead>
<tr>
<th>Species</th>
<th>Potash kg/ha</th>
<th>Duplex</th>
<th>White Sand</th>
<th>Yellow Sand</th>
<th>Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne</td>
<td>0</td>
<td>0.6 a</td>
<td>0.5 a</td>
<td>0.4 b</td>
<td>0.3 c</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0.5 a</td>
<td>0.5 ab</td>
<td>0.4 b</td>
<td>-</td>
</tr>
<tr>
<td>Pink serradella</td>
<td>0</td>
<td>5.8 a</td>
<td>5.2 ab</td>
<td>4.0 c</td>
<td>3.7 c</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>6.7 a</td>
<td>4.7 b</td>
<td>4.1 c</td>
<td>-</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences (P < 0.05) between soil types.

DISCUSSION

The contrasting performance of the species across the soil types reflects major physical and chemical differences which in this dry establishment year, interacted in ways yet to be resolved. For example, both species on the yellow sand showed symptoms of phosphorus deficiency and could have also been poorly rooted. This probably reflects the positional non-availability of phosphorus that will be concentrated near the surface of this soil, which was dry for much of the season. In contrast, phosphorus on the white sand would be deeper leached and hence in moist soil for longer periods of time. Soil acidity in the deeper layers of the yellow sand was probably associated with aluminium toxicity (which would not occur to the same extent on the white sand while the duplex probably held enough moisture above any aluminium toxic layer).

The duplex soil probably held water within the depth of a relatively shallow root zone but with the sandy surface preventing major evaporative losses. The white sand allowed deep moisture penetration and these deep-rooted species were very likely able to grow into the moisture at depth and so prolong their growing season. The gravel was heavier textured, held moisture near the surface where it was subject to evaporative losses which caused prolonged periods of mid season drought. It may also have been P deficient.

Although all of the above is speculative, most of it will be testable when data of water, soil and tissue become available. For this report we considered valuable to present at least our results on dry matter production. Taking advantage of soil variability we set up this experiment to evaluate on field conditions different soil types in the same environment. We thank Bill Bowden for his help to prepare this discussion.

This study will continue for two more growing seasons. During this period information on plant densities, plant phenology, dry matter production, soil and plant nitrogen, water use, root depth and nodulation will be collected. Evaluation at the end of the pasture phase will allow comparing production and water use between species. This information will be analysed by an economist and interpreted in the context of the farming system.

This research is part of the Low Recharge Cropping Systems Project funded by GRDC, Land and Water and the Department of Agriculture.

KEY WORDS
lucerne, serradella, soil type, dry matter

GRDC Project No.: DAW 659
Paper reviewed by: Bill Bowden
The effect of spray topping on newly established lucerne

Keith Devenish, Agriculture Western Australia, Jerramungup (formerly Northam)

KEY MESSAGE

Newly established lucerne showed good tolerance to being spray topped with paraquat and Spray.Seed® but glyphosate was too damaging and killed most lucerne plants.

BACKGROUND

Spray topping newly established lucerne is not a recommended practice in Western Australia although research is limited in this area. Farmers are reluctant to use grass-selective herbicides on lucerne to control grass weeds because of herbicide resistance and rely on trifluralin as a pre-emergent grass control. Trifluralin only gives about 80 per cent ryegrass control and surviving plants can tiller extensively and become a problem if allowed to mature and set seed. Spray topping is a technique used on annual pastures during spring by applying paraquat or glyphosate for grass control. There is a need to test their effect on newly established lucerne.

AIM

To measure the effects of spray topping herbicides on newly established lucerne.

METHODS

Lucerne (Pioneer L69) was sown 11 July on a sand-over-gravel soil, pH 5.2 (CaCl₂), with 70 kg/ha AGYIELD fertiliser and 1.6 L/ha trifluralin as a pre-emergent for grass weed control. The spray topping treatments were applied in spring on 25 September when rye grass was flowering and lucerne was 10–15 cm high. The three spray treatments were paraquat (250 g/L ai) at 750 mL, Spray.Seed® at 1 L and glyphosate (450 g/L ai) at 1 L per hectare compared to no-spray for the control treatment in a randomised plot design with three replicates. Lucerne plant densities were measured before spraying as well as post spraying on 3 November and 4 December by counting the number of lucerne plants in a 0.5 m² quadrat and averaging 10 counts per plot. The mean was then calculated for each treatment.

RESULTS

Lucerne stand density normally declines early summer (November/December) as the soil dries out. The reduction in lucerne plant density was significantly greater for the glyphosate treatment (97%) compared to the no spray, paraquat and Spray.Seed® treatments for November and December.

Table 1. The effect of spray topping herbicides on plant density for newly established lucerne

<table>
<thead>
<tr>
<th>Date</th>
<th>Control - no spray</th>
<th>Paraquat 750 mL</th>
<th>Spray.Seed 1 L</th>
<th>Glyphosate 1 L</th>
</tr>
</thead>
<tbody>
<tr>
<td>September</td>
<td>43</td>
<td>41</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>November</td>
<td>27</td>
<td>33</td>
<td>36</td>
<td>8</td>
</tr>
<tr>
<td>December</td>
<td>26</td>
<td>25</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>% Reduction</td>
<td>39%</td>
<td>39%</td>
<td>17%</td>
<td>97%</td>
</tr>
</tbody>
</table>

5% LSD = 7

CONCLUSION

The results show that glyphosate should not be used to spray top newly established lucerne. Although this work needs repeating before general recommendations can be made and the herbicide rates used were higher than normal, these results show that paraquat caused very few losses and that newly established lucerne has reasonable tolerance to Spray.Seed®.
ACKNOWLEDGMENTS
The Grains Research and Development Corporation funded this research. Appreciation goes to Steve Bell and the staff of the Wongan Hills Research Station for their assistance in conducting the trial.

KEY WORDS
lucerne, spray topping, herbicide, ryegrass

GRDC Project No.: DAW 593
Paper reviewed by: Terry Piper
Leakage from phase rotations involving lucerne

Phil Ward, CSIRO Plant Industry

KEY MESSAGE

A simple model was developed to assess the impact of lucerne in a phase rotation (3 years lucerne, 3 years crop) on average water leakage from the whole rotation. At both Merredin and Katanning, in order to reduce leakage by 90%, lucerne must create extra soil water storage (a buffer) of about four times the average annual water leakage under crops in the absence of lucerne in the rotation (20 mm at Merredin and 82 mm at Katanning). This amounts to a buffer of 80 mm at Merredin, and 328 mm at Katanning. Lucerne has demonstrated a capacity to create buffers of the order of 50-100 mm at many sites around Australia, and so lucerne appears to be a more effective option to control water leakage in the drier regions. Drier regions also allow an extended cropping phase (up to 8 years at Merredin, but only 2 years at Katanning, depending on the run of seasons) before the buffer refills and leakage recommences.

AIMS

Phase farming with perennial pastures such as lucerne (*Medicago sativa* L.) is one of the rotations proposed to help reduce groundwater recharge and secondary salinity in southern Australia. Several studies have demonstrated that the deep roots of lucerne can reduce recharge by drying the soil to a greater depth than traditional crops and pastures. The greater volume of dry soil created by lucerne is used to store water during periods of excess, which usually occur in winter. Under conventional crops and pastures, excess water can contribute to groundwater recharge. However, the impact of lucerne on leakage throughout a rotation is not known, particularly because the amount of leakage tends to vary considerably from year to year. The aim of this paper is to develop and apply a simple model to determine the impact of lucerne, in a 3-year-lucerne/3-year-crop rotation, on average annual water leakage for a duplex soil at Merredin and Katanning.

METHODS

The model requires an estimate of annual leakage from a crop in the absence of lucerne (in mm), and an estimate of the extra soil water storage space (buffer) provided by lucerne (also in mm). The model was run for a 26 year period from 1970 to 1995, using annual leakage numbers (modelled with SWIM) from both Merredin and Katanning, and varying the buffer size between 0 and 400 mm. In the example provided (Table 1), the buffer was set at 50 mm, and was assumed to develop fully in lucerne's first summer. In 1974, leakage under continuous annual vegetation would have been 72 mm. In the spreadsheet model, rotation combinations where 1974 was second year lucerne (R2), third year lucerne (R3), or first year annual (R4) had the full buffer available, and so leakage was 72 - 50 = 22 mm. In R1, where 1974 was second year annual, the 50 mm buffer had been partially filled by 34 mm leakage modelled under annuals in 1973. Leakage under these circumstances was 34 + 72 – 50 = 56 mm. Similarly for R5 and R6, leakage was calculated depending on how much of

Table 1. An example of the spreadsheet model run for Merredin rainfall, with the buffer set at 50 mm. Shaded cells represent years where lucerne was grown, and R (1-6) represents the 6 possible different year/vegetation combinations. Note the different behaviour in 1974 depending on the stage of the rotation

<table>
<thead>
<tr>
<th>Year</th>
<th>Annuals only</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1971</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1972</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1973</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1974</td>
<td>72</td>
<td>56</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>1975</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>1976</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1977</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1978</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1979</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
the buffer was filled in previous cropping years. Average leakage was calculated as the average from each rotation over the 26-year period.

RESULTS
Average leakage (1970-1995) from the annual vegetation was 82 mm at Katanning and 20 mm at Merredin. Leakage at Merredin was dominated by a few wet years, shown by the median leakage (8 mm) being substantially less than the average, whereas the median leakage at Katanning (70 mm) was relatively close to the average.

In a phase rotation of three years of lucerne followed by three years of annual vegetation, a buffer of 57 mm (as measured in a trial at Katanning) reduced average leakage from 82 mm to 55 mm at Katanning (a 27 mm reduction), and from 20 mm to 6 mm at Merredin (a 14 mm reduction). A buffer of 150 mm was sufficient to reduce leakage at Merredin to 0 mm, but average leakage at Katanning was still 29 mm at this buffer size.

When percentage reduction in leakage was plotted as a function of buffer size relative to average annual leakage (Figure 1), lucerne was marginally more effective in the area where leakage was less episodic (Katanning). In both locations, a buffer size of approximately 4 times the average annual leakage under annual crops was required to reduce leakage during the whole rotation by 90%. A 50% reduction in leakage was achieved with a buffer of approximately 1.5 times the average annual leakage (30 mm at Merredin, 120 mm at Katanning).

![Figure 1. Effectiveness of a phase rotation involving lucerne in reducing average leakage, relative to average annual leakage under crops.](image)

The analysis used in this model also allows the calculation of how long a buffer of, say, 50 mm will last before it is refilled in each of the environments. At Katanning, where substantial leakage under annuals occurred in most years, the maximum period was only 2 years. However, at Merredin, where leakage under annuals was zero about half the time, the maximum time to refill a 50 mm buffer was as much as 8 years. In other words, the cropping phase in a phase rotation at Katanning could only last for a maximum of 2 years before the buffer refills, whereas crops could be grown for up to 8 years after lucerne in the Merredin region (depending on the run of seasons) without significant leakage occurring.

CONCLUSIONS
In order to achieve a 90% reduction in leakage, a buffer of the order of 4 times the average annual leakage under annuals needs to be established. Lucerne is more likely to achieve this goal in drier parts of the wheat belt, where average annual leakage is less than 50 mm. These also appear to be the areas in Western Australia where the risk of secondary salinity is highest. Fortunately, the episodic nature of recharge in these areas suggests that the (more profitable) cropping phase can often be extended by several years, making the incorporation of perennials into a phase rotation more financially attractive.

In wetter regions of WA, where topography becomes more undulating, lucerne may still be effective, as a smaller percentage reduction in leakage may be sufficient to impact on salinity. Lucerne in its own right is also likely to be more productive and profitable in these regions.

Paper reviewed by: Frank Dunin, CSIRO; Perry Dolling, UWA/Department of Agriculture
Fungal diseases present in Western Australian lucerne crops

Dominie Wright and Nichole Burges, Department of Agriculture, Western Australia

KEY MESSAGES

- Six leaf diseases were common in lucerne pastures throughout the WA wheatbelt. It was common for pastures to have more than one leaf disease present. These leaf diseases can cause premature leaf drop, hence the yield and quality of the hay or feed is reduced.

- Four root diseases were common in older pasture stands in WA wheatbelt. It was common for more than one pathogen to be involved in causing either root rot or crown rot. These diseases can reduce the production and life of the infected pasture. Recurrent traffic of farm machinery mechanically damages the pasture and can contribute to an increase in the level of crown rot.

- Many of these diseases also infect clover and medic pastures. This then has a major impact on crop rotation within the pasture system, due to disease carryover and the green bridge affect.

- More information is required to determine the level of impact these diseases have on lucerne production under WA conditions.

BACKGROUND

As the area of lucerne being planted throughout the wheatbelt of Western Australia is increasing, it is important to assess what diseases are present in current crops and determine the potential these diseases have in providing a source of disease for other legume crops.

A survey was conducted during the spring growing season (September-November 2001). Thirty properties from throughout the wheatbelt were selected and sampled. The survey concentrated on third-year stands as the level of disease present in the crops would be higher than stands that were newly sown or only a year old. By concentrating on three-year old stands pathogens that are endemic would be detected.

Twenty individual plants were sampled per pasture. These were tested for eight common leaf pathogens of lucerne by moist tray incubation. The plants were then bulked together and tested for common root pathogens as well as two exotic pathogens not found in lucerne crops in Western Australia previously. The following number of pastures were sampled in each Agzone: Agzone 1 (North West) 4, Agzone 2 (Central) 12, Agzone 3 (South West) 7, Agzone 4 (North East and Central) 4 and Agzone 5 (Lakes/Mallee) 3. Approximately 8 different varieties were sampled during the survey. In some cases the varieties present were unknown or the farmers had sown a varietal mixture that could not be determined.

SURVEY RESULTS

Eight leaf diseases were detected across the pastures sampled during the survey. Phoma leaf spot (Phoma medicaginis), Stagonospora leaf spot (Stagonospora melliloti) and Stemphylium leaf spot (Stemphylium sp.) were the most common leaf diseases detected. All varieties collected in the survey were susceptible to Stemphylium leaf spot and Phoma leaf spot, and the majority of them were also susceptible to Burn (Leptosphaerulina trifolii), Stagonospora leaf spot, and Rust (Uromyces striatus). Table 1 shows the number of positive pastures in each Agzone, and the distribution of leaf diseases in each Agzone. In most cases the pastures sampled had more than one leaf disease present.

Four pathogens that can cause root disease were commonly detected in the pastures sampled during the survey. There was often more than one root pathogen infecting individual lucerne stands. The pathogen Rhizoctonia sp. was only detected in the roots. The type of Rhizoctonia was found to be binucleate which is not the same as the R. solani types that cause root diseases in cereal and pulse crops. Charcoal rot (Macrophomina phaseolina) was detected in all varieties and in all Agzones. This is a common pathogen for legumes and is usually present in older legume crops. It tends to be more prevalent when seasonal conditions are dry than when they are wet. Fusarium spp. were detected across all varieties and Agzones. This is a common soil pathogen and causes both root rots and...
crown rots in dry conditions. The pathogens *Sclerotinia* sp. and *Pythium* sp. were both detected in some pastures. These pathogens are generally associated with root rots when conditions are cool and wet. The exotic pathogen *Phytophthora megasperma* was not detected in any of the samples.

**Table 1a.** Leaf diseases detected in lucerne pastures surveyed from throughout the WA wheatbelt. Figures give the number of positive pastures, and the numbers in brackets indicate the minimum and maximum number of positive plants per paddock.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracnose</td>
<td>3 (1-4)</td>
<td>2 (1)</td>
<td>1 (2)</td>
<td>1 (1)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Burn</td>
<td>2 (1-2)</td>
<td>5 (1-3)</td>
<td>2 (2-3)</td>
<td>1 (2)</td>
<td></td>
</tr>
<tr>
<td>Downy Mildew</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phoma leaf spot</td>
<td>2 (2-5)</td>
<td>10 (1-20)</td>
<td>6 (1-15)</td>
<td>2 (12-13)</td>
<td>2 (6-9)</td>
</tr>
<tr>
<td>Common Leaf spot</td>
<td>1 (1)</td>
<td>1 (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rust</td>
<td>1 (11)</td>
<td>1 (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stagonospora leaf spot</td>
<td>1 (5)</td>
<td>3 (1-2)</td>
<td>2 (2-5)</td>
<td>3 (1-9)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Stemphylium leaf spot</td>
<td>3 (2-18)</td>
<td>11 (1-19)</td>
<td>7 (2-16)</td>
<td>3 (3-20)</td>
<td>3 (4-13)</td>
</tr>
</tbody>
</table>

**Table 1b.** Number of times root and crown diseases were detected in pastures sampled throughout the WA wheatbelt.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusarium crown rot</td>
<td>Crown</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Fusarium root rot</td>
<td>Root</td>
<td>4</td>
<td>11</td>
<td>7</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Charcoal rot</td>
<td>Crown</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Charcoal rot</td>
<td>Root</td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pythium root rot</td>
<td>Root</td>
<td>4</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Rhizoctonia root rot</td>
<td>Root</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Sclerotinia</td>
<td>Crown</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sclerotinia</td>
<td>Root</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Leaf diseases were common and prevalent in lucerne pastures and most had more than one disease present. Control for these diseases is mainly through heavy grazing or removal of the affected hay from the paddock.

Root disease pathogens were quite prevalent throughout lucerne pastures in WA wheatbelt. In these older pastures crown rots caused by the pathogens *Macrophomina* and *Fusarium* were more prevalent. If high levels of root rot or crown rot become more prevalent within the stand, it may be necessary to replace the pasture with another crop rather than waiting until the end of the cropping cycle. There are no fungicide control treatments available.

Old lucerne stands provide a source of disease for other legume pastures and possibly some other legume crops (e.g. peas) through a green bridge affect. For example, *Phoma medicaginis* on peas and *Macrophomina phaseolina* on lupins, peas.

**ACKNOWLEDGMENTS**

We would like to thank Peter Hill and Allan Sweetman for collecting the samples and Sandy Mack and Johnathon Warden for help with processing the samples in the laboratory.

**Paper reviewed by:** Dr Roger Jones
Survey of Western Australian lucerne stands reveals widespread virus infection

Roger Jones and Danae Harman, Crop Improvement Institute, Department of Agriculture, and Centre for Legumes in Mediterranean Agriculture, University of WA

KEY MESSAGES

• In a survey of three year old lucerne pastures in the Western Australian wheatbelt in 2001, 30 out of 31 pastures sampled were found infected with alfalfa mosaic virus. Incidences were often high (up to 98% of plants infected), with more than 50% infection within 20 of them.
• Infection with luteoviruses was detected in 11 out of 31 pastures sampled, bean leaf roll virus being found for the first time in WA, subterranean clover red leaf virus for the first time in the wheatbelt, and beet western yellows virus for the first time in lucerne in the State.
• Infection with viruses in lucerne stands is cause for concern not only because of production losses within the infected stands but also because they provide an infection reservoir for virus diseases to survive over summer and subsequently spread to nearby crops of pulses and lupins, and to annual pastures.

BACKGROUND

The benefits provided by sowing lucerne in pastures in the wheatbelt need to be balanced against problems that their widespread cultivation will bring. For example, they provide a ‘green bridge’ for legume pests and diseases to survive in. Such a continuous ‘green bridge’ is absent with annual pastures as they die from lack of moisture over summer.

At the 2001 Crop Updates, we reported that commercial seed stocks of lucerne being sown widely in the Western Australian wheatbelt are commonly infected with alfalfa mosaic virus and occasionally also with cucumber mosaic virus. We also pointed out that an inevitable consequence of sowing untested, unknowingly-infected lucerne seed stocks is unnecessary introduction of seed-borne virus infection within pastures. We predicted that this practice will cause epidemics of alfalfa mosaic virus, which is readily seed-borne in lucerne and spread by aphids. Such epidemics not only induce losses in lucerne production but also can spread to cause serious epidemics of alfalfa mosaic virus in nearby pulse crops and annual pastures.

At the 2001 Crop Updates, we also suggested that a likely long-term consequence arising from widespread sowing of lucerne in the wheatbelt is damaging epidemics of luteoviruses in pulses like those that occur where lucerne pastures are abundant in NSW. In eastern Australia, luteovirus diseases of legumes are caused by a complex of 3 different viruses, beet western yellows, subterranean clover red leaf and bean leaf roll. They are spread by aphids, are not seed-borne and require a ‘green bridge’ of herbaceous hosts to survive the dry summer period. Lucerne is a key reservoir host for them. In NSW, epidemics of these luteovirus diseases are a major cause of growers’ giving up sowing pulses.

In September-November 2001, a large-scale survey was done to determine the incidence of virus infection in three year old lucerne stands growing in locations throughout the wheatbelt. For this, 100 shoot samples (1/plant) were taken at random from each of 31 lucerne pastures. These samples were tested in the laboratory for presence of six different viruses using virus-specific antibodies, and the ELISA and TBA techniques.

SURVEY RESULTS

Infection with alfalfa mosaic virus was found within 30 of the 31 lucerne pastures sampled. Incidences within individual pastures were high with 50-98% of plants infected in 20 of them, and only four having less than 10% infection. Lucerne varieties found infected included Aquarius, Eureka, Fairdale, Genesis, L69, Salado, Sceptre, Trifecta and various varietal mixtures. Table 1 shows the numbers of pastures infected within each Agzone. Two other seed-borne viruses, cucumber mosaic and bean yellow mosaic, were not detected. Bluegreen aphid infestations were common in the pastures sampled and cowpea aphid was also often found. Both aphid species are efficient vectors of these three viruses.
Tests for luteoviruses revealed infection in 11 of the 31 pastures sampled, with infection incidences within them ranging from 1-5%. In five of the infected stands, the luteovirus(es) present were not identified further. In the six others, one or more of the three luteoviruses were detected, beet western yellows, bean leaf roll and subterranean clover red leaf. One pasture had infection with both bean leaf roll and subterranean clover red leaf, three had beet western yellows alone, and one each had bean leaf roll or subterranean clover red leaf alone. Lucerne varieties infected with luteoviruses included Salado, Sceptre and various varietal mixtures. Table 1 shows the numbers of pastures found infected within each Agzone.

Table 1. Numbers of lucerne pastures found infected within each Agzone

<table>
<thead>
<tr>
<th>Virus name</th>
<th>Agzone 1 (4 stands)</th>
<th>Agzone 2 (13 stands)</th>
<th>Agzone 3 (7 stands)</th>
<th>Agzone 4 (4 stands)</th>
<th>Agzone 5 (3 stands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa mosaic</td>
<td>4</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Cucumber mosaic</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bean yellow mosaic</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Beet western yellows</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bean leaf roll</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Subterranean clover red leaf</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Luteovirus +ve (unidentified)</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

CONCLUSIONS

As predicted last year, widespread sowing of untested lucerne seed stocks has resulted in high levels of infection with alfalfa mosaic virus in lucerne stands in the WA wheatbelt. To avoid such unnecessary, large-scale introduction of seed-borne infection in the future only tested seed of lucerne with < 0.1% infection should be sown. This should provide herbage productivity increases of 10-30%. Development of a local lucerne seed industry to produce healthy stocks may be required to ensure that sufficient healthy seed stocks are available.

As predicted, provision of a continuous ‘green bridge’ of herbaceous plant material all year round through sowing lucerne has resulted in accumulation of infection with luteoviruses. Of the three found, bean leaf roll, the most damaging for pulses, has not been detected before in WA, and its presence is cause for concern for pulse growers. Subterranean clover red leaf has previously only been found in the State in perennial white clover pastures in the Harvey irrigation area, never in the wheatbelt. Infection of lucerne with beet western yellows virus is not unexpected as it has a wide host range, and already commonly infects wild radish weeds, and canola and pulse crops in the region.

Introduction of luteoviruses to perennial pastures cannot be limited by seed testing as such viruses are not seed-borne but enter sown pastures from nearby naturally infected perennial hosts. However, because they are persistently transmitted by aphids, spread of luteoviruses within pastures can be suppressed by application of pyrethroid insecticides, which have rapid knockdown and persistent anti-feeding properties. Pyrethroid insecticides are also effective at suppressing spread of non-persistently aphid–borne viruses like alfalfa mosaic within pasture swards but not in crops.

KEY WORDS

perennial pasture, lucerne, legumes, crops, disease, losses, productivity, risks, threat, ‘green bridge’, seed testing, seed health, control measures

ACKNOWLEDGMENTS

We thank Brenda Coutts for helping with testing samples. Peter Hill and Allan Sweetman collected the samples. The Department of Agriculture funded the work.

REFERENCE

Disease risk to crops and pastures from widespread sowing of lucerne. In 2001 Crop Updates - Farming Systems and Sustainability, p. 37-38.

Paper reviewed by: Martin Barbetti
The use of Twist Fungus as a biosecurity measure against Annual Ryegrass Toxicity (ARGT)

Greg Shea, GrainGuard Coordinator and George Yan, Biological and Resource Technology

KEY MESSAGE
ARGT is a serious disease of livestock in the Wheatbelt where the natural biological control agent, Twist Fungus, has not become established. The disease has serious implications for the wheatbelt farming system and Twist Fungus is a cost effective biosecurity measure against this problem.

HISTORY AND PREVALENCE OF ARGT
ARGT was first detected at Black Springs in the mid-north of SA in 1956. In WA, the first outbreak was reported near Gnowangerup in 1968. Since then ARGT has occurred over much of the wheatbelt between Dalwallinu and Jerramungup, and as far east as Grass Patch, in areas where farmers commonly use crop-pasture rotations. It has been reported on more than 1700 farms in WA since 1968. An estimated 250,000 sheep and 600 cattle have been killed by ARGT in WA since 1969. In the 30 years since the first discovery of ARGT, the biological control agent Twist Fungus has become endemic in the Great Southern and the number of cases of ARGT has been severely reduced. Significant spread of Twist Fungus into the wheatbelt has not occurred through natural means.

Disease biology
ARGT is a neurological disease of livestock caused by the ingestion of Annual Ryegrass (*Lolium rigidum*) infected by a bacterium (*Rathayibacter toxicus*) which produces corynetoxins in the ryegrass seedhead. It is often fatal. The bacteria are carried into the seedhead by a parasitic nematode (*Anguina funesta*) where they multiply and induce the formation of a gall, containing yellow masses of toxin-producing bacteria in place of the normal seed.

Grass seedlings may become infected with a nematode soon after germination, and the nematode larvae move up the growing tip of the newly emerging plant by being passively carried up the stem as the plant grows. As the plant matures, juvenile nematodes burrow into the developing ovaries, where galls develop. The nematodes feed inside the galls, grow into adults, and lay eggs that produce the next generation of larvae, that lay dormant until the next summer. Autumn rain breaks down the gall and the immature nematodes become active in the soil and the cycle begins again. The nematode itself is not toxic.

*R. toxicus* is also found in the soil and adheres to the surface of immature nematodes. It is then carried onto the grass plant and into the ovaries where the gall is formed. Toxin production starts at the time of flowering and increases rapidly from the time of seed set and during senescence of the plant. Most livestock are intoxicated during spring and early summer when the bacterial galls are easily accessible in the seed heads.

EFFECTS OF ARGT ON THE FARMING SYSTEM
As well as its effects on animal production, ARGT has undesirable effects on the rest of the farming system. Being unable to graze pastures effectively reduces the ability to control seed set of problem weeds. Also, hay is potentially contaminated by infected ryegrass and measures need to be taken to manage the problem.

ARGT builds up in cropping rotations and affects stock grazing the stubbles. Riley and Gill (1994) found that the use of selective herbicides for ARGT control may have contributed to the rapid development of herbicide resistance in annual ryegrass. Also, herbicide use to maximise crop yield has resulted in increased herbicide resistance in annual ryegrass leading to increased *A. funesta* populations.

BIOLOGICAL CONTROL WITH TWIST FUNGUS
*Dilophospora alopecuri*, is a naturally occurring fungus in Southern WA and has been developed as a biocontrol agent for ARGT in Australia. The twist fungus, as it is commonly known, also attaches itself to the nematode and is carried into the seed head. The fungus limits nematode development and
multiplication of the bacterium and as a result the level of nematode and bacterial galls is reduced, lowering toxin levels and the risk of ARGT.

**How the Twist Fungus reduces the risk of ARGT**

After autumn rainfall, ryegrass seeds germinate, nematodes emerge from galls in the soil, disperse on the soil surface, and carry the bacterium into the ryegrass plant. As the ryegrass plant starts tillering, the nematode juveniles invade the ryegrass and congregate at the growing point. After floral initiation, the juveniles feed on the developing ovary and stimulate the production of a gall in place of a normal seed. In galls into which the bacterium has been carried, the bacterium multiplies, killing the nematodes, filling the gall with densely packed yellow bacterial cells. Large numbers of bacteria may also appear as a yellow slime covering the ryegrass heads and leaves. The slime and bacterially-colonised galls are toxic to livestock. Sheep consuming ryegrass contaminated with high levels of bacterially-colonised galls and slime may develop ARGT.

The twist fungus is carried into ryegrass by adhering to the nematode. With the introduction of the twist fungus, the number of nematodes entering the ryegrass is reduced as spores of the fungus hinder nematode movement. Once inside the ryegrass plant, the twist fungus colonises the plant, limiting the development of the nematode and the multiplication of the bacterium in the process. As a result, the level of nematode and bacterial galls is reduced and the risk of ARGT lowered.

The effect of twist fungus is cumulative. Although results of field experiments have shown that the fungus is capable of reducing the bacterial level by up to 100% and nematode level by 50-70%, this may not be realised in inoculated paddocks for some years. In inoculated paddocks, the twist fungus population gradually builds up causing the nematode and bacterial populations to decrease, with both populations eventually stabilising at a lower level, therefore lowering the risk of ARGT. It may take three to five years for the risk of ARGT to be substantially reduced, depending on conditions and the initial inoculation rate.

**Field application**

The minimum recommended inoculum application rate is 200 g/ha. Field application is easier done in bands rather than attempting to cover the whole paddock. If bands are spaced at 60 m intervals, one (1) bag of inoculum will inoculate a 2000 m band. To achieve even coverage the inoculum can be mixed with sand or sawdust. At the recommended minimum application rate, there will be no significant reduction in the risk of ARGT in the year of application. The full benefit of the fungus may take 3-5 years to be realised.

In situations where a more rapid result is desired, a higher application rate would be needed. Ideally paddocks selected for treatment should: (1) have a history of ARGT; (2) have moderate to high density of ryegrass; (3) be crop paddocks likely be in pasture in the next year. Development of the fungus during the year of application is best in cropped paddocks.

Harvesting and other activities will further spread the fungus around the paddock and farm. Hence, crop paddocks are better for local dispersal of the fungus. If the inoculated paddock is in pasture in the year following inoculation, the build up of the fungus will be promoted by the high ryegrass population provided that grazing is not too heavy.

The fungal inoculum is easy to apply in the field. Any machinery capable of spreading solid materials can be used. Super spreaders and air seeders have been used successfully. If large areas are to be inoculated, aerial application may be a viable alternative. Where applying the inoculum by machine, drying the inoculum may be necessary to give smooth flow. Opening the bags 1-2 hours under warm and dry conditions before spreading should be sufficient to overcome possible blockage problems.

To be effective the inoculum must not be buried as the fungus produces spores that are spread by rain. Application bands should be run across the slope to facilitate dispersal by surface water flow. Field application should be done during May to early July. Spreading the fungus after ryegrass tiller elongation is not recommended. Once established, the fungus will persist wherever ryegrass and the ARGT nematode persist and re-application of the fungus should not be necessary.

**REFERENCE**


**Paper reviewed by:** Bob French
Limitations and opportunities for increasing water use by annual crops and pastures

David Tennant¹, Phil Ward² and David Hall³
¹Department of Agriculture, South Perth, ²CSIRO, Plant Industries, Floreat Park, ³Department of Agriculture, Esperance

KEY MESSAGE

Water use of cool season annuals occurs largely over spring and early summer to develop soil water deficits to act as buffers against winter rain in the following year to reduce drainage and ground water recharge.

- Best increases in water use, of the order of 40 to 70 mm, have been reported on deep sands and loamy sands from deep ripping to ameliorate traffic pans, replacing pasture species with deeper rooted crop species and selection of acid tolerant crops and pasture species on acid sands. In the wider landscape, which is dominated by duplex soils, increases in water use from adoption of high yielding crop practices are limited to 20 to 40 mm in long season high rainfall environments and to 5 to 15 mm in low rainfall short season environments.

- Soil water deficits arising from these increases are often eroded by rainfall received over summer and autumn.

Substantial increases in crop yields since the 1970s (average wheat yields from 0.7 to 1.7 t/ha) have not been matched by evidence showing impact on rising watertables. On balance, over a period of years, there is little scope to significantly reduce ground water recharge and slow the spread of salinity by increasing the water use of cool season crops and pastures. Given that a large proportion of the landscape will continue to be covered by annual crops and pastures for some time yet, it is worth ensuring that any opportunity to reduce recharge from under them, even by small amounts, be taken.

BACKGROUND

Cool season pastures and crops regenerate or are sown sometime in late autumn-early winter, and grow through winter and spring to early summer. For most of winter, rainfall exceeds evaporative demand. As the soil surface remains wet over this period, soil evaporation from bare soil is similar to water use (soil evaporation + transpiration) by growing crops and pastures. Increases in transpiration are matched by decreases in soil evaporation. Differences if any in water use are small irrespective of levels of leaf area and dry matter produced.

As rainfall decreases in spring, environmental demand for water increases. Water use increases and transpiration becomes the dominant component of water use. The soil surface dries and plant water needs are increasingly met from soil water reserves, established by root depth and soil storage capacity. The combination of a drying surface soil and limited access to deeper water leads to lower water loss from soil evaporation than from crops and pastures. Water use of crops and pastures continue to equate to potential evaporation rates for as long as soil water reserves are readily available. When soil water reserves are reduced to around 30% of maximum plant available water (PAW), plants are less able to access and transport water to meet this demand. Differences in leaf area and root depth impact on demand for and access to soil water reserves and differences in water use between species and varieties and between good and bad crops develop.

Drainage below the root zone usually occurs over the winter months when most agricultural species can have little effect on water use. Water use over spring (cool season annuals and perennials) and summer (warm season annuals and perennials) impacts on drainage in the following year. This is achieved by setting up soil water deficits by the end of summer, to act as a buffer against winter rainfall. Drainage occurs when excess rainfall (rainfall-water use) is greater than this buffer. The larger the buffer, the lower the drainage. In this scenario, cool season annuals in farming systems where the land is bare over summer have no capacity to respond to summer rain. Deficits established by the end of the growing season are frequently eroded by significant rainfall events.
WATER USE OF ANNUALS

Deeper rooting
Selection of deeper-rooted crop and pasture species is often invoked, as the option most likely to contribute to greater water use, yet depths reported for annual crops and pastures are limited. Maximum root depths found range from 2 to 3 m for annual crops and from 1 to 1.5 m for annual pasture species. These depths are achieved in deep sand and loamy sand soils with no obvious restrictions to root growth. In more widely distributed gradational and duplex soils, root depth can be restricted by an impermeable B horizon (duplex soils), low pH (acid soils), high pH (alkaline soils), boron toxicity, salinity or possibly one or more of several other factors. On these soils, root depths of agricultural species are at best around 1.5 m, and more typically in the range 0.5 to 1.1 m. Species and even variety differences in root depth on these soils reflect tolerances to the dominant impeding condition. In many situations, the limiting condition has uniform effect and there is little or no difference in species rooting depth.

Higher water use follows from deeper root exploration to access more plant available water. On soils allowing deeper rooting (deep sands and loamy soils), the increase in plant available water can range from 30-60 mm/m of root depth increase. Deep ripping to ameliorate traffic pans, selection of acid tolerant crop and pasture species and amelioration of acidity on deep sands and loamy sands have been shown to generate increases in water use of this order. Few if any gains in root depth and presumably therefore of water use have been noted on duplex soils.

Longer growing
Later maturing cereal crop varieties have been shown to use more water (20-40 mm) than early maturing crop varieties in long season high rainfall environments (Esperance), due to access to late season rains and deeper water extraction. In short season, low rainfall environments (Merredin, Mullewa), in most years growth is limited by terminal drought, and water use is at best only marginally higher (5-10 mm) with later maturing varieties. Similarly, canola, a semi-indeterminate species, has been shown to use more water than determinate crop species at Esperance, but not at Merredin.

Higher yielding
There has been a substantial increase in the production of annual crops in many areas of Western Australia and in the area sown to crops, since the early 1970s. Average wheat yields have increased from around 0.7 to 1.7 t/ha. For a variety of reasons, higher water use is widely inferred from these and other yield increases. In many instances, these yield increases have reflected increases in transpiration at the expense of soil evaporation and better transpiration efficiencies. Transpiration as a proportion of water use can vary from around 30% in poorly managed crops to as much as 70-80% in well managed crops. When increases in transpiration are combined with improvements in transpiration efficiency, substantial increases in yield are possible without any increases in water use. As a generalisation, higher water use from adoption of high yielding crop practises is observed in high rainfall years and high rainfall environments. Increases of the order of 20 to 40 mm have been recorded at Esperance. Increases in water use are not usually found in low rainfall years and low rainfall environments. Small gains, of the order of 5 to 15 mm have been recorded in some years at Merredin and Mullewa.

CONCLUSION
Two key issues are identified. Firstly, water use cannot be inferred from production. Substantial increases in production can be achieved with little or no increase in water use, through a combination of increases in transpiration at the expense of soil evaporation and higher transpiration efficiencies. Secondly, water use impacts on drainage in the following winter and not in the winter and spring of crop and pasture growth.

KEYWORDS
Water use, evaporation, transpiration, transpiration efficiency

GRDC Project No.: DAW 622
Paper reviewed by: Doug Abrecht
Developing pasture species mixtures for more productive and sustainable cropping systems - 2001 crop performance

Anyou Liu, Clinton Revell and Candy Hudson, Centre for Cropping Systems, Department of Agriculture WA, Northam

KEY MESSAGE

Wheat crops were more productive after a pasture species mixture than that after pure sub. clover. Nitrogen supply is implicated in this response. Good seasonal conditions in spring are required for crops to express yield benefits from previous pasture history.

BACKGROUND AND AIMS

The idea that a mixture of different pasture legume species should result in a more productive and sustainable cropping system has been tested over the last few years in a large rotation experiment near Northam. The mixture treatment includes sub. clover, serradella, biserrula, gland clover and arrowleaf clover; the control treatment is sub. clover only. The rotation was sown pasture, wheat, regenerating pasture, regenerating pasture, and wheat. The aim of the trial is to examine whether a wheat crop following pasture legume species mixtures will perform better than crop following sub. clover, in terms of production and quality. This paper reports results from the first wheat crop grown in the year after pasture establishment.

METHODS

Pasture treatments were sown in 2000 at a total seeding rate of 10 kg/ha. The main treatments (mixture vs sub. clover) were replicated three times. Total production of the two pasture treatments was similar (Crop Update 2001). In 2001, the wheat variety Carnamah was sown at 60 kg/ha on 6 June with 110 kg/ha superphosphate. Three nitrogen (N) rates (0, 25, 50 kg/ha N in the form of urea) were applied as subplots in each main plot to test crop responses to applied nitrogen. Measurements were taken of biomass at anthesis, together with grain yield and quality at final harvest. Quality data are yet to be processed.

RESULTS

Biomass at anthesis

Generally, wheat following the pasture species mixtures produced more biomass at anthesis than that following sub. clover (Figure 1). Averaged across the three N levels, the biomass at anthesis was 16% higher for the wheat crop following species mixture than wheat following sub. clover. The response of biomass to N application was similar following both pasture treatments.

Grain yield

Although the season in 2001 was relatively dry, conditions during grain filling were good and grain yields approached 4.5 t/ha. Wheat following the pasture species mixture produced an average grain yield of 4.26 t/ha, while wheat following sub. clover produced 3.83 t/ha (Figure 2). When no nitrogen was applied, wheat following the species mixture was nearly 15% higher than wheat following sub. clover. At 50 kg/ha nitrogen, there was no effect of pasture treatment on wheat yield.
DISCUSSION AND CONCLUSION

Crop performance did respond to previous pasture treatments and benefited from the pasture species mixture. The basis of this response is unclear since total levels of pasture production (and presumably nitrogen fixation) were similar in 2000. However, nitrogen appears to be implicated since the addition of fertiliser N to crops grown after sub. clover alleviated the difference. The availability of nitrogen may be higher following the pasture mixture treatment due to the presence of the soft seeded Cadiz serradella component. In this species less N is tied up in hard seed reserves. Further investigations are needed to clarify this. As indicated in previous updates, a good finish to the season is required for the potential benefits from previous pasture history to be expressed in crop performance. The research supports the concept that productive legume pastures can result in substantial benefits for following crops.

ACKNOWLEDGMENTS

We thank Murray and Fiona Siegert for allowing the trial on their property; EDSCO, Paramont Seeds, CLIMA, Ballard Seeds, and SGB for contributing seed to the pasture phase; and GRDC for financial support.

KEY WORDS

species mixture, wheat, pasture legumes, nitrogen

GRDC Project No.: DAW 634
Paper reviewed by: Dr James Fisher
Developing pasture species mixtures for more productive and sustainable cropping systems - weed management in regenerating mixtures

Anyou Liu and Clinton Revell, Centre for Cropping Systems, Department of Agriculture, Northam

KEY MESSAGE

- Chemical control can be used to reduce competition from weeds and give the legume component of the pasture some advantage.
- Weed control should be early - to allow the desirable species more time to recover from any damage that might occur and more time to grow to take advantage of the gaps left after weed removal.
- The herbicide management of a species mixture is difficult since legumes vary widely in their herbicide tolerance. Information on rate, timing, and the relative effect on weeds and legumes is critical in attaining a desirable result and is being collected.
- Grazing can be used effectively to control weeds. Grazing should commence soon after the break of the season, but not before seedlings are well established.

BACKGROUND AND AIMS

The idea that a mixture of different pasture legume species should result in a more productive and sustainable cropping system has been tested over the last few years in a large rotation experiment near Northam. The mixture treatment includes sub. clover, serradella, biserrula, gland clover and arrowleaf clover; the control is sub. clover. The rotation was sown pasture, wheat, regenerating pasture, regenerating pasture and wheat. Although there have been positive results indicating an advantage of using pasture species mixtures, it was found that weed management in regenerating pastures could be an important factor to the success of this strategy. Of particular concern is the lack of competitive ability in legume species with small seedlings, such as gland clover. Grazing and chemical treatments were applied to test their effectiveness in controlling weeds.

METHODS

Chemical treatment - a bromoxynil strip (2 m by 100 m) at a rate of 1.5 L/ha was applied to second year regenerating pastures of both mixture and sub. clover treatments on 12 June. Plant number and dry weight was estimated at key stages after the application, but only the results for the mixture treatment are reported here. All treatments were replicated three times at the site.

The effect of grazing was estimated using steel exclosure cages. Pasture was covered with cages (4 per plot) at the beginning of the season to exclude grazing from sheep (at 12 sheep/ha). The break of season at the site was 12 May and sheep were grazed on the plots from 19 June. Plants were counted and separated into different species at key stages.

RESULTS

Herbicide treatment

As indicated in Figure 1, control using bromoxynil significantly reduced the percentage of broadleaf weeds (mainly capeweed) in pastures and legumes became the predominant species. However, the proportion of grass weeds also increased. The total biomass of legumes was reduced initially by the herbicide application (28% lower on 27 June), but then recovered to a level higher than that in the unsprayed areas (34% higher on 21 August).
Grazing generally reduced the height of the sward, but appeared to selectively suppress weeds more than the legume components, especially at the beginning of the season when most legume plants were small (Figure 2). While the total plant number was lower under grazing, the legume plant number was little changed. The reduction in grass weed numbers was particularly notable.

CONCLUSION

Although most new aerial seeding legume species are unlikely to tolerate the same heavy grazing pressure as sub. clover, grazing can still be used as an effective tool in weed management in regenerating alternative pasture legumes. We suggest that pasture should be grazed soon after the break of season but not before seedlings have had time to establish. In this trial, the sheep were introduced about 4 weeks after emergence and this was shown to be beneficial to the legume components. Earlier grazing may be possible but we suspect that deferring grazing for 2-3 weeks after the break will optimise the establishment of legume seedlings.

Early chemical treatment will be another important tool but farmers need to be mindful of legume sensitivity to herbicides, limited registrations of pasture herbicides and cost of treatment. Information on the relative susceptibility of different species to different herbicides is being collected (for detail see paper by Clinton Revell).

ACKNOWLEDGMENTS

We thank Candy Hudson for technical support, Murray and Fiona Siegert for allowing the key trial on their property, and GRDC for financial support.

KEY WORDS

species mixture, grazing, herbicide, weed control

GRDC Project No.: DAW 634
Paper reviewed by: Dr Terry Piper
Aphid tolerance of annual pasture legumes

Andrew Blake, Natalie Lauritsen, Department of Agriculture, Geraldton

KEY MESSAGE

Aphid tolerance varied greatly between different species and lines with all serradellas, new medic varieties and Hykon rose clover displaying the most tolerance. The level of aphid damage was highly correlated with aphid numbers.

BACKGROUND

Blue-green (Acyrthosiphon kondoi) and cowpea (Aphis craccivora) aphids are major pests of pasture legumes with severe infestations resulting in reduced dry matter production, lower seed yields and premature pasture senescence. Information about the aphid tolerance of advanced breeding lines helps breeders to maximise the level of aphid tolerance in commercial cultivars. Farmers should also find this information useful when deciding which pasture varieties to grow.

This trial aimed to screen the advanced breeding lines from the National Annual Pasture Legume Improvement Program (NAPLIP).

METHODS

A replicated field trial was conducted near Dongara, Western Australia on a clay loam pH (CaCl$_2$) 5.0. 170 existing pasture cultivars and advanced breeding lines were screened for their tolerance to aphids with pasture lines hand sown in 1m long rows. Assessment of aphids and consequent damage was based on visual ratings. The first measurement (29 August) was a rating (0-10) of aphid infestation (0 = no aphids and 10 = severe infestation). The second (7 September) and third (20 September) ratings were an assessment (0-10) of damage caused to the plant (0 = no damage, 10 = severe damage).

RESULTS

Table 1. Rating of aphid infestation (0-10) performed 29 August and of aphid damage to plants (0-10) measured twice during September in pasture legumes. The most tolerant varieties are highlighted in bold print

<table>
<thead>
<tr>
<th>Genus/species</th>
<th>Variety</th>
<th>Cultivar</th>
<th>Days to 50% flowering</th>
<th>Aphid number (29/8)</th>
<th>Aphid damage (7/9)</th>
<th>Aphid damage (20/9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biserrula pelecinus</td>
<td>Biserrula</td>
<td>Casbah</td>
<td>103</td>
<td>7.8</td>
<td>7.5</td>
<td>7.6</td>
</tr>
<tr>
<td>Medicago littoralis</td>
<td>Strand Medic</td>
<td>Herald</td>
<td>73</td>
<td>1.6</td>
<td>1.3</td>
<td>1.6</td>
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<tr>
<td>Medicago polymorpha</td>
<td>Burr Medic</td>
<td>Serena</td>
<td>67</td>
<td>4.1</td>
<td>5.0</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Burr Medic</td>
<td>Santiago</td>
<td>74</td>
<td>4.3</td>
<td>5.2</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Burr Medic</td>
<td>Circle Valley</td>
<td>82</td>
<td>5.3</td>
<td>5.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Medicago tornata</td>
<td>Disc Medic</td>
<td>Toreador</td>
<td>67</td>
<td>2.5</td>
<td>1.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Medicago truncatula</td>
<td>Barrel Medic</td>
<td>Jester</td>
<td>83</td>
<td>0.9</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>Barrel Medic</td>
<td>Cyprus</td>
<td>67</td>
<td>8.8</td>
<td>8.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Ornithopus compressus</td>
<td>Yellow Serradella</td>
<td>Charano</td>
<td>85</td>
<td>0.9</td>
<td>0.6</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Yellow Serradella</td>
<td>King</td>
<td>85</td>
<td>0.9</td>
<td>0.7</td>
<td>0.3</td>
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<tr>
<td></td>
<td>Yellow Serradella</td>
<td>Santorini</td>
<td>89</td>
<td>1.3</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Ornithopus sativus</td>
<td>French Serradella</td>
<td>Cadiz</td>
<td>107</td>
<td>1.5</td>
<td>0.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Genus/species</td>
<td>Variety</td>
<td>Cultivar</td>
<td>Days to 50% flowering</td>
<td>Aphid number (29/8)</td>
<td>Aphid damage (7/9)</td>
<td>Aphid damage (20/9)</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------</td>
<td>----------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>-------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Trifolium glanduliferum</td>
<td>Gland clover</td>
<td>Prima</td>
<td>91</td>
<td>3.5</td>
<td>3.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Trifolium hirtum</td>
<td>Rose clover</td>
<td>Hykon</td>
<td>98</td>
<td>4.5</td>
<td>2.9</td>
<td>0.9</td>
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<tr>
<td>Trifolium michelianum</td>
<td>Balansa clover</td>
<td>Paradana</td>
<td>112</td>
<td>5.9</td>
<td>3.5</td>
<td>4.9</td>
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<tr>
<td></td>
<td>Balansa clover</td>
<td>Frontier</td>
<td>93</td>
<td>7.1</td>
<td>5.5</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Balansa clover</td>
<td>Bolta</td>
<td>127</td>
<td>8.0</td>
<td>6.5</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>Sub. clover</td>
<td>Dalkeith</td>
<td>91</td>
<td>7.3</td>
<td>3.7</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Sub. clover</td>
<td>Nungarin</td>
<td>77</td>
<td>7.9</td>
<td>3.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Trifolium resupinatum</td>
<td>Persian clover</td>
<td>Nitro Plus</td>
<td>114</td>
<td>7.5</td>
<td>6.5</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>Persian clover</td>
<td>Prolific</td>
<td>113</td>
<td>7.5</td>
<td>8.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Least Significant Difference (p &lt; 0.05)</td>
<td></td>
<td></td>
<td></td>
<td>0.85</td>
<td>1.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**CONCLUSION**

- The level of aphid damage was highly correlated with aphid numbers. Notable exceptions were Hykon rose clover and both subterranean clover varieties which had low to moderate damage despite high aphid numbers.
- Aphid numbers and damage to plants was very low in all serradella varieties.
- Among the medics Herald, Toreador and Jester demonstrated high levels of aphid tolerance.
- Cyprus barrel medic was very susceptible to aphids and all burr medic varieties were moderately affected.
- Hykon rose clover had the highest level of tolerance of the Trifolium species. Balansa and Persian clovers were severely damaged.
- Some flowering dates are likely to be delayed by stress from aphids.
- High levels of aphid damage are likely to be reflected in lower seed production.

**KEY WORDS**

pasture, legume, aphids

**ACKNOWLEDGMENTS**

This research is funded through the National Annual Pasture Legume Improvement Program (NAPLIP) by GRDC and AWI. Thanks to the Chris Gillam and family for providing the trial site.

GRDC Project No.: UWA360
Paper reviewed by: Dr Clinton Revell
Selecting the right variety for phase pasture systems

Keith Devenish, Department of Agriculture, Jerramungup (formerly Northam)

KEY MESSAGE
- Matching pasture species to soil type is an important management decision.
- Cadiz\textsuperscript{(l)} serradella is a productive option for pasture phases of one or two years.
- Herald\textsuperscript{(l)} medic and Dalkeith sub. clover are productive options for two or three years of pasture.
- The hardseeded Casbah\textsuperscript{(l)} biserrula and Santorini\textsuperscript{(l)} yellow serradella can also maintain reasonable levels of production over three years.

BACKGROUND
Selecting the right pasture cultivar according to soil type and length of pasture phase is an important consideration for grain growers wanting to sow new legume pasture. The ‘phase pasture system’ is being broadly adopted by grain growers as a modification to the ‘ley pasture’ system but with less emphasis on livestock production and more on the cropping enterprise. Short term pasture phases (1-3 years) are used to break up long cropping sequences (3-8 years) to control troublesome weeds and to increase soil nitrogen and organic carbon levels.

The re-sowing of legume pasture after a cropping phase is essential and some of the newer pasture species need to be tested for their longevity in pasture phases of more than one year. Recently released cultivars such as Cadiz\textsuperscript{(l)} French serradella (\textit{Ornithopus sativus}), Charano\textsuperscript{(l)} and Santorini\textsuperscript{(l)} yellow serradella (\textit{Ornithopus compressus}), Casbah biserrula (\textit{Biserrula pelecinus}), Primav\textsuperscript{(l)} gland clover (\textit{Trifolium glanduliferum}) and Frontier\textsuperscript{(l)} balansa clover (\textit{Trifolium michelianum}) are all aerial seeded cultivars that need to be compared with traditional pasture species. Herald\textsuperscript{(l)} strand medic (\textit{Medicago littoralis}) is also relatively new to Western Australia and is softer seeded than most other medics currently in use.

AIM
The aim of this trial was to evaluate several new annual legume pasture cultivars for their performance in pasture phases of different lengths. The new pasture species were compared to traditional pasture cultivars of Dalkeith subterranean clover (\textit{Trifolium subterraneum}), Santiago burr medic (\textit{Medicago polymorpha}) and Paradana balansa clover (\textit{Trifolium michelianum}) in a one, two and three-year pasture phase.

METHODS
The site was situated on a property east of Buntine (average rainfall 330 mm) on a loamy sand over clay, soil pH 5.2 (CaCl\textsubscript{2}). Pasture cultivars (3 reps) were sown with a cone seeder on 17 June 1999 with 100 kg per hectare of SuperPhos (9 units P) fertiliser. Telstar\textsuperscript{®} was applied as a bare earth insecticide treatment to control red-legged earth mite. The average seedling density for each plot was measured each year (5 x 0.1 m\textsuperscript{2}) after the break of the season and total dry matter (DM) was measured before senescence in year two and three using visual assessments (5 x 0.1 m\textsuperscript{2}) calibrated by pasture cuts that were dried and weighed. The composition was visually estimated for each plot to calculate the legume dry matter component from total DM production. The plots were not grazed during the growing period but were grazed in common during summer.

RESULTS
All the pastures were established successfully in 1999 with most cultivars having in excess of 100 plants/m\textsuperscript{2} (Table 1). Dry matter production was not measured although Cadiz\textsuperscript{(l)} serradella clearly produced the most dry matter. In the second year (2000) there was a false break to the season following March rains. The two balansa cultivars had the second and third highest number of germinated seedlings but a considerable number failed to survive. The density of seedlings that were present in July was highest for Herald\textsuperscript{(l)} medic and Cadiz\textsuperscript{(l)} serradella (Table 1). Consequently these pastures also produced the greatest dry matter and had the highest legume composition. In the third year (2001), Dalkeith sub. clover, Casbah\textsuperscript{(l)} biserrula and Herald\textsuperscript{(l)} medic had the highest number of germinated seedlings (Table 1). However, Casbah\textsuperscript{(l)} and Herald\textsuperscript{(l)} were superior at senescence with nearly 2000 kg/ha dry matter and the highest proportion of legume. The next best performer was Santorini\textsuperscript{(l)} yellow serradella, followed by Dalkeith sub. clover.
Table 1. Sowing rate, seedling density, legume dry matter* and legume component for annual legume pastures grown for three years on a sandy loam at Buntine (Liebe group)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Species</th>
<th>Seed rate (kg/ha)</th>
<th>Plants (/m²) Year 1</th>
<th>Plants (/m²) Year 2</th>
<th>Plants (/m²) Year 3</th>
<th>Leg. DM (kg/ha)* Year 2</th>
<th>Leg. comp Year 2</th>
<th>Leg. DM (kg/ha)* Year 3</th>
<th>Leg. comp Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casbah</td>
<td>biserrula</td>
<td>8</td>
<td>117</td>
<td>238</td>
<td>900</td>
<td>2445</td>
<td>60%</td>
<td>1939</td>
<td>78%</td>
</tr>
<tr>
<td>Herald</td>
<td>strand medic</td>
<td>10</td>
<td>74</td>
<td>629</td>
<td>740</td>
<td>3783</td>
<td>92%</td>
<td>1734</td>
<td>74%</td>
</tr>
<tr>
<td>Cadiz</td>
<td>serradella</td>
<td>15</td>
<td>117</td>
<td>542</td>
<td>230</td>
<td>4167</td>
<td>92%</td>
<td>632</td>
<td>30%</td>
</tr>
<tr>
<td>Dalkeith</td>
<td>sub. clover</td>
<td>12</td>
<td>105</td>
<td>429</td>
<td>980</td>
<td>2857</td>
<td>90%</td>
<td>788</td>
<td>57%</td>
</tr>
<tr>
<td>Santorini</td>
<td>serradella</td>
<td>8</td>
<td>122</td>
<td>83</td>
<td>340</td>
<td>1442</td>
<td>43%</td>
<td>1057</td>
<td>46%</td>
</tr>
<tr>
<td>Santiago</td>
<td>burr medic</td>
<td>10</td>
<td>122</td>
<td>338</td>
<td>543</td>
<td>1957</td>
<td>67%</td>
<td>241</td>
<td>14%</td>
</tr>
<tr>
<td>Prima</td>
<td>gland clover</td>
<td>8</td>
<td>247</td>
<td>267</td>
<td>520</td>
<td>2118</td>
<td>57%</td>
<td>699</td>
<td>33%</td>
</tr>
<tr>
<td>Frontier</td>
<td>balansa</td>
<td>8</td>
<td>239</td>
<td>375</td>
<td>620</td>
<td>2839</td>
<td>73%</td>
<td>94</td>
<td>7%</td>
</tr>
<tr>
<td>Paradana</td>
<td>balansa</td>
<td>8</td>
<td>255</td>
<td>263</td>
<td>422</td>
<td>2294</td>
<td>67%</td>
<td>169</td>
<td>15%</td>
</tr>
</tbody>
</table>

* Mean legume dry matter was calculated by measuring total dry matter multiplied by the proportion of legume in each plot.

CONCLUSION

Soil type has a major influence on the productivity of pasture cultivars and this sandy soil may have limited the performance of Santiago medic and the shallow rooted species such as balansa clover and gland clover. The lack of grazing may also have disadvantaged some of the smaller seeded species, which are less competitive with weeds.

One-year pasture phase

Cadiz (serradella) appears to be one of the best pasture options to produce large amounts of legume dry matter (and associated nitrogen fixation) on sandy soils for one year of pasture. Other trial results also suggest that Cadiz performs well for one season on heavier soils where high seed yield is not required. Cadiz is tolerant of soil acidity and is usually not affected by pasture aphids.

Two-year pasture phase

Cadiz (serradella), Herald (medic) and Dalkeith sub. clover performed the best over two years of pasture. Herald (medic) strand medic is softer seeded than most other medics and the results from this and other trials suggest it is well suited to two years of pasture on appropriate soil types. Herald (medic) seed is readily available and it has very good aphid tolerance but requires the soil pH to be above 5.8 (CaCl₂), higher than at this site. Frontier (balansa) performed well in the first year but showed some sensitivity to the false break in year two and did not perform as well after that.

Three-year pasture phase

Casbah (biserrula) and Herald (medic) medic were the most productive in the third year of pasture. The hard seeded Santorini (yellow serradella) also maintained a reasonable level of production into the third year and Dalkeith sub. clover persisted well (considering there was no grazing).

Farmers might consider sowing a pasture mix for a two or three year pasture phase. This will be particularly important if hardseeded species such as biserrula and yellow serradella are used which tend to have low regeneration in the second year of pasture. The best choice of species will depend on soil type and seed cost.

ACKNOWLEDGMENTS

This research was funded by the Grains Research and Development Corporation. The assistance of Gary Halliwell and family who supplied the land for three years is greatly appreciated. This site was selected as part of the Liebe group’s activities.

KEY WORDS

pasture, serradella, biserrula, medic

GRDC Project No.: DAW 593

Paper reviewed by: Clinton Revell
Responses of alternative annual pasture and forage legumes to challenge with infectious subterranean clover mottle virus

John Fosu-Nyarko, Roger Jones, Lisa Smith, Mike Jones and Geoff Dwyer, State Agricultural Biotechnology Centre and Centre for Bioinformatics and Biological Computing, Murdoch University, Department of Agriculture, and Centre for Legumes in Mediterranean Agriculture

KEY MESSAGES

• For SCMoV, nine new host species of alternative annual pasture or forage legumes were found: biserrula (*Biserrula pelecinus*), cupped clover (*Trifolium cherleri*), helmet clover (*T. clypeatum*), eastern star clover (*T. dasyurum*), gland clover (*T. glanduliferum*), Morrocan clover (*T. isthmocarpum*), bladder clover (*T. spumosum*), arrowleaf clover (*T. vesiculosum*) and Trigonella (*Trigonella balansae*).

• The SCMoV host status of four other alternative annual pasture species, crimson clover (*T. incarnatum*), balansa clover (*T. michelianum*), purple clover (*T. purpureum*) and Persian clover (*T. resupinatum*) was confirmed.

• The most susceptible and severely damaged alternative pasture or forage legume hosts included Trigonella, and bladder, cupped, crimson, eastern star, helmet, Morrocan, and purple clovers.

• Non-hosts among alternative pasture or forage legumes included hairy canary clover (*Dorycnium hirsutum*), sulla (*Hedysarum coronarium*), pink serradella (*Ornithopus sativus*) and yellow serradella (*O. compressus*).

• The targeting of less vulnerable genotypes and species for sowing in pastures in highest risk zones for the virus is suggested.

• The need for ‘duty of care’ screening for vulnerability to the virus prior to release of new varieties is emphasised.

BACKGROUND

The most economically important virus infecting subterranean clover within pastures in Australia is subterranean clover mottle virus (SCMoV) which is transmitted by trampling and grazing of stock, on mower blades, on the wheels of vehicles and through seed. SCMoV was originally discovered in 1979 in plots of subterranean clover at Karridale in south-west Australia. Subsequently, infection was shown to be common in high rainfall pastures in Western Australia, Tasmania, South Australia, New South Wales and Victoria. It was also found naturally infecting some other cultivated annual clovers, and wild annual clovers, such as cluster clover. Diseased clover plants show obvious symptoms consisting of leaf mottling, leaf distortion, decreased leaf size and plant stunting. The incidence of infection often reaches high levels within old pastures. Infection decreases herbage and seed production, diminishing feed for stock and ability of pastures to regenerate annually from seed. The virus contributes to the decline of the subterranean clover component within pastures.

Although the reactions of subterranean clover and annual medics to infection with SCMoV are known, there is incomplete information on whether infection with SCMoV might pose a threat to the productivity of pastures sown with the alternative annual pasture and forage legumes currently under evaluation for their commercial potential or already being sown commercially.

METHODS

Genotypes of different species of alternative pasture and forage legumes were inoculated with infective sap in the glasshouse, and their reactions to infection with SCMoV recorded. Samples of inoculated and tip leaves of each species were tested for SCMoV presence by RT-PCR or ELISA assays.
RESULTS

Nine new host species of alternative pasture or forage legume species were found: biserrula cv. Casbah (*Biserrula pelecinus*), cupped clover cv. Lisare (*Trifolium cherleri*), helmet clover CFD13 (*T. clypeatum*), eastern star clover 24GC39 and 42BT (*T. dasyurum*), gland clover ATC87181-2 (*T. glanduliferum*), Morrocan clover MAR14.10.1 (*T. isthmocarpum*), bladder clover 87144 and 24BP (*T. spumosum*), arrowleaf clover cv. Seelu (*T. vesiculosum*) and Trigonella SA5054 (*Trigonella balansae*). Also, the host status of four other alternative annual pasture species, crimson clover cv. Caprera (*T. incarnatum*), balansa clover cv. Paradana (*T. michelianum*), purple clover 136780 (*T. purpureum*) and Persian clover cv. Persian Prolific (*T. resupinatum*), was confirmed. Apart from biserrula and gland clover, all of these 13 species became infected systemically developing obvious symptoms.

The most susceptible and severely damaged alternative pasture or forage legume hosts included Trigonella, and the following clovers: bladder, cupped, crimson, eastern star, helmet, Morrocan, and purple. The types of symptoms that developed commonly in infected plants were initial vein clearing followed by mottle, pallor, leaf deformation, reduction in leaf size and stunting. Unusual systemic symptoms not recorded previously included necrotic spotting and/or stem streaking in helmet and eastern star clovers, necrotic line patterns in Trigonella and tip leaf curling in bladder and Morrocan clovers. No infection was detected in inoculated or tip leaves of the following alternative pasture or forage species: hairy canary clover SA1111 (*Dorycnium hirsutum*), sulla cv. Grimaldi (*Hedysarum coronarium*), pink serradella cv. Cadiz (*O. sativus*) and yellow serradella cv. Santorini (*O. compressus*).

CONCLUSIONS

Information on the reactions of pasture and forage legume species to inoculation with SCMoV helps provide an indication of the likelihood that losses might occur on their release into pastures in regions of different relative risk for this virus. Regions of south-west Australia with pastures at greatest risk of damage from SCMoV are those within the high rainfall cropping areas VH3, VH4, VH5, H4 and H5. Obviously, the greatest likelihood of damage in such districts comes from sowing any genotype of pasture or forage species identified as having high levels of vulnerability to the virus, i.e. those that become infected readily, are invaded systemically and develop severe symptoms. Examples of vulnerable genotypes identified in this study are those tested of helmet, eastern star and Morrocan clovers and Trigonella. From the standpoint of SCMoV vulnerability, such genotypes are best targeted for lower risk regions while those most appropriate to sow in pastures in high SCMoV-risk regions are ones that do not become infected systemically, like the genotypes of biserrula and gland clover we tested or non-hosts like sulla or yellow serradella.

It is important for plant improvement programs to challenge advanced selections of alternative pasture and forage legumes with SCMoV prior to release of new varieties so that vulnerable genotypes can be identified. Such genotypes should be considered for culling or targeting for sowing in lower risk regions.

KEY WORDS

pasture, forage, legumes, disease, virus, SCMoV, losses, risk

ACKNOWLEDGMENTS

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REFERENCE


Paper reviewed by: Martin Barbetti
Nutrition in 2002: Decisions to be made as a result of last season

Bill Bowden, Western Australia Department of Agriculture, Northam

KEY MESSAGE

- Keep flexible in your fertilising strategies and get your advisers to give you the answers to the “what happens if …?” questions.
- Use the diagnostic power of windrow effects in crops - and make a mint.
- Nutrient budgeting has its place in determining fertiliser requirements, but you need to know the nutrient status/fertility of your paddocks so use soil tests or direct diagnostics.
- Potassium nutrition is now emerging as an issue which almost every farmer should be considering. Get soil tests done and monitor your different paddock situations regularly.

BACKGROUND

I was asked to give a talk on “Nutrition in 2002: Decisions to be made as a result of last season”. Last year I gave such a talk many times. It is a routine and boring talk where I look at the idiosyncrasies of the season (plus/minus summer rains, early/late break, with/without strong leaching rains, high/low production giving good/bad cash flow with the degrees of freedom to spend high/low amounts on fertiliser). The State enjoyed any of the above conditions (good season in the south east, poor in the north east, summer rain in the north and east but not in the south and west, six week drought after a mid May sowing through much of the central regions), so any general statement from me will be wrong for all but a few situations. This is the nature of average recommendations and packages across a whole range of agronomic management areas (and for that matter, most fields of human endeavour). In another context, it is known as ‘the tyranny of the mean’ - the average is used because it is easily understood, but most of the individual situations (particularly in biology and sociology) behave differently from the mean.

In recognising this truism, I have spent my career trying to develop (fertiliser recommendation and other) systems which allow individuals to make their own choices given the best information we can muster on variation with season, site and management. This means presenting options rather than recipes, dollar and yield response functions rather than prescribed rates. The approach means the decision maker/manager needs to know the answer to questions such as "what happens (to production, quality and dollars) if …?” he/she chooses or is forced to spend more or less on fertiliser, or “what happens if ….?” next year is a good or bad season?

So, go out and apply the existing methods of making nutrition decisions but make sure you do not rely solely on a recipe or package answers. Get estimates of nutritional status which take account of last season’s effects and which are tailored to your individual situation. Make sure you get answers in dollar and production terms of "what happens if ….?” you change the levels of input, placement, source etc and particularly "what happens if….?” 2002 is a good, bad or average season. If hard pressed, your fertiliser company advisers/agronomists and certainly your consultants, can get such answers for you.

DISCUSSION

Some observations from 2001 on nutrition and its implications for the 2002 season

Adapting your management is one of the best ways to capitalise on seasonal variation. When you have a good season growing large amounts of legume crops or pastures (e.g. 1999, most places in WA, 2001 in south coast - east) then you can obviously think about using less nitrogen fertiliser on your non-legume crops in the following year). Again, if you have significant summer rain (> 50 mm in an event, e.g. last three summers in the north and east) then you can expect extra nitrogen mineralisation and the need for less nitrogen fertiliser at seeding. However, you should try to retain flexibility in your nitrogen fertilising policy. If you get significant leaching rains (e.g. the 2nd Moora flood in at the end of May in 1999) you need reserves of dollars to buy and apply late nitrogen - particularly where your yield potential is high because of deep stored soil moisture from those leaching and/or summer rains. It can be well worth trying to increase your flexibility to change your nitrogen inputs, depending on how the season is proceeding. Last year, with early sown canola on an early break, yield potentials looked promising and we were predicting high nitrogen requirements. However in many regions, there was a 6-week drought after seeding, which made nonsense of earlier nitrogen recommendations (and caused a lot of early phosphorus deficiency). The policy of a small amount of nitrogen at seeding with the option to apply more in the next 6-8 weeks depending on the nature of the season has its attractions.
This year we will be releasing our latest-and-greatest nitrogen calculator, SYN (select your nitrogen). It is designed to let you put in the specifics of your situation (rotation, tillage, soil type, fertiliser preferences and timing) and it lets you see the impact of any real and/or imagined rainfall pattern on nitrogen availability, yield, quality and dollar returns from wheat, barley and canola.

**Nag! Nag! Windrows as a direct diagnostic of soil fertility problems**

Often in crops following burnt windrows, you observe yield variability with better growth on the windrows than off. We have been pushing the use of this effect for the diagnosis of nutritional and soil fertility problems for a few years now. It is far easier to diagnose a nutritional problem from the comparison of plant and soil analyses from paired, good and bad areas in a crop when you know that the variation is due to some simple management difference. The crop is a very good bioassay of its own problems. Traditional diagnostic methods, which compare individual samples from problem areas with nebulous, textbook critical levels (which vary with age and stage of the crop), are far more difficult to interpret. Add to this soil sampling problems and root pruning, and the direct paired sampling method of diagnosis becomes a winner.

In season 2001, most of the burnt windrow responses have revealed potassium deficiency as the major problem. Responses to the liming effect of burning the windrows have been seen in some circumstances. The effects are seen not only with crops following canola windrows, but also for crops following cereal and lupin windrows. We have now seen major responses in following crops of wheat, oats, barley, faba beans, lupins, peas and canola. Despite the late start to the season, we have seen responses to applications of potassium up to 8 weeks after seeding and we have seen major residual effects from potassium dressings applied across windrows last year. The correction of the problems, even in the year of the crop in which it was diagnosed, can return a small fortune. I have been harping on this point for 3 years because even at 100 km/hr I see big areas of WA crops performing well below their potential as indicated by the wave effect.

There are big and long term dollars to be made by correcting problems diagnosed in this way, so keep your eyes open for such effects in 2002 and capitalise on them; the remedies to some of the problems diagnosed in this way, have been very cost effective.

**Potassium nutrition and nutrient budgeting**

Potassium deficiency is the emerging giant for crop nutrition in WA. We have always known that our light soils are very low in K. Through continued crop removal and redistribution, K deficient crops can be found anywhere in WA. The predicted run down of soil K reserves has been exacerbated by more cropping, higher yields and in latter years, the expansion of the hay industry.

You can now get responses to K which match those for N and both nutrients cost similar amounts so the application of K is now very cost effective in responsive situations. On all but the gutless, low organic matter sands in high rainfall areas, potassium does not leach out of the root zone and has a relatively high residual value. So when in doubt about the adequacy of your soil K levels, bung some on if the bank balance allows it. Don’t worry about which phase of the rotation you put it on, just make sure you don’t put it too close to the seed as it (muriate of potash - KCl) is very soluble and will cause salt toxicity, particularly in drying seedbed conditions.

If we judge by the diagnostic windrow effect, the K status can vary quite markedly around a paddock, so stratified sampling and/or using observed windrow effects is the way to go.

Potassium status can have a marked effect on grain size, which correlates negatively with screenings and reflects post-anthesis water use efficiency and green leaf area duration. In some parts of the world, potassium is known as ‘the poor man’s irrigation’ and it seems to fulfill that role in WA.

In most circumstances in WA K does not leach (except low CEC, high rainfall sands) from the root zone and does not lose availability to soil chemical processes (because we rarely have ‘fixing’ clays). Apart from losses in products or erosion and to uneven redistribution through animals, it has a high residual value. This means that if the current crop does not benefit from an application, a future crop probably will. It is difficult to waste dollars on K except for the interest forgone while you wait for a paying response.

Potassium use in WA is one of the rare situations where replacing what you remove is a reasonable way of thinking about your fertiliser requirements. This is not necessarily the case for other nutrients which lose availability through time before a paying (responsive) crop can use them.

The nutrient budgeting approach to fertiliser policy has its place but usually can not be divorced from understanding the nutrient status of the soil and its ability to render fertiliser inputs less available through time.

**Paper reviewed by:** Doug Sawkins
Profitability of deep banding lime

Michael O’Connell, Chris Gazey and David Gartner, Department of Agriculture

KEY MESSAGES
• Trials results from 2001 demonstrate that lime can be successfully deep banded into acidic subsoil with immediate yield benefits. Subsoil pH was raised by as much as 0.3 pH units in the first season, with further increases anticipated in 2002. Such increases in pH would usually take 3-7 years to achieve with surface applied lime, and only then at heavy rates.
• Further field work is required to examine the long term implications of deep banding, to identify situations where it will be feasible, to highlight unforeseen side effects, and to examine alternative methods of getting lime into the subsoil. In the meantime, bio-economic modelling highlights some future opportunities for deep banding of lime.
• Based on preliminary bio-economic modelling, the following criteria are suggested for profitable use of this technology: selection of soil types known to have aluminium toxicity at low pH AND subsoil pH below 4.2 to 4.5 AND a rotation that includes high value acid sensitive crops such as barley and canola. The deep banding operation is a costly procedure, and the benefits are unlikely to cover costs if these criteria are not met. For growers who regularly deep rip and were intending to rip an acidic paddock anyway, the marginal cost of including lime is going to be a lot less, thereby making the technology financially feasible over a wider set of circumstances.

BACKGROUND
The most common method of managing soil acidity is by applying lime to the soil surface using a fertiliser spreader, usually followed by some incorporation into the top 5-10 cm at seeding. This method offers a rapid and cost effective means of ameliorating acidity in the topsoil.

Dealing with subsoil acidity is more problematic, particularly below 15 cm. This is because initial applications of surface applied lime are mostly consumed in the topsoil. The small amount that does leach into the subsoil offers only slow and incomplete amelioration of subsoil acidity. Using a high rate of lime (over 2.5 t/ha) can improve the amount of lime leaching (Whitten et al. 2000). However this technique carries the risk of inducing nutrient deficiencies in the topsoil and is less profitable than covering a wider area at say 1 to 1.5 t/ha lime. High rates of lime are therefore not recommended for general use in broadacre agriculture.

In response to this issue, research is underway that aims to develop methods for deep banding of lime into acid subsoil. Such technology would offer the dual benefit of removing any physical hardpans caused by compaction and removing the chemical ‘hardpan’ that subsoil acidity creates. In this paper we present results from the first year of field trials and use a bio-economic model to further explore the opportunities for deep banding technology.

METHODS

Field trials
Four field trials were established in 2001 at Kalannie, Perenjori, Wongan Hills and Bodallin. Lime was deep banded using a modified deep ripper capable of delivering up to 1 t/ha of lime to depth. The trials were designed so that the effects of ripping and liming could be isolated. Treatments used were:
• Control
• Rip to 15 cm
• Rip to 15 cm + 1 t/ha lime
• Rip to 15 cm, then rip again to 25 cm (Perenjori and Bodallin only)
• Rip to 15 cm + 1 t/ha lime, then rip to 25 cm + 1 t/ha lime (Perenjori and Bodallin only).

Bio-economic modelling - Optlime
In the absence of sufficient trial data, modelling can provide valuable insights into the likely impacts of deep banded lime on pH, yields and profitability. We used the Optlime bio-economic model for this
purpose. Optlime is a model that simulates the effect, over time, of applying lime to acid soils. It is computer based and operates within Microsoft® Excel. The model can be used to explore a wide range of issues, both biological and economic.

RESULTS

Field trials

There was a trend in all trials for an increase in subsoil pH of 0.2 to 0.3 pH units following deep banding of lime. Actual pH values varied widely within trials due to the fact that deep banding places the lime in rows. As a result the differences in pH between limed and unlimed treatments were not statistically significant, and more intensive sampling procedures are likely to be needed to allow adequate description of the effects. Alternatively, the crop performance can be used as a bioassay to indicate the impact of the treatments. Not withstanding these limitations we believe this to be an excellent result considering that with surface applied lime it would usually take 3-7 years for such increases in average subsoil pH to occur, and only then with a heavy rate of lime. Furthermore, it is likely that some of the lime deep banded in 2001 remains undissolved and further increases in pH should occur during 2002.

All trials also showed a trend for increasing yields with ripping and liming (Table 1). For example, in the 2 t/ha treatments deep ripping and lime each contributed about 100 kg/ha at Perenjori and 200 kg/ha at Bodallin.

Table 1. Grain yields (t/ha) from deep banding trials in 2001

<table>
<thead>
<tr>
<th></th>
<th>Kalannie Barley</th>
<th>Perenjori Wheat</th>
<th>Wongan Hills Canola</th>
<th>Bodallin Wheat</th>
</tr>
</thead>
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<tr>
<td>Control</td>
<td>1.83</td>
<td>1.21</td>
<td>0.90</td>
<td>2.63</td>
</tr>
<tr>
<td>Rip to 15 cm</td>
<td>2.12</td>
<td>1.29</td>
<td>1.03</td>
<td>2.75</td>
</tr>
<tr>
<td>Rip to 15 cm +1 t/ha lime</td>
<td>1.92</td>
<td>1.28</td>
<td>1.08</td>
<td>2.56</td>
</tr>
<tr>
<td>Rip to 15 cm; rip again to 25 cm</td>
<td></td>
<td>1.34</td>
<td></td>
<td>2.86</td>
</tr>
<tr>
<td>Rip to 15 cm +1 t/ha lime; rip to 25 cm +1 t/ha lime</td>
<td>1.44</td>
<td></td>
<td></td>
<td>3.04</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>0.22</td>
<td>0.10</td>
<td>0.06</td>
<td>0.19</td>
</tr>
</tbody>
</table>

While this trend is encouraging, it must be noted that the effect of lime on grain yields was only statistically significant in the 2 t/ha treatment at the Perenjori trial. Therefore, further trial observations are required before recommendations can be made with a high degree of confidence. In the meantime bio-economic modelling can be used to provide valuable insights into important questions that remain unanswered:

- What are the long term benefits of deep banding lime?
- How much does the deep banding operation cost?
- Under what circumstances are the benefits of deep banding likely to sufficiently cover the costs?
- How does deep banding compare to surface application? When is deep banding likely to be the preferred option?

Bio-economic modelling - Optlime

Based on modelling results, we would expect deep banding of lime to provide not only faster, but also more complete amelioration of subsoil acidity than surface application. This is expected to be the case even where high rates (e.g. 2.5 t/ha) are applied to the soil surface. This concept of faster and more complete amelioration is demonstrated in Figure 1.

The soil pH profiles in Figure 1 are outputs from the Optlime model where different liming treatments have been entered. Five years after application, surface applied lime has had only a modest impact on subsoil pH, and yield losses are still likely to be occurring. By contrast, the deep banded lime has increased pH down the profile, and will have largely corrected the subsoil acidity. As a consequence we would expect large and ongoing yield benefits, particularly where acid sensitive crops are included in the rotation. The actual size of the yield benefits from deep banding will vary depending on factors such as pH, aluminium toxicity of the soil and acid sensitivity of the crop. However, in general we would expect yield increases in the order of 5 to 30%.
While these benefits are encouraging, they must be balanced against the costs of deep banding. Not surprisingly, the costs associated with deep banding are considerably higher than for surface application of lime. In our analyses, we work on operating costs of about $40/ha for deep banding, not including the cost of buying lime. By contrast we would usually allow $5 to $15/ha for surface application. In addition, the deep banding operation inflicts considerable wear and tear on machinery and, at least in principle, will reduce the re-sale value of items used, especially the tractor. We have allowed about $25/ha for extra depreciation over and above that which would occur with normal use.

As a result of these costs deep banding is only expected to be profitable under specific situations. In many cases it will be more cost effective to use a limited lime budget to surface apply lime over a large area rather than deep band over a small area. Based on preliminary modelling results we suggest the following requirements will apply for deep banding to be profitable:

- Selection of soil types known to have high levels of aluminium toxicity at low pH.
- AND subsoil pH below 4.2-4.5.
- AND a rotation that includes high value acid sensitive crops such as barley and canola.

If any one of these criteria are lacking then deep banding is expected to be less profitable than surface application of lime, and could even lose money. An exception to this may be where a farmer was planning to deep rip a paddock anyway. In this situation the marginal cost of including lime will be a lot less, and the deep banding technology will have wider application.

It must be emphasised that these are preliminary findings, and further research is required to identify situations where deep banding of lime will be profitable. Further research is also required to investigate other methods of getting lime into the subsoil. For example high rates of lime applied to the soil surface in bands should increase lime leaching into the subsoil, without necessarily inducing nutrient deficiencies in the topsoil. This approach, along with other untried methods for ameliorating subsoil acidity, warrant further investigation.

ACKNOWLEDGMENTS
The authors gratefully acknowledge Sandy Pate for technical assistance; Norrish Service Group for the generous loan of machinery; and Ian Stanley, Tony Mason, and Joel Kent for generously providing the trial sites on their farms.

REFERENCES

KEYWORDS
Lime, soil acidity, deep banding, bio-economic modelling

GRDC Project No.: GRDC Project UWA259
Paper reviewed by: David Pannell
Lime efficiency percentage … the new measure of lime effectiveness for Western Australia

Amanda Miller, Department of Agriculture, Lake Grace

KEY MESSAGE

- The use of Agricultural Lime in Western Australia has increased five-fold over the last five years.
- A new lime quality standard has been introduced called Efficiency Percentage (EP) (formally known as Effective Neutralising Value (ENV)).
- EP is the Neutralising Value (NV) of each of five particle size ranges for each product, plus the ability of the product to change soil pH.
- Twenty-nine lime deposits representing 80 per cent of the volume of the Agricultural Lime market have been tested for EP. Each pit participating in the Code of Practice now has its own efficiency profile. Consumers will be able to easily assess lime quality and this is a significant step forward for the industry.
- From the 2001/02 season, the Agricultural Lime Industry Code of Practice Product Information sheets will show the EP. This information will allow advisors and growers instant assessment and comparison between product types.

BACKGROUND

Agricultural lime use in Western Australia has increased by a staggering 495,851 tonnes between 1994/95 and 1998/99. Given that very few farmers are liming areas for a second time, this means that almost 2.1 million hectares of acid soils have been treated since 1994/95.

During this time, lime quality has been the single most important issue that has arisen. Growers have been consistently frustrated with the wide use of jargon in the lime industry and an apparent lack of consistent reporting of lime quality.

The Australian Fertiliser Services Association recognised this issue, and worked with the Agricultural Lime Industry to develop a Code of Practice. The primary focus of this Code was to devise new lime quality standards.

NEW LIME QUALITY TESTING PROCEDURE

A knowledge of the testing procedure will increase understanding and adoption of the new EP measure. The procedure used for lime quality testing is outlined below.

1. Initial sampling and analysis

Once pits are registered with the Agricultural Lime Industry under the Code of Practice, an independent person takes samples at individual pits.

The following analysis will be conducted on the initial sample:

- % Calcium (Ca dissolved by 1M HCl)
- % Magnesium (Mg dissolved by 1M HCl)
- % Sodium (Na dissolved by 1M HCl)
- % Moisture (as received at the laboratory)
- % Moisture (maximum, i.e. to field capacity)
- % Moisture (minimum, i.e. air dry under standard conditions)
% Neutralising value  (overall sample)
Particle size distribution  5 fractions, % by weight
1000 plus  microns
500-1000  microns
250-500  microns
125-250  microns
125 minus  microns
Each of the above fractions are analysed for:
  % Neutralising value
  Efficiency percentage (formally known as Effective Neutralising Value (ENV))

2.  EFFICIENCY PERCENTAGE
Efficiency Percentage is a method that has been devised to capture the relative effectiveness of different sieve fractions for an individual lime when tested in soil. The process is as follows:

  a)  Standard soil preparation
A sandy loam subsoil, relatively low in organic matter, of pH 4.2 to 4.5 will be used as the standard soil. The test does not require sterilised soil.

  b)  Weigh out standard soils
For each test fraction (five particle size fractions per lime sample) a 1 kg bag of dry standard soil is placed into a plastic bag.

  c)  Add lime fraction to the soil and mix
For each test fraction the equivalent of an application rate of 2 t/ha is added to the standard soil. The bags are shaken to distribute the lime throughout the soil.

  d)  Controls
Triplicate positive controls (equivalent of 2 t/ha of analytical grade calcium carbonate powder and negative controls (no lime added) are included with each batch of limes being tested.

  e)  Test containers
The plastic bags of mixed soils are placed into 100 mm diameter * 150 mm depth containers.

  f)  Field capacity
Determine the volume of distilled water required to achieve field capacity, i.e. wet top 1/3 and allow draw down to 2/3, the bottom 1/3 is to remain dry. The containers are not sealed and the surface area of the soil must be allowed to go through ‘wetting and drying cycles’.

  g)  Storage
All test containers are to be stored and maintained as one unit under identical conditions. While controlled temperature and humidity are not essential, extremes must be avoided. The preferable temperature range is 15-20°C. Care must be taken to eliminate any margin/boundary effects that could bias results.

  h)  Wetting and drying cycles
Monitor moisture levels on a weekly basis. When the soil is approximately 50 per cent dry, add distilled water to restore soil moisture to field capacity. All limes/fractions under the test are to be wet at the same time. Continue wetting and drying cycles for the duration of the test period.

  i)  pH test schedule
Soil pH is to be determined for each sample (including controls) at 2, 4, 8, 16, 32 and 52 weeks.

  j)  Sampling for pH tests
Core samples are to be taken with a 5 mm cork borer from the surface of each soil to a depth of 10 mm. Five cores are to be taken and are to be pooled and dried. pH will be determined to two decimal places in a 1:5 water to calcium chloride (0.01M CaCl₂) ratio.

RESULTS
Lime samples were collected from each of 29 lime pits (sources) and categorised according to mineral (dolomite, limestone, limesand or other). These 29 pits represent 80 per cent of lime supplied by the Agricultural Lime Industry.

Each pit now has its own lime quality profile including the new quality measure Efficiency Percentage.
The agricultural lime industry has traditionally described the different products using NV of the whole sample. This has created difficulty for growers who would like to make comparisons between products. The problem has been that a product with high NV can have poor efficiency in changing the pH of the soil if its particle size distribution is too large.

The determination of EP that takes into account the NV of five particle size ranges as well as the products ability to change soil pH is a significant step forward in assessing and describing lime quality.

From the 2001/02 season, the Agricultural Lime Industry Code of Practice Product Information sheets will show the EP. This information will allow an instant assessment and comparison between product and the relative value of using each one.

**IMPACT FOR 2001/2002 LIMING SEASON**

The impact of using EP is being trialed by the industry this season.

**Note:** EP will read lower than Neutralising Value (NV) because it combines product fineness and product mineralogy. EP is a laboratory measure for comparison between products.

EP (formally known as Effective Neutralising Value (ENV) should be used in the following way:

\[
\text{Cost of product delivered and spread} \times 100 \div \text{Efficiency Percentage} = \text{Lime Efficiency per tonne}
\]

\[
\text{i.e. } \$45/\text{tonne (delivered and spread)} \times 100 \div 70\% \text{ EP} = \$64/\text{tonne of Lime Efficiency}
\]

Growers should aim to minimise the cost per tonne of Lime Efficiency to achieve the maximum value for each dollar spent.

For a list of Agricultural Lime suppliers who are participating in the Code of Practice refer to the 2002 Farm Budget Guide page 16.

**GRDC Project No.:** NHT 983206  
**Paper reviewed by:** Chris Gazey and Barb Clews and Associates
Boron - should we be worried about it

Richard W. Bell\textsuperscript{A}, K. Frost\textsuperscript{A}, Mike Wong\textsuperscript{B} and Ross Brennan\textsuperscript{C}

\textsuperscript{A}School of Environmental Science, Murdoch University, Murdoch WA 6150
\textsuperscript{B}CSIRO Land and Water, PO Box 5, Wembley WA 6913
\textsuperscript{C}Department of Agriculture Western Australia, Albany WA 6330

KEY MESSAGE
Soil B levels are marginal in sandy, acid soils in West Australia, especially those developed on sandstones of the Dandaragan plateau.

In pots, B deficiency decreased seed yield of canola and lupin in sandy acid soils from the west Moora-Dandaragan area.

Low B levels in seeds of lupin and canola harvested from low B soils decreased seed viability and vigour.

Foliar B increased canola seed yields in simple on-farm trials in 1998 in the Great Southern Region, but in 14 field trials carried out in 2000 and 2001, no positive responses to soil or foliar B application were found.

No general recommendations for B fertiliser application seem warranted at this stage but soil and plant analysis should guide its use on a case-by-case basis for the time being.

Care needs to be taken not to overuse B as toxicity was induced in lupin and canola on sandy soils on the Yuna sandplains with only 5-10 kg borax/ha

AIMS
• Determine the spatial distribution of B deficiency in canola and lupin; these crops are more sensitive to B deficiency than cereals.
• Investigate the role of B in soil and plants for grain yield of canola and lupin; and
• Develop management options for B to take account of soil properties and crop requirements.

METHODS
Young leaves of canola and lupin crops and soil (0-10;10-30 cm) were sampled for B analysis at over 150 sites in the wheatbelt, predominantly on sandy soils in 1998. Surface horizons of 73 Reference Soils of SW Australia were analysed for hot CaCl\textsubscript{2} extractable B, and these values were correlated with soil properties (pH, clay, sand) reported by McArthur (1991). From the above Reference Soils, 14 (including sub-soils of 4 soils) were selected for a pot experiment with canola and lupins (8 soils only) as test crops. Plants were grown in pots with and without added B, and harvested at maturity for seed yield. On farm trials were carried out in 1998 using foliar B applications. In 2000 and 2001 cropping seasons, 14 field trials tested soil and foliar B fertiliser applications.

RESULTS
Levels of B in young leaves of canola and lupin crops in 1998 and in soil samples suggested that 10-20\% of sites were potentially B deficient. Although predominantly sandy soils were selected, these sites were widely distributed throughout the wheatbelt.

In Reference Soils of southwest Australia, extractable soil B was positively correlated with clay content and pH, negatively with sand content but not with organic matter levels. This suggests that low clay content (< 10\%) and low pH (< 5 in CaCl\textsubscript{2}) are useful predictors of low soil B status.

Boron fertiliser increased growth and seed set in canola on four low B soils from the northern sandplains (Table 1). These soils are acid sandy soils and were formed on sandstone rather than granitic parent rocks. In lupins, B increased pod set only on the MRA 5 soil from east of Dandaragan. In lupin, seed viability was about as sensitive to low soil B as seed yield. Decreases in seed viability can be expected when seed B is < 12 mg/kg, and especially at < 6 mg/kg. The symptoms of B deficiency observed on pods may be a useful field guide to the probability of harvesting lupin seed which is low enough in B to impair seed viability. In canola, seed yield was more sensitive to low soil B than in lupin. However, at marginal B levels in the soil, seed harvested may have decreased germination and vigour. The critical seed B levels for viability and vigour of canola could not be defined with the data available.
In the 2000 field experiments, no seed yield increases from B fertiliser application were recorded in either lupin or canola. However, canola yields were very low at Corrigin and Yuna due to low growing season rainfall. Yields of lupin were reasonable at Yuna due to early sowing and Moora, but there was no positive effect of adding B fertiliser. In 2001, canola yields were higher but still no positive responses to foliar or soil applied B fertiliser were found. Indeed at three sites, adding 5 or 10 kg borax/ha at sowing depressed seed yield, mostly by decreasing plant density.

Table 1. Properties of soils on which B application increased growth or seed set in canola in pots

<table>
<thead>
<tr>
<th>Soil code</th>
<th>Soil type</th>
<th>pH (CaCl₂)</th>
<th>Sand (%)</th>
<th>Clay (%)</th>
<th>Soil B (mg/kg)</th>
<th>Parent material</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTN 05</td>
<td>Siliceous sand Uc 5.11</td>
<td>5.1</td>
<td>90</td>
<td>7</td>
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<td>sandstone</td>
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<tr>
<td>MRA 05</td>
<td>Siliceous sand Uc 4.21</td>
<td>4.5</td>
<td>99</td>
<td>1</td>
<td>0.1</td>
<td>sandstone</td>
</tr>
<tr>
<td>MRA 08</td>
<td>Yellow duplex Dy 4.51</td>
<td>4.6</td>
<td>98</td>
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</tr>
<tr>
<td>MRA 09</td>
<td>Siliceous sand Uc 5.11</td>
<td>5.2</td>
<td>92</td>
<td>6</td>
<td>0.2</td>
<td>sandstone</td>
</tr>
</tbody>
</table>

Table 2. Yield, soil B (0-10 cm) and leaf B concentrations (at budding) in canola and lupin crops with B fertiliser (B 0) and significant B responses to B fertiliser in field experiments in 2000 and 2001. *B tox indicates that yield was depressed by B toxicity at 5-10 kg borax/ha

<table>
<thead>
<tr>
<th>Soil code</th>
<th>B 0 yield (t/ha)</th>
<th>B response</th>
<th>Soil B (mg/kg)</th>
<th>Leaf B (mg/kg)</th>
<th>B 0 yield (t/ha)</th>
<th>B response</th>
<th>Soil B (mg/kg)</th>
<th>Leaf B (mg/kg)</th>
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</thead>
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<tr>
<td>Canola 2000</td>
<td>Lupin 2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Yuna</td>
<td>0.77</td>
<td>ns</td>
<td>0.5</td>
<td>25</td>
<td>Yuna</td>
<td>2.15</td>
<td>*B tox</td>
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<td>ns</td>
<td>0.7</td>
<td>27</td>
<td>Dandaragan</td>
<td>1.89</td>
<td>ns</td>
<td>0.4</td>
</tr>
<tr>
<td>Canola 2001</td>
<td>Lupin 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Moora</td>
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<td>ns</td>
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<td></td>
<td>Yuna</td>
<td>0.98</td>
<td>*B tox</td>
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<td>Yuna</td>
<td>1.36</td>
<td>*B tox</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSIONS

Our results confirm that the risk of B deficiency cannot be discounted but field evidence suggests it is not severe in any of the areas studied. The areas most at risk have sandy, acid soils and occur on the sandplains of the Dandaragan Plateau, stretching from West Midlands to the Eruadu sandplains.

No general recommendations for the use of B fertiliser on lupin and canola are warranted at this stage. However, farmers should remain vigilant for B deficiency symptoms especially on sensitive crops (canola, lucerne, chickpea); request soil and plant tests for B if concerned about B deficiency risk; and act on this information plus the advice of their local agronomist.

Soil or foliar B applications can be used to treat B deficiency. Foliar application is rapid acting but the correct timing of the application is important. Solutions of 1% (w/v) solubor (containing 21% B) are commonly used. Soil applications generally last longer although B may be leached from acid sandy soils and this may reduce the effectiveness of B fertiliser. Rates of B application should be < 5 kg of borax/ha on sandy soils to prevent the risk of B toxicity.

KEY WORDS
boron, deficiency, sandy acid soils, seed set, seed viability, soil analysis, toxicity

REFERENCES

GRDC Project No.: UMU69 Meeting the boron needs of legumes and canola in WA
Impact of claying and other amelioration on paddock profit

N.J. Blake¹, G. McConnell², D. Patabendige¹ and N. Venn¹
¹Western Australian Department of Agriculture
²PlanFarm P/L

INTRODUCTION

The objective of this research is to enable better decisions on where to ‘Invest, vary or cull’ (i.e. invest in amelioration or merely vary inputs on poor performing areas or cull poor performing areas from crop rotation).

Hypothesis

Research from the 2001 season has substantiated the hypothesis that amelioration lifts farm profits when: 1) site-specific agronomy is applied with the amelioration; and 2) zone management is applied to the paddock (refer to survey results and group research results).

Survey results

A key conclusion from the 1999/2000 survey of 28 grower groups was that most poor performing paddocks had wide ranging spatial variability. This variability had to be managed because expenditure on ameliorative treatments would not/could not be made until methods were developed for ensuring consistent returns from investing in amelioration (e.g. zone management).

RESEARCH SITES


RESULTS

The results up to season 2001 were reported in the 2001 Crop Updates. Results in 2001 at Wongan, Corrigin, Casuarinas (SW Mullewa) and Brookton reinforce the original hypothesis. The 2001 results from Brookton (Kweda) Trial # 00 AD 77 are presented below in Table 1.

Lake Mears TopCrop Research Group results

Property - Kim Wilkinson-Kweda (East Brookton). The focus for this group is the amelioration of water repellency and the resulting impact on productivity, grass weed seed banks and herbicide resistance (see systems implications below).

Table 1. Treatment of non-wetting sands incl. claying as ameliorative treatment by paddock zone.

<table>
<thead>
<tr>
<th>Trial # 00AD77 ZONE</th>
<th>Controls average</th>
<th>Clayed at 100 t/ha</th>
<th>Clayed at 200 t/ha</th>
<th>Quality range</th>
<th>RGM# $/s/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low incorp.</td>
<td>Hi incorp.</td>
<td>Low incorp.</td>
<td>Hi incorp.</td>
</tr>
<tr>
<td>1. Medium sandy Duplex</td>
<td>2081**</td>
<td>2575**</td>
<td>3016**</td>
<td>2649**</td>
<td>3095**</td>
</tr>
<tr>
<td>2. Coarse sandy Duplex</td>
<td>1692**</td>
<td>2182**</td>
<td>3009**</td>
<td>2069**</td>
<td>2850**</td>
</tr>
<tr>
<td>Mean yield</td>
<td>1.89 t/ha</td>
<td>2.38 t/ha</td>
<td>3.01 t/ha</td>
<td>2.36 t/ha</td>
<td>2.97 t/ha</td>
</tr>
</tbody>
</table>

LSD 247 kg/ha

# Note that the rotational gross margins are for two years only. The lupin phase is to be in year 2002. There was a significant grain quality response to the claying treatments. Screenings in the barley were > 7% and protein > 11% for untreated areas while most samples in treated areas were < 6% screenings and within the protein window. Refer to table 2 for impact of treatments on crop establishment.

These Central wheatbelt results on claying as an ameliorative treatment are consistent with the comprehensive results obtained by Dr D. Carter and R. Hetherington for the South Coast in the GRDC project ‘Claying for profit’ (DAW 596 WR).
### Table 2. Impact of treatments on establishment of crop plants and control of grass weeds (00 AD 77)

<table>
<thead>
<tr>
<th>Treat no.</th>
<th>Management of non-wetting soils trial with Lake Mears group</th>
<th>Establishment-plants/m²</th>
<th>Background ryegrass and bromegrass counts/sq. m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yr 2000</td>
<td>Yr 2001</td>
</tr>
<tr>
<td>1 A &amp; B</td>
<td>Control</td>
<td>126</td>
<td>36.7**</td>
</tr>
<tr>
<td>2 A</td>
<td>Clay 100 t/ha high incorporation</td>
<td>136</td>
<td>115.5</td>
</tr>
<tr>
<td>2 B</td>
<td>Clay 100 t/ha min. incorporation</td>
<td>134</td>
<td>109.1</td>
</tr>
<tr>
<td>3 A</td>
<td>Clay 200 t/ha high incorporation</td>
<td>139</td>
<td>100.7</td>
</tr>
<tr>
<td>3 B</td>
<td>Clay 200 t/ha min. incorporation</td>
<td>124</td>
<td>94.6</td>
</tr>
<tr>
<td>4 A</td>
<td>Furrow sow with wetter (yr 2000 only)</td>
<td>122</td>
<td>32.3**</td>
</tr>
<tr>
<td>4 B</td>
<td>Furrow sow without wetter (yr 2000)</td>
<td>111</td>
<td>37.9**</td>
</tr>
</tbody>
</table>

** NB: The 2001 controls (Treatments 1 and 4) had delayed and staggered germinations with lowered plant vigor.

### MAJOR CONCLUSIONS AND OUTPUTS

- The lower rate of claying (100 tonne per hectare rate with high incorporation) is achieving the primary gain. The 2001 results by W. Crabtree (WANTFA) in the CWB are also consistent with this conclusion and different to previous results from the WANTFA trials. In the Department of Agriculture trial, the claying treatment had average crop establishment densities of 112 plants/sq.m compared with the controls with 37 plants/sq.m and grass weed control was significantly higher.

- Claying treatments had significantly lower** background weed populations (Zone 1 - ryegrass and Zone 2 - bromegrass) and weed seed banks are trending down compared to untreated areas (see Table 2). Pre-harvest weed seed estimations reinforced this conclusion.

- The Rotation Gross Margins for the different zones substantiate the hypothesis that using zone management when investing in ameliorative treatments increases reliability of returns (i.e. RGM by zone). For example in the broadscale trial above the course sandy duplex had the best $ return on investment in amelioration. Amelioration responses are seasonally dependent and seasons 2000 and 2001 were particularly difficult starts. To assess the average impact on the rotational gross margins the responses will be modelled to provide a more comprehensive tool for decision making.

- The financial analysis tool IVC ('Invest, vary or cull') developed in this project by Graeme McConnell will be further evaluated at the forthcoming ‘Better Soils’ workshops and will be launched at the 2003 Crop Updates.

### Systems implications

The results from the project studies have significant implications for future systems. From the extract of project results provided above, the systems implications on weed management strategies, that the ameliorative treatment provides (claying in this case) have far reaching sustainability benefits. Water repellency areas (untreated) provide foci of high weed seed banks with staggered germinations that then necessitate increased use of post emergent selectives. This initiates the spread of resistance in a rather significant parallel to the way non-wetting provides wind erosional foci. By contrast, in the treated areas the weed seed banks have a significant trend downward both in the trials and with grower observation on test strips. Interactions between the ameliorative investments and the agronomic options are very significant and will be used with the groups to develop better management practices at the forthcoming ‘Better Soils’ workshops.

### Linkages

Through collaboration with specialised research projects there has been substantiation that ameliorative options are delivering significant results. These include the soil acidity group research (Gazey et al.), Raised beds (Hamilton), Claying (Carter, Hetherington, Department of Agriculture and Crabtree, WANTFA), Renovation Cropping (Hoyle and Hamza), Nutrient balances (Bowden, CSIRO and CSBP Wong, Cook, Adams - CSO 205 and CSO 194) and Tramlining for removing soil compaction (Blackwell). The on-farm testing project (Russell - DAW599), S. Cook (CGIAR), PlanFarm research and the FAST program (Clark, van Rees et al. - Victoria, NSW and SA) have also contributed.

### ACKNOWLEDGMENTS

GRDC, PlanFarm P/L, CBH (quality testing), Jane Speijers (Biometrics), Growers managing trials: Peter Sadler, Kim Wilkinson, Ivan Lee, Tony Mason and David Forrester.

**GRDC Project No.:** DAW 633 WR: ‘Future management of poor performing paddocks’

**Paper reviewed by:** Dr Dan Carter
Raised bed farming in the 2001 growing season

Derk Bakker, Greg Hamilton, Dave Houlbrooke and Cliff Spann, Department of Agriculture

KEY FINDINGS

Due to the dry conditions at the beginning of the growing season waterlogging was not a problem at any of the sites. The yield from the control improved compared to previous seasons and the benefits of the raised beds reduced. Furthermore crop establishment problems on the beds contributed to the lack of benefits.

INTRODUCTION

Over four years (1997-2000) it has been demonstrated that raised beds eliminate the incidence of waterlogging, increase the run-off and improve yields. Those years were characterised by average or above average rainfall during June, July and August. The 2001 growing season which had a very dry start and was the last year of a five year project funded by the Department of Agriculture and the GRDC is discussed in this paper. More details on our work are in the paper available on the CD.

METHODS

Nine sites were sown between the middle of May and June and all had been included in the raised bed cropping program previously. Prior to seeding several sites were completely renovated (Mt Barker Research Station (MBRS), Esperance Downs Research Station (EDRS), Beverley, and Toolibin) whilst other were partly renovated (Badgebup (BP), Cranbrook and South Stirling (ST)). Woodanilling had been partly renovated in 2000. The bed renovations were carried out with the bed former in renovation mode that consisted of two ripper shanks equipped with subsoiling blades in each bed. Seeding was done with a triple disc seeder. In the control plots the inter-row spacing was 25 cm and was changed to about 19 cm on the beds to accommodate 7 plant rows on each bed. The crop grown on the various sites varied from site to site depending on the place in the crop rotation. During the season dry matter and other parameters were measured.

RESULTS

Weather

Following an average to dry start to the season at most sites, the conditions became extremely dry. At all sites, except EDRS the lowest rainfall on record in June and July (until about 28/07) was recorded. The conditions at the end of July, August and September became ‘wetter’ than average at most sites. The early dry conditions resulted in very little incidences of waterlogging in the control plots.

Agronomy

The sandy or clayey nature of the top soils at Quairading, Beverley and Toolibin (particularly the latter) delayed germination whilst the crop grown on the more loamy areas germinated well and made some progress even during the very dry period.

Problems were experienced this year with seeding of the beds that affected the crop establishment and therefore final yield. The seeder bar had limitations to cater for 7 rows on the beds and often the rows on the shoulders of the beds were seeded too shallow. Stubble pinning, excessive soil cover caused by soil throw from the rear seeder units and poor ability of the seeder units to accommodate for irregular bed profiles also led to irregular plant establishment on the beds. Some sites were more affected by these problems than others.

The effect of establishment problems is reflected in the dry matter production in late August and presented in Table 1 as is the crop type and final yield. The yield at MBRS had not yet been determined at the time of writing this paper.
Table 1. Location, crop and effect of establishment problem on dry matter (% difference compared to control) and grain yield

<table>
<thead>
<tr>
<th>Location</th>
<th>Crop</th>
<th>Dry matter %</th>
<th>Yield (t/ha)</th>
<th></th>
<th></th>
<th>% Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Raised beds</td>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quairading</td>
<td>Barley</td>
<td>-1</td>
<td>0.66</td>
<td>0.90</td>
<td>-27</td>
<td></td>
</tr>
<tr>
<td>Beverley</td>
<td>Wheat</td>
<td>-9</td>
<td>1.60</td>
<td>1.77</td>
<td>-9</td>
<td></td>
</tr>
<tr>
<td>Toolibin</td>
<td>Barley</td>
<td>-29</td>
<td>1.75</td>
<td>1.78</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Woodanilling</td>
<td>Wheat</td>
<td>-17</td>
<td>2.05</td>
<td>2.37</td>
<td>-14</td>
<td></td>
</tr>
<tr>
<td>Cranbrook</td>
<td>Wheat</td>
<td>-20</td>
<td>2.81</td>
<td>3.14</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td>Peas</td>
<td>-34</td>
<td>2.20</td>
<td>2.44</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>Wheat</td>
<td>-51</td>
<td>3.10</td>
<td>4.20</td>
<td>-24</td>
<td></td>
</tr>
<tr>
<td>EDRS</td>
<td>Wheat</td>
<td>-5</td>
<td>3.48</td>
<td>3.66</td>
<td>-5</td>
<td></td>
</tr>
</tbody>
</table>

1: Poor establishment on the shoulders; 2: Excessive soil cover; 3: Staggered germination due to soil type; 4: Stubble pinning; 5: Salt accumulation on shoulders.

In previous years the productivity increase on the raised beds was normally detected during the first dry matter cut because severe waterlogging during the winter months affected the crop growing in the control. The gains made on the beds under those conditions were more than adequate to compensate for the loss in cropped area of the furrows. However adequate rainfall after a period of moisture stress and the lack of waterlogged conditions created good growing conditions in the control areas. In addition detrimental crop establishment problem on the beds resulted in a lower dry matter production on the beds at all sites. These dry matter differences are also reflected in the yield at all sites.

Interestingly, despite the crop establishment problems the wheat yields from the raised beds in the 2001 growing season are comparable to yields at the same site in previous growing seasons on comparable rainfall. The lack of waterlogged conditions however increased the production from the control considerably compared to the previous seasons. This increase reduced the benefit of the raised beds.

GRDC Project No.: DAW 500

Paper reviewed by: Wal Anderson

There is an extended version of this paper on the 2002 Crop Updates CD.
Economics of tramline farming systems

Paul Blackwell and Bindi Webb, Department of Agriculture, and Stuart McAlpine, Liebe Group.

KEY MESSAGE

Some growers are concerned that Tramline farming, or Controlled Traffic is too expensive and difficult to do. Growers who have begun to use marker arms or electronic guidance this season have found the operations less difficult than anticipated. Interpretation of gross margin benefits from trial work also helps to show that the equipment can be easier to afford than some may think.

METHODS

The estimated increase of yield is shown in the table below, based on current trial results and calculations. In Table 1 the trial estimations are reduced by 50% to conservatively estimate what a cropping operation can achieve, due to less precision than in the trial work. Use of electronic autosteering, instead of mechanical guidance will increase the estimated yield benefit.

Table 1. Actual and estimated improvements to wheat yield from different degrees of Tramline farming. This is the first year of a wheat crop on sand, after deep ripping

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Trial estimated increase %</th>
<th>Conservative on-farm effect %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No matching tracks</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Matching tracks, only mechanical guidance</td>
<td>7</td>
<td>3.5 (50% of trial results)</td>
</tr>
<tr>
<td>Matching tracks, with electronic guidance for all operations</td>
<td>7</td>
<td>5 (closer to trial results due to more precision in driving)</td>
</tr>
</tbody>
</table>

In addition, when a tramline controller is used to allow more seeding of tramlines not used for spraying or spreading, an extra 0.5% yield increase is estimated for extra yield in the tramlines. Further improvements to yield benefit come from later seasons as the soil between the tramlines is compacted less and can improve some of it’s structure. The upper limit to date in WA trials is about 14%. Response of barley and canola looks similar to wheat, but effects on lupins seem less.

The reduced costs come from less overlap. When operating round and round, an estimate of 5% less input is reasonable based on trials and farmer experience. When the paddock is seeded up and back, without corner sowing, farm experience shows that a 10% reduction of inputs is reasonable. These estimates are not changed for the analysis, because they are mainly based on on-farm assessments. Costs of the different equipment are shown in Table 2.

Table 2. Approximate costs of different equipment used for tramline farming; matching of seeder, sprayer and spreader is assumed

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost ($)</th>
<th>With 7% discount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker arm</td>
<td>2,500</td>
<td>2,675</td>
</tr>
<tr>
<td>Tramline controller</td>
<td>5,000</td>
<td>5,350</td>
</tr>
<tr>
<td>dGPS autosteer and 2 steering kits</td>
<td>65,000</td>
<td>69,550</td>
</tr>
</tbody>
</table>

RESULTS

Four different cases are considered, ranging from a low cost investment in one marker arm an retaining a round and round pattern, to the most expensive option of dGPS autosteering and a tramline controller. As little as 500 ha of wheat crop grown with Tramline farming will pay for the cost of one marker arm ($2,675) to work round and round and leave fuzzy tramlines. For more investment in electronic guidance, the results are shown in Figure 1. The other cases are explained in the full Update paper and on the Liebe Group website. The calculator spreadsheet is available from the website.
Figure 1. Estimated gross returns by area for dGPS autosteer and 2 steering kits with different levels of yield benefit, according to the closeness of matching track width.

On the graph the lines are for different % yield increases, according to table 1 and a 5% input reduction for one marker arm round and round, while 10% reduction for the others. It is easy to compare the costs in Table 2 with the benefits according to the area cropped and the degree of precision available.

It would be difficult to pay for this equipment in one year from only overlap savings. At least about 3000 ha of sandplain cropping would be needed to pay off the cost when there is good track matching and the full benefit of autosteer is used for seeding and spraying. Individual farm estimates can be made using a spreadsheet we have available. Further details and results of on-farm use of fuzzy tramlines are explained in the extended paper on the CD.

CONCLUSIONS

- As little as 500 ha of wheat crop grown with Tramline farming will pay for the cost of one marker arm ($2,500) to work round and round and leave fuzzy tramlines. This can be any soil type.
- On sandplain soil responsive to deep ripping, Tramline farming on 3000 ha of crop will pay for the costs of electronic guidance (dGPS autosteer and 2 steering kits) worth $69,550; if the wheeltracks are well matched.
- These results assume that the seeder and sprayer already match 2 or 3 to 1, yields are 2 t/ha, on-farm price for wheat is $150/t and cost are $60/ha for fertiliser and $40/ha for herbicides.

KEY WORDS

tramline farming, controlled traffic, yield, costs, benefits, adoption

GRDC Project No.: DAW 718
Paper reviewed by: Richard Olive

There is an extended version of this paper on the 2002 Crop Updates CD.
RELAY PLANTING from TRAMLINES to increase water use and productivity of summer crops

Dr Paul Blackwell, Department of Agriculture, Geraldton District Office
Neil and Kim Diamond, Buntine. Liebe Group

KEY MESSAGE

Relay planting summer crops proved successful in a lupin crop at Buntine. The system offers about 10 weeks earlier summer crop seeding, little yield penalty to the winter crop and better water use and productivity of the summer crop. The Relay Planting system is likely to be most successful in those parts of the landscape that remain wetter longer such as the mid and lower slopes and hollows.

BACKGROUND

Tramline farming offers the opportunity to do innovative new farming methods between rows of crop. Relay planting is one such method. Relay Planting allows cropping operations ‘to keep the water use moving’, because a summer crop is planted into a winter crop while the winter crop is maturing and water use is declining. Thus the summer crop ‘takes over the baton of water use’ from the winter crop before the winter crop is harvested. To take the analogy further, our current winter crop use ‘drops the baton’ by stopping using water between maturity and harvest! Another way to look at it is that the overlapping of growing seasons in relay planting is like the overlapping of running by two members of a relay team. Anyway, enough of sport! The main attraction of the method is to take advantage of soil conditions which are wet and warm enough for summer crop establishment, even though the winter crop is unharvested; and especially if the winter crop has finished water use (e.g. after leaf drop of lupins). The mature lupins then act as a ‘hedge’ to reduce further soil drying while the summer crop establishes. In this way the summer crop can be established well before normal methods of seeding summer crops after winter crop harvest. Under ideal conditions we should expect no yield penalty for the lupins with occasional rows 500 to 600 mm apart (to accommodate the possible shield spraying and summer crop planting): there may even be a yield benefit in a dry season.

METHODS

This trial tested three varieties of maize (3527, 3153/3257 and 3335) at two different planting depths (20 mm and 40 mm) relay planted between rows of lupins which were seeded in a tramline setup which matched the airseeder, spray boom and summer crop planter. The seeding was successful in early October, about 10 weeks before the lupins were harvested.

<table>
<thead>
<tr>
<th>Lupins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot size and replication</td>
</tr>
<tr>
<td>Soil type</td>
</tr>
<tr>
<td>Sowing date and seeding rate</td>
</tr>
<tr>
<td>Conditions at sowing</td>
</tr>
<tr>
<td>Machinery</td>
</tr>
<tr>
<td>Fertiliser</td>
</tr>
<tr>
<td>Herbicides and Insecticides</td>
</tr>
<tr>
<td>Paddock history</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot size and replication</td>
</tr>
<tr>
<td>Sowing date and Seeding rate</td>
</tr>
<tr>
<td>Conditions at sowing</td>
</tr>
<tr>
<td>Machinery</td>
</tr>
</tbody>
</table>
RESULTS

Figure 1. Graph showing seeding depth (mm), leaf number, height (cm) and dry weight (g/plant*100) of three varieties of maize measured on November 6. The LSD is shown as a vertical bar.

CONCLUSIONS

All varieties of maize were short enough to fit under a well controlled cutter bar harvesting the lowest pods of the lupins. The shallow sown variety had less leaves, was shorter and had produced less dry matter on 6 November than any of the deeper sown varieties. Relay planting summer crops can be successful in a lupin crop at Buntine. This offers about 10 weeks earlier summer crop seeding, little penalty to the winter crop and better water use and productivity of the summer crop.

KEY WORDS

relay planting, lupins, summer crop, tramlines

ACKNOWLEDGMENTS

This demonstration was conducted in collaboration with an AFFA (Agriculture, Forestry, Fisheries Australia) funded project ‘Controlling salinity by the introduction of new cropping systems mid-slope’ run by the Diamonds.

GRDC Project No.: DAW 718
Paper reviewed by: Andrew Blake
Evidence-based zone management of paddock variability to improve profits and environmental outcomes

M.T.F. Wong\textsuperscript{A}, D. Patabendige\textsuperscript{B}, G. Lyle\textsuperscript{A} and K. Wittwer\textsuperscript{A}
\textsuperscript{A}CSIRO Land and Water, PO Box 5, Wembley WA 6913
\textsuperscript{B}Department of Agriculture Western Australia, Northam WA 6401

KEY MESSAGE

- Yield mapping for more than five years in WA shows large spatial variability with grain yield ranging typically from 0.4 to 4.0 t/ha within the paddock.
- The historical data show that some areas of the paddock perform consistently poorly and lower the overall financial performance of the paddock.
- In order to improve profits and environmental benefits, the poor performing areas should be either: (1) ameliorated where economically feasible; or (2) re-assigned to a more suitable land use.
- Weight of evidence modelling uses spatial data derived from paddock/farm information. These include yield and soil property maps, remote and proximal sensed data, on-farm response experiments and expert knowledge to determine zones in the paddock that: (1) perform well, (2) can be ameliorated economically; and (3) should be considered for reassignment for an alternative land use.
- The amount of data collected for each paddock by yield mapping and from other spatial information sources is huge and potentially confusing. A new tool developed by CSIRO Land and Water (as part of CSO 213) allows the cataloguing and management of this data in a logical manner.

AIMS

- Improve the financial and environmental efficiency of farm operations by zone farming to ensure that inputs are not used uniformly and indiscriminately over the paddock irrespective of site-specific land capability.
- To develop a tool to manage the huge amount of spatial data the precision agriculture generates.

METHODS

The case study is based on a 70 ha paddock in Three Springs using a 3-year wheat-lupin-wheat rotation. Soil was sampled and analysed. Maps of potassium, organic carbon content and nitrate release were made using Inverse Distance Weighting interpolation in ArcView. In addition, an NDVI image for mid-August 2000 and a soil type map for the paddock were also attained. A potash and nitrogen trial was also set up in 2000 in order to determine the current year and residual fertiliser response.

In order to manage and document the data, an automated data management tool has been developed which categorises the data into the logical hierarchical structure of farm, paddock, year and operation. The tool then processes the spatial data into a useable and manageable form at either a farm or paddock level within a GIS environment.

The weight of evidence model used: 1) a map of historical performance zones based on the normalisation of the three years of yield maps by gross margin analysis; 2) soil property and soil type maps; 3) remotely sensed imagery; 4) land degradation hazards; and 5) fertiliser response. These factors were all included to form a cartographic model that identified poor performing paddock zones that: (1) can be improved in a profitable manner; or (2) can be assigned to alternative perennial vegetation to increase water use. The ambiguity introduced by temporal and spatial variability was represented by converting the spatial data into fuzzy sets that define the degree of association to a particular class.
RESULTS

The fertiliser trial showed that wheat and lupins responded to potassium fertilisers and less to nitrogen. The potassium response was marked in zones of low soil potassium test values. These zones coincided with areas of deep pale sand where crop yield was consistently poor (less than 0.8 t/ha). The poor crops resulted in high response in percentage terms but in poor response in absolute terms. The gross margin maps allow historical performance zones to be identified (Figure 1).

Figure 1. Historical performance zones derived from weighted linear combination of fuzzy sets of gross margins analysis for 1998-00 for an average risk strategy.

The dark areas have a greater degree of unsuitability for cropping.

Decision for land use change is an important long-term consideration since this commits part of the paddock for decades in an alternative land use. This decision should therefore be soundly based with evidence from as many independent sources as possible and should use the best available knowledge and experience. Our model allowed these sources of evidence and knowledge to be evaluated mathematically. The output is shown in Figure 2.

Figure 2. Land use zones based on evidence provided by maps of gross margin analysis, soil properties, nvdi, fertiliser response and expert knowledge.

The green areas represent a greater degree of suitability for cropping.

CONCLUSIONS

The application of the data management tool provided a logical and convenient way to organise large historical data sets available for this analysis.

The broad similarity between Figures 1 and 2 is due to the consistency of all the layers of evidence in this particular case study. The application of fertilisers improved yield in the poor performing areas but not to a level that was economically viable. However, other inputs such as claying could and the economic and environmental benefits for this approach compared to changes in land use should be assessed.

GRDC Project Nos: CSO 205 and CSO 213
How much soil water is lost over summer in sandy soils?
Perry Dolling¹, Senthold Asseng², Ian Fillery², Phil Ward² and Michael Robertson³
¹University of Western Australia/Department of Agriculture Western Australia/CSIRO
²CSIRO Plant Industry ³CSIRO Sustainable Ecosystems, Indooroopilly, Queensland

KEY MESSAGE
- Soil water measurements on sandy surface soils over the non-growing season (summer/autumn) indicated only 25% of the rainfall during this period and water left in the profile at harvest was retained in the soil profile at the end of the non-growing season. Most of the retained water is below 30 cm.
- Most of the water lost over the non-growing season was due to evaporation from the soil surface, although in some cases transpiration from weeds, water draining below the root zone and run-off can also contribute to the water loss.
- A long-term simulation at Wongan Hills using the Agricultural Production Systems Simulator (APSIM) indicated that the median plant available water at the end of the non-growing season was 22 mm. However, the soil only required another 49 mm before the soil reached field capacity and the subsequent commencement of drainage during the growing season.

BACKGROUND
In a paper published in last years Crop Update we showed that in the Western Australian environment the key factor influencing drainage below the root zone is how dry the soil is before winter. The drier the soil is at the start of the growing season the lower the drainage below the root zone. However, limited analysis has been made of how much water is lost over the non-growing season in sandy soils. We know that many rainfall events are light (< 10 mm) over this period and soil evaporation can be significant. Increasing our understanding of water loss over the non-growing season will allow us to more accurately predict crop yields, drainage below the root zone and assist in developing solutions to the problem of salinity.

The work will also allow us to test the performance of the APSIM computer model over this period and make improvements if required. The soil water balance aspect of APSIM has been well tested within the growing season, but validation of the model during the non-growing season has been less extensive.

METHODS
Daily soil water contents at different depths in the rooting zone were obtained for six non-growing seasons at Moora, three seasons at Wongan Hills and four seasons at Katanning. The soils were deep sand at the first two sites and a duplex soil at Katanning (loamy sand over clay at 45 cm). The sites were either in a cereal lupin rotation or pasture cereal rotation. Crop residues varied from three to six tonnes/ha at the start of the non-growing season. The non-growing season started from harvest (end of November/early December) until the break of the season, which was generally early May. The results were then analysed to determine how much rainfall occurred, how much water was lost, and where in the profile the water was stored at the end of the non-growing season.

The APSIM computer model developed by Agricultural Production Systems Research Unit Queensland was calibrated to improve its prediction of the soil water content over the non-growing season (not shown). Based on this calibration a long-term simulation (1900-2001) was conducted at Wongan Hills with the soil water being reset to no plant available water on 1 December of each year. From the simulation the following data was selected: the measured average rainfall during the non-growing season (1 December-30 April the following year), the soil water content at the end of the non-growing season and the average drainage below the root zone during the non-growing season. No plants were grown during the simulation although plant residues were reset each year at five tonnes/ha on the 1 December of each year.

RESULTS
The observed data indicated that the loss of soil water over the non-growing season was closely related to the rainfall during the non-growing season (average 94 mm) and the available soil water (average 16 mm) at the start of the non-growing season ($r^2 = 0.97$). Of the total input (rain + soil water at the start of the period) 75% was lost from the soil and 25% was retained (Table 1). Most of the water at the end of the non-growing season was stored below 30 cm especially in the more coarse textured soils (Table 1).
Table 1. Measured rainfall over the non-growing season, measured plant available soil water (PAW) at the start and end of the non-growing season for Moora (0-150 cm), Wongan Hills (0-140 cm) and Katanning (0-100 cm)

<table>
<thead>
<tr>
<th>Site</th>
<th>Season</th>
<th>Rain (mm)</th>
<th>PAW start (mm)</th>
<th>Water lost (mm)</th>
<th>PAW end (mm)</th>
<th>PAW end below 30 cm (%)^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moora</td>
<td>1995/96</td>
<td>62</td>
<td>36</td>
<td>76</td>
<td>22</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>1996/97</td>
<td>112</td>
<td>28</td>
<td>93</td>
<td>47</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>1997/98</td>
<td>37</td>
<td>20</td>
<td>43</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>1998/99</td>
<td>129</td>
<td>3</td>
<td>90</td>
<td>42</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>1999/00</td>
<td>131</td>
<td>40</td>
<td>144</td>
<td>27</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>2000/01</td>
<td>24</td>
<td>5</td>
<td>26</td>
<td>3</td>
<td>90</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>83</strong></td>
<td><strong>22</strong></td>
<td><strong>79</strong></td>
<td><strong>26</strong></td>
<td><strong>80</strong></td>
</tr>
<tr>
<td>Wongan Hills</td>
<td>1998/99</td>
<td>161</td>
<td>5</td>
<td>124</td>
<td>42</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>1999/00</td>
<td>229</td>
<td>13</td>
<td>180</td>
<td>62</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>2000/01</td>
<td>34</td>
<td>11</td>
<td>35</td>
<td>10</td>
<td>62</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>141</strong></td>
<td><strong>10</strong></td>
<td><strong>113</strong></td>
<td><strong>38</strong></td>
<td><strong>72</strong></td>
</tr>
<tr>
<td>Katanning</td>
<td>1995/96</td>
<td>51</td>
<td>9</td>
<td>39</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>1996/97</td>
<td>61</td>
<td>6</td>
<td>53</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>1997/98</td>
<td>136</td>
<td>10</td>
<td>105</td>
<td>29</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>1998/99</td>
<td>57</td>
<td>17</td>
<td>51</td>
<td>30</td>
<td>64</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>76</strong></td>
<td><strong>10</strong></td>
<td><strong>63</strong></td>
<td><strong>23</strong></td>
<td><strong>61</strong></td>
</tr>
</tbody>
</table>

^a Soil water as a percentage of the total PAW. Total potential PAW was 70 mm at Moora, 71 mm at Wongan Hills and 54 mm at Katanning.

At Wongan Hills, the simulated median available soil water at the end of the non-growing season (30 April each year) was 22 mm (50% probability, Figure 1) based on 101 seasons, representing 31% of the total potential plant available water. This is lower than the measured average values presented in Table 1 because in 1999/00 the rainfall over the non-growing season was the second highest in 101 seasons and in 1998/99 it was the sixth highest. The non-growing season measured median rainfall at Wongan Hills was 63 mm (380 mm for the year), based on 101 seasons. Simulated drainage below 140 cm during the non-growing season occurred in 20% of years (Figure 1).

![Cumulative probabilities](image)

**Figure 1.** Cumulative probabilities (1900-2001) over the non-growing season for measured rainfall, for simulated plant available soil water (PAW) at the end of the period and simulated drainage below 140 cm at Wongan Hills over the period. For example, PAW end at 50% probability was 22 mm, in one half of all the years the value was higher than 22 mm and the other half the value was lower than 22 mm.

**CONCLUSIONS**

In sandy surface soils the measured data indicated that most of the inputs of water during the non-growing season is lost before the start of the growing season. Both observations and modelling have shown losses are due mainly to soil evaporation, although in some cases transpiration from weeds, water draining below the root zone and run-off can also contribute to the water loss.

The long-term simulation at Wongan Hills indicated that the amount of water at the end of the non-growing season in most years is low (22 mm). Because the maximum (or potential) plant available water is also low (71 mm) the soil profile only requires another 49 mm before it reaches field capacity. Once field capacity is reached drainage will commence during the growing season.

Perry Dolling is supported by a GRDC postgraduate scholarship. We would like to thank Agricultural Production Systems Research Unit Queensland for technical support with the simulation model.

**Paper reviewed by:** Imma Farré (CSIRO Plant Industry)
Economic comparisons of farming systems for the medium rainfall northern sandplain. No. 1
Caroline Peek and David Rogers, Department of Agriculture

KEY MESSAGES
- Wheat area needs to be maintained at as high a level as possible.
- Production and production efficiency need to be continually improved to offset declining terms of trade. The higher the cost of an enterprise the more important this becomes.
- Pasture and livestock options are potential economic alternatives.
- Land dropped out of cropping to combat herbicide resistance needs to return an income.

AIMS
The major wheat/lupin based cropping system is currently under threat. The lack of diversity in this system has resulted in the following problems:
- Ryegrass and radish are developing resistance to current herbicide chemistry.
- Vulnerability to disease and markets.
- Reliance on a single crop legume - lupins to drive the system.

The aim of this work is to do an economic evaluation of alternatives to the current system. Pasture based alternatives were chosen because of the interest in the farming community stimulated by:
- the need for integrated weed management;
- the development of more suitable pasture legumes for the sandplain system;
- introduction of sheep that do not require management associated with wool producing sheep;
- current improved livestock commodity prices.

METHOD
A model is being developed that has the ability to look at different farming systems over time. Using the current wheat/lupin system as the starting point we moved the farm business over a ten year period to several different systems. These systems were then compared as fully established systems.

The farm is a sandplain farm of 3,500 ha of which 3,100 ha are croppable and 400 ha are not. The high level of cropping is resulting in a high risk of herbicide resistance developing. The farming systems we chose to evaluate were:

1. Benchmark system of wheat, lupin and some canola, pre herbicide resistance (wl). Wheat area is 1550 ha. Total crop 3100 ha (89% cropping). Merino sheep grazed on the 400 ha at 3DSE.

2. A suggested system to combat herbicide resistance and maintain a high level of cropping. Two years of a Cadiz serradella pasture followed by 3 years of crop (ppw). Wheat area 1240 ha. Total crop 1860 ha (53% cropping).

We used the Cadiz pasture phase in this system in several different ways:
- Dorper sheep run as a prime lamb enterprise.
- Merino sheep run as a self-replacing wool enterprise.
- No livestock on the property. The pasture phase was used as brown manure. Wheat yields were either held at the average or increased by 16% following the pasture phase. There was also a reduction in nitrogen and herbicide use in the wheat after the pasture phase.

3. An improved permanent pasture system rotated with wheat and stocked with dorpers (ppw). Wheat area is 934 ha. Total crop is 1034 ha (30% cropping).

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Crop yields were based on the average taken from a recent Planfarm survey. Wheat yields 2.15 t/ha, lupin yields 1.63 t/ha, and canola yields 1 t/ha. Yields increased at 1.5% per year to simulate better varieties and management with time. Stocking rates on Cadiz and improved permanent pasture were 6 DSE. The uncroppable 400 ha pasture was unimproved and carried 3DSE. Costs associated with the farming enterprise were based on averages. Machinery value and debt were varied with the scale of the cropping enterprise. Long term average prices were used of $4.50/kg greasy wool spring shorn, $30 net per prime lamb and cash prices $190/t wheat, $180/t lupins and $290/t canola. Merino lambing rates were set at 95% and Dorper at 120%.

To simulate terms of trade all costs were increased at 3.5% pa and all returns increased by 2% pa.

RESULTS

The following tables highlight the results of comparing the fully established systems.

Table 1. Comparisons of the start and end farm operating surplus and the resulting cumulative financial position of the farm after 10 years. Operating surplus includes variable and fixed costs and is not discounted in year 2011

<table>
<thead>
<tr>
<th>Farming system</th>
<th>Operating surplus $/ha 2001</th>
<th>Operating surplus $/ha 2011</th>
<th>Cumulative financial position of farm after 10 years $</th>
</tr>
</thead>
<tbody>
<tr>
<td>wl benchmark system</td>
<td>90</td>
<td>142</td>
<td>2,135,283</td>
</tr>
<tr>
<td>ppwl Dorper sheep</td>
<td>60</td>
<td>88</td>
<td>1,040,180</td>
</tr>
<tr>
<td>ppwl merino sheep</td>
<td>61</td>
<td>86</td>
<td>956,673</td>
</tr>
<tr>
<td>ppwl no stock yield boost in wheat</td>
<td>48</td>
<td>80</td>
<td>748,392</td>
</tr>
<tr>
<td>ppwl no stock average yield wheat</td>
<td>38</td>
<td>66</td>
<td>261,549</td>
</tr>
<tr>
<td>ppw Dorper sheep</td>
<td>48</td>
<td>61</td>
<td>564,678</td>
</tr>
</tbody>
</table>

The benchmark wheat/lupin farming system is the most lucrative, but is becoming unsustainable. The best ppwlw system falls short of the benchmark system. This changes where farms are achieving lower lupin yields or are able to achieve better livestock figures. These results are discussed in the companion paper ‘Sensitivity analysis of farming systems for the medium rainfall northern sandplain’. Where the pasture phase is not utilised in the ppwlw system, the crop yields have to be increased and costs reduced to compensate for the losses in the pasture phase. A yield boost of 16% in wheat following Cadiz was used in this example but this is not as good as the grazing option. This system may work for farmers that are able to continually achieve higher crop yields than average. The ppw system lacks the area of wheat to allow it to compete with the higher cropping options.

Table 2. Cropping and livestock gross margins (includes only variable costs)

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Crop gross margins $/ha</th>
<th>Livestock gross margins $/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1</td>
<td>Year 10</td>
</tr>
<tr>
<td>wl benchmark system</td>
<td>156</td>
<td>224</td>
</tr>
<tr>
<td>ppwlw Dorper sheep</td>
<td>170</td>
<td>244</td>
</tr>
<tr>
<td>ppwlw merino sheep</td>
<td>170</td>
<td>244</td>
</tr>
<tr>
<td>ppwlw no stock yield boost in wheat</td>
<td>193</td>
<td>277</td>
</tr>
<tr>
<td>ppwlw no stock average yield wheat</td>
<td>175</td>
<td>251</td>
</tr>
<tr>
<td>ppw Dorper sheep</td>
<td>197</td>
<td>282</td>
</tr>
</tbody>
</table>

The cropping gross margins increase with decreasing lupin areas. The crop gross margins increase over the ten-year period because the 1.5% increase in yield is offsetting the increasing costs of production. If these yield increases are not achieved the gross margins slip backwards. An increase in production has not been assigned to the sheep enterprise (because of the above average stocking rates used and lack of information for the northern sandplain) and the gross margins decrease over
time. This is more noticeable in the merino enterprise where the costs are higher. Where the Cadiz pasture is not grazed the losses are quite substantial and need to be offset by better yields in the crop enterprise if farmers are not interested in livestock. The livestock gross margins are highest in the ppw rotation because the pasture does not have to be established each year as with the Cadiz pasture in the ppwlw system.

CONCLUSION
The transitional budget model used in this paper is currently being developed as a decision aid so that the farming community can better assess their options and understand some of the factors that have a major influence on changing these systems and making them pay.

The model encompasses whole farm economics and will allow individuals to use their own figures. The three papers written in this booklet cover some of the different uses for this model when making decisions about change.

KEY WORDS
farming system, established systems, economics, model

ACKNOWLEDGMENTS
Department of Agriculture Economist Alan Herbert for transforming the idea into spreadsheets and modeller Anne Bennett for continuing development.

Department of Agriculture Projects: SHQ, SMO
NHT Project No.: 963001
Paper reviewed by: Mike Clarke and Ciara Stockdale
Sensitivity analysis of farming systems for the medium rainfall northern sandplain. No. 2

Caroline Peek and David Rogers, Department of Agriculture

KEY MESSAGES
- When planning to enter into a new enterprise it is important to know what production benchmarks you have to achieve to succeed financially.
- Changes in production and price have large impacts on the cumulative profitability of the enterprise.

AIMS
- To introduce sensitivity analysis into the comparisons of farming systems from the companion paper (‘Economic comparisons of farming systems for the medium rainfall northern sandplain’).
- To produce theoretical benchmarks for consideration by farmers and researchers. Actual benchmarks that relate to the production capabilities of new breeds of livestock and new pasture varieties on the northern sandplain are not available yet.
- To discover what needs to be achieved by the pasture/livestock phase in a system to compete with the benchmark wl system.

METHOD
The work was done using the transitional budgeting model that is currently being developed. Using the example of the ppwlw Dorper sheep system discussed in the companion paper, a sensitivity analysis of lambing percentages, carrying capacities and product values was carried out.

Lupin yields are often more variable than wheat yields in the benchmark (wl) system. A sensitivity analysis was conducted to look at the effects of lupin yield on the cumulative financial position of the benchmark system.

By varying the production of the two legume phases more comparisons could then be made between the two systems.

RESULTS
The cumulative position for the benchmark wl system was $2,135,283 (1.63 t/ha lupin yield see companion paper). The assumptions in the companion paper for the ppwlw Dorper sheep enterprise were 6 dse/winter grazed ha, 120% lambing and $30 net per lamb. These capabilities achieved a position of $1,040180, about 50% of the wl rotation.

Table 1 shows that the higher the lambing percentage, carrying capacity and lamb price the better the returns. Table 2 shows the effect that lower lupin yields can have on the cumulative position of the farm. Wheat needs a legume to perform on the sandplain. The lower the return from lupins in the benchmark system the better that a well managed pasture option will compete. Wheat yield has been held constant at 2.15 t/ha increasing at 1.5% pa.

Table 1. Showing the resulting cumulative position of the farm after 10 years with a range of lamb prices, lambing percentages and carrying capacities for the ppwlw Dorper sheep enterprise

<table>
<thead>
<tr>
<th>Average lambing %/year</th>
<th>Carrying capacity in DSE</th>
<th>10 year average lamb sale value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$25</td>
<td>$30</td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$168,119</td>
<td>$401,366</td>
</tr>
<tr>
<td>6</td>
<td>$405,415</td>
<td>$675,876</td>
</tr>
<tr>
<td>120%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$438,753</td>
<td>$687,471</td>
</tr>
<tr>
<td>6</td>
<td>$749,553</td>
<td>$1,040,180</td>
</tr>
<tr>
<td>140%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$679,911</td>
<td>$937,885</td>
</tr>
<tr>
<td>6</td>
<td>$1,016,496</td>
<td>$1,360,701</td>
</tr>
<tr>
<td>160%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$890,939</td>
<td>$1,182,332</td>
</tr>
<tr>
<td>6</td>
<td>$1,302,466</td>
<td>$1,704,172</td>
</tr>
</tbody>
</table>
Table 2. The sensitivity of the wil system cumulative position to changes in lupin yield

<table>
<thead>
<tr>
<th>Lupin yield in t/ha</th>
<th>10 year cumulative position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.93</td>
<td>$2,752,929</td>
</tr>
<tr>
<td>1.83</td>
<td>$2,547,047</td>
</tr>
<tr>
<td>1.73</td>
<td>$2,341,165</td>
</tr>
<tr>
<td><strong>Average 1.63</strong></td>
<td><strong>$2,135,283</strong></td>
</tr>
<tr>
<td>1.53</td>
<td>$1,929,401</td>
</tr>
<tr>
<td>1.43</td>
<td>$1,723,519</td>
</tr>
<tr>
<td>1.33</td>
<td>$1,517,636</td>
</tr>
<tr>
<td>1.23</td>
<td>$1,311,754</td>
</tr>
<tr>
<td>1.13</td>
<td>$1,105,872</td>
</tr>
<tr>
<td>1.03</td>
<td>$899,990</td>
</tr>
</tbody>
</table>

This is only a theoretical financial representation and it is up to researchers and farmers to answer questions as to what is achievable in the field.

- Is it possible to carry 6 dse per winter grazed ha through the year on the sand plain without causing erosion?
- Herbicide resistance control measures on pastures being utilised for grazing may have large effects on the pasture productivity.
- Long term market outlooks for livestock need to be considered.
- To what levels can management be undertaken that allows the targeting of markets of higher value?
- Capabilities of new breeds of livestock need to be more clearly understood. The Dorper sheep is claimed to be able to lamb out of season and have three lambing events in two years. Achievements in the field need assessing and the findings extended to landholders.

CONCLUSIONS

For a livestock enterprise to compete with the an average lupin yield of 1.63 t/ha it needs to have a marked increase in productivity/price over what was a possible average. Relatively small changes in production capabilities of enterprises and of commodity prices can have huge financial implications for a farm business, particularly over extended periods of time. Farmers need to make as accurate assumptions as possible, on production capabilities for new enterprises, for their situation and farm. Good knowledge to base these assumptions on is essential to produce relevant business plans for the future. On-ground knowledge via research and from case studies of landholders trying new systems, is urgently needed to enable more informed decision-making.

KEY WORDS

sensitivity, farming systems, legume phase

ACKNOWLEDGMENTS

Department of Agriculture Economist Alan Herbert for transforming the idea into spreadsheets and modeller Anne Bennett for continuing development.

Paper reviewed by: Mike Clarke and Ciara Stockdale

Department of Agriculture Projects: SHQ, SMO

NHT Project No.: 963001
Transition analysis of farming systems in the medium rainfall northern sandplain. No. 3

Caroline Peek and David Rogers, Department of Agriculture

KEY MESSAGES

- Different transition strategies can have big effects on the financial position of the farm.
- If a rapidly emerging problem is driving farmers to make big changes to their farming system, they need to assess the possibilities before the problem becomes widespread. This gives them time to select and implement the transition strategy that is right for their situation.
- Wheat currently returns the highest gross margins. Maintaining a high level of wheat through the transition phase helps fund the changes.

AIMS

The aim of this work is to do economic evaluations on the transition from the current benchmark (wl) farming system to alternative systems.

Farmers faced with the possibility of having to make potentially major changes to their current farming systems need to know:

- How the current problem is likely to impact on them financially over time.
- What changes they can afford to make.
- How quickly they can afford to make them.
- Whether the system will be financially viable after the changes have been made.

METHOD

A model is being developed that has the ability to analyse the change from one farming system to another over time. Using the model, the benchmark wheat/lupin system was used as the starting point. The farm business was then changed over a ten-year period to several different systems. The result of moving to one of these systems is discussed in this paper.

The farm is a sandplain farm of 3500 ha of which 3100 ha are croppable and 400 ha are not. The high percentage of cropping is resulting in herbicide resistance developing. The farm was moved from the benchmark system of wheat, lupin and canola (wl) (89% crop) to a suggested system to combat herbicide resistance and maintain a reasonable level of cropping (53% crop). This new system is based on 2 years of a Cadiz serradella pasture followed by 3 years of crop (ppwlw). The original flock on the farm was a merino flock with 400 ewes. Dorper rams were purchased and a Dorper prime lamb enterprise was bred up from this original ewe flock to match the pasture development. Additional merino ewes were purchased at $30/hd to speed the upbreeding process. Merino lambing rates were set at 95%. Where the early Dorper and Dorper cross flocks consisted of maiden ewes, lambing percent was set at 60% increasing to 80%, 110% and finally 120% with the fully established flock. First cross (F1) dorpers were shorn but no income was received for the fleece. Second cross (F2) and above were not shorn. Rams cost $1000 and were turned over every 3 years. The same crop yields and economics apply as that described in the companion paper 'Farming systems for the medium rainfall northern sandplain'.

Three transition scenarios from the benchmark wl system to the ppwlw with Dorper sheep farming system were analysed over a 10 year period:

- Long transition period: 310 ha (10% of cropped area) was sown to first year Cadiz pasture each year. At the end of 10 years the entire cropping area had been treated with a 2-year pasture phase and the new farming system was in place.
- Rapid transition period: 620 ha (20% of cropped area) was sown to first year Cadiz pasture each year. After 5 years the cropped area had been treated with the 2-year phase pasture and the system was in place.
- Delayed but rapid transition period: The farmer cropped until forced in year 5 to start sowing 620 ha of first year Cadiz pasture every year. The new system was in place at end of the ten-year model run.
RESULTS

Table 1. Structure of the farm area (ha) at the start and end of the 10-year change over period

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>1,550</td>
<td>1,240</td>
</tr>
<tr>
<td>Lupin</td>
<td>1,250</td>
<td>620</td>
</tr>
<tr>
<td>Canola</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Cadiz pasture</td>
<td>0</td>
<td>1,240</td>
</tr>
<tr>
<td>Unimproved pasture</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Crop %</td>
<td>89</td>
<td>53</td>
</tr>
<tr>
<td>Total Merino DSE</td>
<td>1,160</td>
<td>0</td>
</tr>
<tr>
<td>Total Dorper DSE</td>
<td>0</td>
<td>8,682</td>
</tr>
</tbody>
</table>

Table 2. The progressive financial position of the farm and the annual surplus/deficits for each of the three transition scenarios. The starting balance for the 3 comparisons was zero

<table>
<thead>
<tr>
<th>Year</th>
<th>Long transition period</th>
<th>Rapid transition period</th>
<th>Delayed rapid transition period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cumulative Position</td>
<td>Surplus/deficit</td>
<td>Cumulative Position</td>
</tr>
<tr>
<td>2001</td>
<td>$89,191</td>
<td>$89,191</td>
<td>$90,282</td>
</tr>
<tr>
<td>2002</td>
<td>$164,864</td>
<td>$68,537</td>
<td>$140,560</td>
</tr>
<tr>
<td>2003</td>
<td>$214,126</td>
<td>$36,073</td>
<td>$79,338</td>
</tr>
<tr>
<td>2004</td>
<td>$300,795</td>
<td>$69,539</td>
<td>$89,493</td>
</tr>
<tr>
<td>2005</td>
<td>$388,395</td>
<td>$63,536</td>
<td>$76,524</td>
</tr>
<tr>
<td>2006</td>
<td>$517,882</td>
<td>$98,416</td>
<td>$112,043</td>
</tr>
<tr>
<td>2007</td>
<td>$581,192</td>
<td>$21,880</td>
<td>$179,781</td>
</tr>
<tr>
<td>2008</td>
<td>$627,214</td>
<td>-$474</td>
<td>$255,944</td>
</tr>
<tr>
<td>2009</td>
<td>$735,957</td>
<td>$58,566</td>
<td>$340,465</td>
</tr>
<tr>
<td>2010</td>
<td>$852,841</td>
<td>$58,007</td>
<td>$431,464</td>
</tr>
<tr>
<td>2011</td>
<td>$996,537</td>
<td>$77,469</td>
<td>$549,796</td>
</tr>
</tbody>
</table>

Table 2 shows that transition strategies can result in very different financial outcomes for the farm. Including a livestock enterprise in the farming system at average long term prices and having to reduce the wheat area potentially reduces the profitability of the farming system (see Farming systems for the medium rainfall sandplain). A paddock sown to a Cadiz pasture will lose money for the system unless it can be utilised. Building up a flock to take advantage of this pasture costs money.

The long transition manages this by making sure the change is financed by keeping the cropping, particularly wheat, as high as possible until the livestock enterprise starts paying for itself in 2009. The cropping buffers the farm from returning a deficit in all but one year. The longer transition period also allows the building of skills to manage a completely different enterprise to cropping.

The rapid transition put an increased strain on the farm finances, trying to build up an enterprise while rapidly diminishing the biggest money earner wheat. The farm suffers two years of deficit. This deficit is partly a result of the pasture area increasing at a faster rate than the number of sheep to utilise it. The low starting number of sheep is the cause of this. The livestock gross margins become positive in 2007.

The delayed rapid transition has worked because the farm is cropped for the first five years and the rapid transition is started from a stronger financial position of $615,000 to help absorb the financial losses that establishing pasture and rapidly building up a flock to match the pasture entail.

CONCLUSION

Transition strategies can make a big difference to the financial position of the farm. Where a problem such as herbicide resistance has a high probability of occurring, individual farmers need to assess their strategies before it becomes widespread. This gives them time to make the best decisions that current information will allow. Maintaining a high level of wheat helps to finance the cost of change.

KEY WORDS

transition, farming systems, economics

ACKNOWLEDGMENTS

Department of Agriculture Economist Alan Herbert for transforming the idea into spreadsheets and modeller Anne Bennett for continuing development.

Paper reviewed by: Mike Clarke and Ciara Stockdale
Department of Agriculture Projects: SHQ, SMO
NHT Project No.: 963001
Implementing on-farm quality assurance

Peter Portmann, Manager Research and Development, The Grain Pool of Western Australia

A pilot Quality Assurance (QA) training program was successfully completed in 2001 with 245 grower enterprises completing SQF1000/Great Grain QA training. The last of this group are currently going through the audit phase for accreditation. The general feedback from those who have undergone the training is that QA is a logical and straight-forward process that adds a useful dimension to the management of the farm. The increase in overheads has been insignificant for those who are currently operating near what is considered best practice, including the area of records management. There has been general satisfaction amongst such people in adopting a system that gives them a benchmark by which they can be confident they are operating at best practice levels. The overheads are greater for those whose records and practices are not up to scratch, but the potential benefits in improving their farm operations are also there.

The pilot program has identified areas where grain supply chain management can be improved and these areas will be addressed to help simplify and streamline the system further. Computerised record management systems, currently on the market, are also integrating QA recording into their system. Electronic pocket organiser links are being developed to provide as much in situ recording of data as possible and minimise administrative workloads. The Grain Pool, CBH and AWB Ltd are co-sponsoring an industry wide working group to facilitate the integration of such QA support services and maximise the integration of QA across the whole of the grains industry.

The biggest issue identified out of the pilot program is that of off-label and over-label use of chemicals. Although illegal, such practice has become endemic in the grains industry and has been widely practiced by growers and advocated by consultants and retailers. It is almost stating the obvious that a QA program cannot condone any illegal practice. Because of this, QA training has highlighted this problem; it has not created it. It is recognised that the grains industry has to have the freedom to adopt new practices and remain efficient, competitive and viable, but to continue to achieve that by ignoring the law is not a viable long-term solution.

The practice of applying untested chemical regimes without an assessment of the impact on food safety is clearly inappropriate. If allowed to continue, the practice runs an increasing risk of causing a food safety disaster that could irreparably damage our grains reputation and expose the industry to major litigation. The Grain Pool has therefore established a whole of industry working group including chemical manufacturers, retailers, grain grower organisations, marketers, bulk handlers, regulatory authorities, research funders and QA trainers. The purpose of this group is to identify the issues, implement strategies to resolve the current conflicts between practice and legal limits and manage future changes in practices in a way that ensures ongoing food safety management on farm. This will at the same time ensure compliance with QA requirements.

Market signals continue to indicate that QA will progressively become mandatory in the grains industry over the next five years. It is becoming clear that a functional HACCP compliant QA system within the industry will be an essential base on which to build effective segregation and identity preservation systems. This will be highlighted with the first release of GM varieties when effective segregation of the GM and non-GM streams will be vital to provide maximum market opportunities.

An ongoing program for QA training has been implemented for 2002. This program, sponsored by the Grain Pool, Cooperative Bulk Handling Ltd and AWB Ltd has been structured to cater for up to 800 growers over the year with training courses run at centres throughout regional agricultural areas.

QA Information Packs ‘Leading the Way, QA Today’ are available for further information.

Paper reviewed by: Christine Kershaw, Agrifood Training Centre
On-farm research - principles of the ‘Test As You Grow’ kit

Jeff Russell, Department of Agriculture, Centre for Cropping Systems, Northam

RESEARCH BY THE FARMER, FOR THE FARMER

Farmer based research has now become easier to do with the release of the ‘Test As You Grow’ kit last February.

On-farm research, which is also known by a number of terms such as farmer based trials, broad-scale experiments or demonstrations is gaining popularity throughout Western Australia with many farmer groups using it to assist with better decision making.

In response to this the Department of Agriculture with the assistance of the GRDC and in conjunction with TOPCROP have developed the ‘Test as You Grow’ kit.

Launched in 1999 at the Crop Updates the kit underwent field testing and review and after 3 years of refinement with the cooperation between department, industry and growers the ‘Test As You Grow’ kit is now ready for general use.

The ‘Test As You Grow’ kit has been designed as a guide to make on-farm research as simple and as practical as possible. The new kit will enable growers to set up their own on-farm research tests as they carry out normal cropping operations, with a minimum disruption to their own cropping program.

The number of crop types, crop varieties and flexibility in cropping systems and inputs has changed considerably in the last decade or two. Growers now have a choice of many more crop species and a wider range of varieties. There are also more complex rotations, many new cropping practices such as direct drill, no-till and furrow sowing and a tremendous diversity and flexibility with crop protection systems.

Programs on research stations and agricultural experimental work in the State have not been able to increase to match the need created by the increase in crops, varieties, practices and crop protection options. There is therefore a need for on farm research to be done to complement the programs of small plot intensive experiments. The methods outlined in the ‘Test as You Grow’ kit can be used as a guide by farmers in their efforts to plan and run appropriate types of on farm research in their paddocks.

The kit contains a manual and supporting resources for use as a guide for groups or individual growers, in planning their on-farm research.

The ‘Test as You Grow’ manual provides examples of broad-scale design and layout of varying levels of sophistication, as well as some general guidelines or requirements for each level. Farmers and groups participating in on farm research will have different needs in planning their crop research. This may range from simple whole paddock comparisons to well replicated broad-scale experiments.

The manual explains some of the simple statistical principles, such as the control of error in experiments, the need for replication and provides some suggestions on site selection and logistics. There is also a section linking on farm research to precision agriculture technologies.

Input from specialists is advised in the design of experiments and the interpretation of the results. As such a fax-back service for getting design advice and in the interpretation of the results is included as a service of the kit.
Design suggestions are faxed back after consultation with specialists on how to best achieve the research objectives with the most simple and practical designs.

The ‘Test As You Grow’ kit would be a useful addition not just for the farmer but for agronomists, consultants and research and development officers involved in crop nutrition, seed production, crop protection and machinery development.

The Kunjin TOPCROP group has been one of the principle supporters and developers of the ‘Test As You Grow’ kit. For over the last five seasons they have been conducting large scale wheat variety comparisons. This season the Liebe Group did likewise.

The results from these have been used to complement those derived from small plot variety comparisons conducted by Agritech Crop Research. From consideration of these results, decisions are made on variety adoption for the future. The results of these have been featured in previous Crop Update publications.

Members of the Kunjin TOPCROP group used the principles as outlined in the ‘Test As You Grow’ kit in 2001 for wheat variety comparisons that included the new variety Wyalkatchem.

New developments in on-farm research have included the use of digital sensing for assessing yield measurements. Last year Multi Spectral Imaging of the Wubin site was undertaken. The image below shows the site and yield variation within plots and across the site for plot. Such a technique may be useful in assessing the performance of treatments applied without the need to take final yield measures or as a backup to yield analysis if adverse seasonal circumstances affect the site.

Other developments have included the establishment of a ‘Test As You Grow’ website. This has been developed in partnership with TOPCROP and GRDC. Current access is through TOPCROP http://topcrop.grdc.com.au.

It is hoped that the site will be able to be internet site: http://www.agric.wa.gov.au/topcrop for on farm research as they are posted on the GRDC

\[\text{can be obtained from Jeff Russell at the Centre for}\]
Broadscale wheat variety comparisons featuring Wyalkatchem

Jeff Russell, Department of Agriculture, Centre for Cropping Systems, Northam

HARNESSING ON-FARM TESTING CAPACITY TO EVALUATE CROP VARIETIES

BACKGROUND
The evaluation of crop varieties is often done in small scale intensive research plots. This is beneficial for screening a large number of varieties in a controlled environment. However, such sites are costly and the number of sites that can be established is limited by the financial resources available.

To complement this work, growers can carry out farm scale research themselves. The principles outlined in the ‘Test As You Grow’ kit and the service provided through the kit can help growers to conduct sound farm-scale research on their own properties. Such research can provide additional information of a practical nature and display the performance of the treatments in an environment closer resembling that found in the paddock.

The new APW wheat variety Wyalkatchem (WAWHT2212) was released in August 2001. Wyalkatchem has a number of features that make it to be a suitable replacement variety for Westonia. These being disease resistance and straw height. Previous comparisons have been made between the two varieties in small plot Crop Variety Test (CVT) sites prior to release. In 2001, three large scale sites (Table 1) were established to complement variety comparisons conducted by Agritech. One site with the Liebe Group (Wubin) and two with the Kunjin TOPCROP group (Kunjin and Lomos).

Table 1. Site details of the three large scale variety comparisons

<table>
<thead>
<tr>
<th>Sites</th>
<th>Wubin</th>
<th>Kunjin</th>
<th>Lomos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot size</td>
<td>200 m x 12 m, harvested width 10.9 m</td>
<td>200 m x 12 m, harvested width 9.3 m</td>
<td>200 m x 13 m, harvested width 9.3 m</td>
</tr>
<tr>
<td>Replication</td>
<td>Two replicates of each variety with</td>
<td>Two replicates of each variety with</td>
<td>Two replicates of each variety with</td>
</tr>
<tr>
<td></td>
<td>Westonia used as a control every</td>
<td>Westonia used as a control every</td>
<td>Westonia used as a control every</td>
</tr>
<tr>
<td></td>
<td>third plot (nearest neighbour)</td>
<td>third plot (nearest neighbour)</td>
<td>third plot (nearest neighbour)</td>
</tr>
<tr>
<td></td>
<td>Topsoil pH = 5.0</td>
<td>pH = 4.5</td>
<td></td>
</tr>
<tr>
<td>Sowing date</td>
<td>14 May 2001</td>
<td>31 May 2001</td>
<td>5 June 2001</td>
</tr>
<tr>
<td>Seeding rate</td>
<td>67 kg/ha</td>
<td>50 kg/ha</td>
<td>50 kg/ha</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>2 April - Muriate of Potash spread</td>
<td>31 May - Agras 1, 120 kg/ha. 29 June</td>
<td>5 June - Agstar, 100 kg/ha.</td>
</tr>
<tr>
<td></td>
<td>across whole of paddock and across</td>
<td>- 55 kg/ha Urea topdressed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>plots. 14 May - Agstar, 110 kg/ha at</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>seeding. Flexi N - 40 L/ha applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 weeks after seeding.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

Table 2. Yield and quality characteristics of the 3 wheat varieties compared

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plants (/sqm)</th>
<th>Yield (t/ha)</th>
<th>% Yield of Westonia</th>
<th>Protein (%)</th>
<th>Screen (%)</th>
<th>Specific weight (kg/hL)</th>
<th>Staining (%)</th>
<th>Grade</th>
<th>Income ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westonia</td>
<td>87</td>
<td>1.64</td>
<td>100</td>
<td>11.1</td>
<td>1.54</td>
<td>80.4</td>
<td>1.5</td>
<td>APW</td>
<td>434</td>
</tr>
<tr>
<td>Wyalkatchem</td>
<td>90</td>
<td>1.81</td>
<td>110</td>
<td>11.0</td>
<td>0.9</td>
<td>82.1</td>
<td>1.5</td>
<td>APW</td>
<td>483</td>
</tr>
<tr>
<td>Calingiri</td>
<td>110</td>
<td>1.64</td>
<td>100</td>
<td>11.4</td>
<td>0.7</td>
<td>82.5</td>
<td>1.5</td>
<td>ASWN</td>
<td>448</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>42</td>
<td>0.18</td>
<td></td>
<td>0.6</td>
<td>0.3</td>
<td>1.0</td>
<td>ns</td>
<td></td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plants (/sqm)</th>
<th>Yield (t/ha)</th>
<th>% Yield of Westonia</th>
<th>Protein (%)</th>
<th>Screen (%)</th>
<th>Specific weight (kg/hL)</th>
<th>Staining (%)</th>
<th>Grade</th>
<th>Income ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westonia</td>
<td>49.2</td>
<td>2.54</td>
<td>100</td>
<td>9.9</td>
<td>3.08</td>
<td>79.6</td>
<td>0.5</td>
<td>APW</td>
<td>624</td>
</tr>
<tr>
<td>Wyalkatchem</td>
<td>51.5</td>
<td>2.24</td>
<td>88</td>
<td>9.7</td>
<td>1.86</td>
<td>82.0</td>
<td>0</td>
<td>APW</td>
<td>559</td>
</tr>
<tr>
<td>Calingiri</td>
<td>50.4</td>
<td>2.08</td>
<td>82</td>
<td>9.8</td>
<td>2.67</td>
<td>80.7</td>
<td>0</td>
<td>ASWN</td>
<td>592</td>
</tr>
</tbody>
</table>

Kunjín

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plants (/sqm)</th>
<th>Yield (t/ha)</th>
<th>% Yield of Westonia</th>
<th>Protein (%)</th>
<th>Screen (%)</th>
<th>Specific weight (kg/hL)</th>
<th>Staining (%)</th>
<th>Grade</th>
<th>Income ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westonia</td>
<td>84.0</td>
<td>1.97</td>
<td>100</td>
<td>8.1</td>
<td>1.82</td>
<td>81.3</td>
<td>0</td>
<td>APW</td>
<td>453</td>
</tr>
<tr>
<td>Wyalkatchem</td>
<td>69.1</td>
<td>1.82</td>
<td>92</td>
<td>8.6</td>
<td>1.14</td>
<td>83.1</td>
<td>0</td>
<td>APW</td>
<td>417</td>
</tr>
<tr>
<td>Calingiri</td>
<td>75.6</td>
<td>1.70</td>
<td>86</td>
<td>8.4</td>
<td>1.86</td>
<td>81.3</td>
<td>0</td>
<td>ASWN</td>
<td>429</td>
</tr>
</tbody>
</table>

Lomós

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plants (/sqm)</th>
<th>Yield (t/ha)</th>
<th>% Yield of Westonia</th>
<th>Protein (%)</th>
<th>Screen (%)</th>
<th>Specific weight (kg/hL)</th>
<th>Staining (%)</th>
<th>Grade</th>
<th>Income ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westonia</td>
<td>84.0</td>
<td>1.97</td>
<td>100</td>
<td>8.1</td>
<td>1.82</td>
<td>81.3</td>
<td>0</td>
<td>APW</td>
<td>453</td>
</tr>
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<td>Wyalkatchem</td>
<td>69.1</td>
<td>1.82</td>
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<td>83.1</td>
<td>0</td>
<td>APW</td>
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<td>86</td>
<td>8.4</td>
<td>1.86</td>
<td>81.3</td>
<td>0</td>
<td>ASWN</td>
<td>429</td>
</tr>
</tbody>
</table>

AWB base rates used for income, APW $247.00, ASWN $280.00 (21/01/02).

COMMENTS

The acceptance of these results needs to be taken with caution. A problem that occurred at seeding at the Wubin site meant the actual area of Westonia harvested was less by about 10%. The Westonia yield shown in table 2 has been adjusted upwards from the actual plot yields to take this into account. The actual plot yields averaged 1.46 t/ha for Westonia, which would be significantly less than Wyalkatchem.

It would be very useful to compare the results found here with those gained from the respective Agritech sites that were located close by at Wubin and Kunjin, before making decisions on variety performance. These can be found in the extended version of this paper on the CD.

SUMMARY

- At the Wubin site the variety Wyalkatchem out performed Westonia and Calingiri. While at Kunjin it was considerably lower in return.
- Wyalkatchem seemed to have slightly improved quality features with less screenings and greater weight than Westonia.
- When comparing varieties it is important to limit variability by obtaining seed from a common source.
- On-farm research activities such as these are designed to be simple and quick to do and can be used to complement intensive small plot research.

ACKNOWLEDGMENTS

Thanks goes to Ron Carlhausen, Brad Talbot and Clive Turner who gave of their time to conduct these on-farm variety comparisons.

GRDC Project No.: DAW 599
Paper reviewed by: John Blake

There is an extended version of this paper on the 2002 Crop Updates CD.
GrainGuard™ - A biosecurity plan for the Canola Industry

Greg Shea, Western Australian Department of Agriculture

BACKGROUND

The West Australian grains industry is highly exposed to a number of biological threats including incursions of exotic pests, the spread of endemic pests, the development of pesticide resistance and problems associated with grain contamination.

The foundation of GrainGuard is the maintenance of a high level of bio-security beginning at the farm level. Growers, agribusiness and others throughout the grain handling chain are encouraged to be vigilant and report any unusual pest observations and seek identification of these pests or disorders by Department of Agriculture specialists.

This Canola Industry Protection Plan developed under GrainGuard™ sets out how the Western Australian Canola Industry, Agriculture Western Australia and the Agriculture Protection Board will cooperate to assess and respond to new threats by appropriate prevention of entry, early detection and prompt incident response actions.

The first step in developing the plan was to carry out threat identification and risk assessment.

THREAT IDENTIFICATION AND RISK ASSESSMENT

There are five categories of threats to the canola industry in Western Australia. These include insects, diseases, weeds, animal pests, and chemical (residue) threats. Within each group there are many potential threats. The serious threats have been identified through risk assessment and others may be added as a continual watch is kept for development of canola industry threats throughout the world.

Key considerations:

- A threat's entry, establishment and spread potential in Western Australia and its impact on costs of production, productivity and market access?
- What are the consequences?
- How fast does the threat spread, what is its impact on productivity and market access and how difficult is it to control?

By analysing this information, potential threats to canola industry businesses are allocated to one of four Categories ranging from high probability of occurrence and high impact (Category A) to minor impact (Category D). The following two tables summarise these Categories and the most serious threats identified in Category A.
Table 1. Threat category of canola insects, diseases, weeds and animal pests exotic to Western Australia

<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High probability of establishing in Western Australia. Could spread throughout the State’s canola growing areas. Has major trade implications and/or substantial long-term effects on productivity or the cost of production.</td>
</tr>
<tr>
<td>B</td>
<td>Low probability of establishing in Western Australia. Could spread throughout the State’s canola growing areas. Has major trade implications and/or substantial long-term effects on productivity or the cost of production.</td>
</tr>
<tr>
<td>C</td>
<td>Biological restrictions to spread within Western Australia. Only moderate impact on long term productivity or the cost of production.</td>
</tr>
<tr>
<td>D</td>
<td>Minor impact on productivity or the cost of production.</td>
</tr>
<tr>
<td>N</td>
<td>Not yet assessed.</td>
</tr>
</tbody>
</table>

Table 2. Category ‘A’ exotic threats to WA’s canola industry

<table>
<thead>
<tr>
<th>Common name (scientific name)</th>
<th>Threat type</th>
<th>Present in Australia (outside WA)</th>
<th>Primary host crop or weed of</th>
<th>Alternate host crop or weed of</th>
<th>Previously eradicated from WA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verticillium wilt (Verticillium dahliae var. longisporum)</td>
<td>Fungal pathogen</td>
<td>No</td>
<td>Canola</td>
<td>Cruciferous plants</td>
<td>No</td>
</tr>
<tr>
<td>Seed pod weevil (Ceutorhynchus assimilis)</td>
<td>Insect</td>
<td>No</td>
<td>Canola</td>
<td>Cruciferous plants</td>
<td>No</td>
</tr>
<tr>
<td>Branched broomrape (Orobanche ramosa)</td>
<td>Weed</td>
<td>Yes, South Australia</td>
<td>Non cereal crops</td>
<td>Oilseeds, pulses and horticultural crops</td>
<td>No</td>
</tr>
</tbody>
</table>

Additional to these diseases, weeds and pests, the Working Group has identified the contamination of canola by rapeseed varieties which have high erucic acid and other undesirable characteristics as another Category A threat.

A draft plan has been completed by the Working Group and has identified Quarantine, surveillance, research/development management and communication activities that can be carried out by government and industry.
Are Western Australian broadacre farmers efficient?

Ben Henderson, University of Western Australia
Ross Kingwell, Department of Agriculture and University of Western Australia

KEY MESSAGE
The efficiency of over 90 broadacre farms in the southeast and south coast regions was examined for the years 1997 to 1999. Farm efficiency was measured using two different techniques. Main findings are that:

- Most farms demonstrated high levels of efficiency.
- Technical efficiency improved over the three years.
- Both analytical techniques generated consistent rankings of farm technical efficiency.
- Farms identified as being very efficient tended to remain so.
- A range of factors influenced efficiency. However, factors that influence technical efficiency differ from the factors that influence allocative efficiency.
- Farmers with greater levels of education tend to operate their farms at higher levels of technical efficiency. Also, middle-aged farmers tend to be more efficient.

BACKGROUND
Technical efficiency is a measure of farm performance. It describes how effectively a farm business converts its physical and purchased inputs into marketable outputs such as grain and wool. A farm is technically efficient when it achieves maximum output from a given set of inputs (i.e. no wastage or ineffectiveness).

Allocative efficiency is also a measure of farm performance. It describes farmers' ability to select the most profitable mix of inputs and outputs, in accordance with their respective prices and production relationships. A farm is allocatively efficient when it achieves maximum profit from selecting the 'best' combination of enterprises.

METHOD
Some farm management consultants kindly provided client data, in a way that protected their clients' confidentiality. This data set were the physical and financial records of 93 farms in the southeast and south coast regions for the years 1997 to 1999. Two techniques, data envelopment analysis (DEA) and stochastic frontier analysis (SFA), were used to measure farm efficiency.

RESULTS
Analyses of farm efficiency reveal that:

- Most farms were measured as displaying high levels of technical and allocative efficiency.
- Technical efficiency improved over the three years.
- The distribution of technical efficiency among farms was uneven - of concern was the small, yet diminishing portion of farms displaying relatively low levels of technical efficiency (see Figure 1).
- Both analytical techniques, DEA and SFA, generated consistent rankings of farm technical efficiency.
- Farms identified as being very efficient tended to remain so. However, technically efficient farms were not necessarily allocatively efficient.
A range of factors influenced technical efficiency, including rainfall, farm size, tillage method, formal education level of the farmer and their age. Farmers with greater levels of education operate their farms at higher levels of technical efficiency. Middle-aged farmers were more likely to be technically and allocatively efficient. Young and old farmers were less likely to be efficient. Interestingly, farmers using 'min-till' practices displayed higher levels of technical efficiency than those predominately using 'no-till' practices.

Greater gains in profitability are possible by improving allocative rather than technical efficiency.

The variables associated with variation in technical efficiency are different to those explaining the variation in allocative efficiency.

Figure 1. DEA and SFA technical inefficiency distributions for 1999.

CONCLUSIONS

For the farms examined, their technical and allocative efficiency improved from 1997 to 1999. A majority of farms were found to be highly efficient. Greater gains in profitability were found to be possible by improving allocative rather than technical efficiency. Technically efficient farms are not necessarily allocatively efficient. Also, additional analyses reveal that the variables associated with variation in technical efficiency are different to those explaining the variation in allocative efficiency. An implication for R,D&E is that these farmers would most boost their profitability by improving their allocative skills (e.g. getting their enterprise mix 'right').

KEY WORDS

farm efficiency, technical efficiency, profitability

GRDC Project No.: UWA 311 The efficiency of Western region grain growers
WORKSHOP: Pest and disease forecasts for you!
An interactive forum

Tresslyn Walmsley, Jean Galloway, Debbie Thackray, Moin Salam and Art Diggle, Centre for Legumes in Mediterranean Agriculture and Department of Agriculture

The following three papers are presented as part of a workshop on the development of decision supports systems from computer based simulation models. This workshop will be a facilitated interactive forum between the people developing models or computer based decision support systems (DSSs) and the consultants and advisers who will use them.

The objectives of this session are:

- Provide information about DSSs being developed and the data on which they are based.
- Allow the modellers to display the power of the systems being developed.
- Determine how consultants and agronomists will use these tools.
- Invite discussion from consultants on the type of input to, and output from, computer based DSSs.
- Invite consultants to influence future directions in the development of these and other DSSs.

The outcomes of this workshop will be compiled and published on the Crop Updates web-site and will be made available to the Grains Research and Development Corporation.
Blackspot spread: Disease models are based in reality (Workshop paper 1)

Jean Galloway, Department of Agriculture, Northam

KEY MESSAGE

- Blackspot of field pea is windborne and spores are spread to distances of greater than 400 m at relatively low wind speeds.
- Spore release occurs with rainfall amounts as low as 0.2 mm and continues for several hours following the wetting of stubble, the majority of spores are however released in the first half-hour following wetting.
- Spore release from stubble occurs throughout the growing season. Disease severity is highest on early sown peas due to multiple infection opportunities.
- The pattern of spore spread has been established in field experiments in WA and forms the basis on which computer simulation models, that predict disease risk, have been developed.

AIMS

These experiments were conducted to gain a better understanding of how the fungus (*Mycospharella pinodes*), which causes blackspot on field pea, survives on infected pea stubble from one season to the next. Additionally the environmental conditions that lead to disease spread were examined.

METHOD

Naturally infected pea stubble was placed under wire mesh in a grazed pasture paddock at CSIRO’s Yalanbee Research Station at Bakers Hill. This site was selected as it is well isolated from commercial pea growing areas and hence the risk of intercepting blackspot spores from outside of the trial site was minimised. Spores from the stubble were trapped using potted pea plants placed at distances of 0, 10, 50, 100, 200 and 400 m downwind of the stubble source. These trap plants were replaced on a weekly basis from May through to September. The number of spores intercepted by the trap plants during their week’s exposure at the trial site was determined by assessing the plants for disease severity and by counting the number of blackspot lesions per leaf. This data, combined with hourly weather data recorded next to the stubble, was used to determine the environmental conditions leading to spore production during spore dispersal.

At fortnightly intervals throughout the experiment, sub-samples of the naturally weathered stubble were assessed microscopically to determine what type of fruiting bodies were present on the stubble and their state of maturity. The spore production potential of the stubble was also assessed using purpose built wind tunnels in which spores were trapped, onto rotor rods, following wetting.

RESULTS AND DISCUSSION

When are spores released?

Ascospores are released from fruiting bodies (perithecia) on the pea stubble during and after rain events, the majority of spores being released in the half-hour following the start of a rain event. Mature perithecia are present on the stubble at the start of the growing season and disease can be initiated in pea crops from the first rain events that occur after crop emergence. As the growing season progresses the percentage of perithecia containing mature ascospores increases (Figure 1) and reaches a peak during June and July.

Spore trapping in wind tunnels shows that the peak ascospore release occurs in July, however during the remainder of the growing season sufficiently high numbers of spores are discharged from the previous season’s stubble to initiate infection of field pea crops. Early sown pea crops tend to develop more severe blackspot not as a result of being exposed to a blackspot ‘spore shower’ at the beginning of the growing season, as was previously thought, but due to a cumulative effect of multiple infection.
opportunities throughout the growing season. Second year (18 month old) pea stubble does contribute to disease development, but spore production is reduced by an average of 90 % (Figure 1).

![Mature ascospores (%)](image)

**Figure 1.** Blackspot fruiting body maturity (1st year stubble is a mean of 2000 and 2001 data).

**How far do the spores travel?**

The ascospores are wind dispersed and, in the experiments at Bakers Hill, initiated blackspot at a distance of 400 m from the infected stubble. From the shape of the dispersal curve (Figure 2) it is apparent that spore dispersal can occur over greater distances. This spread function has been used in the construction of computer simulation models to estimate the probability of an infection occurring at any distance from the stubble source and extrapolated to distances greater than 400 m.

![Spores trapped/plant (Log Scale)](image)

**Figure 2.** Blackspot spore dispersal over distance.

**CONCLUSION**

Under WA conditions it has been established that blackspot spread is occurring primarily as a result of windborne ascospores from the previous season’s stubble, released during rain events. It has been demonstrated in field experiments that significant infection can occur at distances of 400 m from the stubble. This data, used in combination with weather data, can be incorporated into computer simulation models to predict the spread of blackspot.

**KEY WORDS**

field pea, blackspot, disease spread, computer simulation

**GRDC Project No.:** DAW 619

**Paper reviewed by:** Bill MacLeod
Blackspot spread: Scaling-up field data to simulate ‘Baker’s farm’ (Workshop paper 2)

Moin U. Salam, Jean Galloway, Art J. Diggle and William J. MacLeod,
Department of Agriculture, Western Australia

KEY MESSAGE

- A simulation model has been developed to predict spread of blackspot on a regional scale.
- The model has been employed in three locations, Mingenew, Merredin and Scaddan, to address the effects of regional difference, seasonal variability, and time of sowing on the extent of the disease.
- The direction of prevailing wind during rainfall events is shown to be a key driver of infection and consideration should be given to planting upwind of last year’s pea paddocks where possible.

BACKGROUND

Field experiments have been conducted to gain a better understanding of the fungus (*Mycospharella pinodes*), which causes blackspot in field pea. The fungus survives on infected pea stubble from one season to the next and develops fruiting bodies (perithecia) over time (Galloway, 2000, this book). Investigations have also been made of the conditions that cause release of spores from the matured fruiting bodies and how far the spores travel. This location specific information has been synthesised to develop, calibrate and verify a model of spread of blackspot on a regional scale. A working example is given for ‘Baker’s farm’.

METHOD

The model

A hypothetical property comprised of 24 paddocks (the actual map is a part of Morbinning Catchment located near York, Western Australia) was partitioned into a 50 m grid. Grid elements in paddocks where field pea had been grown in the previous year are the sources of infection. Progress in the degree of spore maturity was assumed to follow a curve that has been derived experimentally. Mature spores are released whenever an hourly rain threshold of 0.2 mm is exceeded. The effect of wind on dispersal of spores is simulated explicitly using Monté Carlo techniques. The distance travelled by spores is dependent on wind speed and is generated from a half-Cauchy distribution (for details see Diggle et al. 2002). The direction of travel of the spores is determined by wind direction. Dispersion of spores is modelled hourly.

The simulation

The model was run using weather data collected from April to October, 2000 at CSIRO-Yalanbee Experimental Station at Bakers Hill, Western Australia. Dispersion of spores up to a distance of 400 m from the source of infection (infected stubble) was calibrated using spore-trap data collected weekly for 21 weeks at the research station (Galloway, 2002, this book). To simulate regional and seasonal effects, the model was run using location-specific hourly weather data for Mingenew, Merredin and Scaddan for 1999 and 2000 seasons. These runs were made assuming a mid-May emergence time. To simulate the effect of sowing time, the model was also run with later dates. In all the runs, the disease susceptibility period was assumed to be 100 days after seedling emergence.

RESULTS

In general, the model’s prediction agreed well with all 21 weeks of observed data. The model shows how far and how intensely the disease can spread from the source of infection. In Figure 1, paddocks 1 and 12 contain infected pea stubble from last year. With this assumption, the model predicts regional difference (A vs. D vs. E), seasonal variability (A vs. C)), and sowing time effect (A vs. B). Figure 1F shows what part of Baker’s property, if any, can be affected by his neighbour’s infected paddocks located above his property.
Figure 1. Spread of blackspot disease in field pea from the infected stubble located in the paddocks 1 and 12. The crop emergence time (designated as sowing time) was considered as mid-May except for ‘B’ which was late, end late-June. See ‘Method’ section for more details.

CONCLUSION

Although the model is in its preliminary stage, its potential is demonstrated! Given that the efforts are continued both on field experimentation and modelling, the model could be an important decision support tool for management of blackspot disease in field pea.

ACKNOWLEDGMENTS

The Grains Research and Development Corporation (GRDC) provide funds for this research. GRDC Project DAW 619 is collaborating with this modelling.

REFERENCES


KEY WORDS

field pea stubble, quantitative epidemiology, modelling

GRDC Project No.: DAW 621
Paper reviewed by: Dr Art Diggle
A decision support system for control of aphids and CMV in lupin crops (Workshop paper 3)

Debbie Thackray, Jenny Hawkes and Roger Jones, Centre for Legumes in Mediterranean Agriculture and Department of Agriculture

KEY MESSAGES

• Aphid outbreaks and CMV epidemics are sporadic in lupins, and for virus control, insecticide applications are not recommended, as they are inefficient at controlling spread of virus by aphid vectors.

• A decision support system (DSS), for use by advisers and growers, forecasts the need for integrated control measures at seeding to diminish virus spread by aphids in lupins.

• The DSS successfully forecasted aphid arrival and build-up, CMV spread, resulting yield losses and infection of harvested seed in lupins in different locations within the WA grainbelt.

• A general forecast for the growing season will be made available in April 2002 through the Internet (http://www.agric.wa.gov.au under CMV in search), PestFax, TopLine, radio, etc.

• Personalised forecasts of likely yield losses based on rainfall and temperature for the user's location, level of CMV infection in seed and sowing details, will be obtainable using the Website.

• The Website also provides background information on CMV and aphids, management recommendations, photographs of aphids and virus symptoms, maps predicting different risk areas, and an explanation of the forecasting model and DSS.

BACKGROUND

Widespread cucumber mosaic virus (CMV) infection poses major limitations on grain yields in lupins, particularly in high rainfall agricultural zones of WA, but its epidemics are sporadic. Aphids also cause sporadic yield losses due to direct feeding damage. CMV is spread in lupin crops by both colonising aphids such as green peach aphid (Myzus persicae) and non-colonising aphids such as oat aphid (Rhopalosiphum padi). Annual and perennial weeds surviving the summer are the main reservoirs of aphids between growing seasons, while CMV is introduced to crops by sowing infected lupin seed.

Planning for CMV control should be done before planting crops, so that integrated control recommendations can be followed at seeding. A forecasting/decision support system (DSS) allows growers to anticipate CMV epidemics and use the integrated control strategy when needed. This strategy includes control measures like planting seed with minimal virus content, promoting early canopy development and stubble retention. The success of systemic pyrethroid applications in controlling barley yellow dwarf virus (BYDV) during the critical first 12 weeks of cereal crop growth has led to attempts to control CMV in lupins in a similar way. However, unlike BYDV, CMV is transmitted non-persistently by aphids so like many other similarly transmitted viruses, it is difficult to control with insecticides. In high value seed crops, regular applications of pyrethroids could be worthwhile for CMV control, but otherwise control is insufficient and uneconomic with single or double applications.

METHODS

In the grainbelt of south-west Australia, the survival of aphids over summer/early autumn determines the likelihood of early aphid arrival and consequent damaging virus epidemics in lupin crops. Abundance of over-summering green plant material is dependent on rainfall. The simulation model that forecasts aphid outbreaks and CMV epidemics in lupin crops therefore uses rainfall during late summer and early autumn to calculate an index of aphid build-up on broad-leaved weeds and crop volunteers in each locality before the winter growing season starts. The index is used to forecast timing of aphid immigration into crops in different localities. For each location, aphid build up, CMV spread from sowing infected seed, likely yield loss and infection of harvested seed are calculated, based on local climate data, lupin variety, level of CMV in seed sown, sowing date and plant density.
RESULTS
The model was validated with 3 years’ detailed field validation data from four different grainbelt sites, and with previous field experiment data representing a wide range of pre-growing season rainfall scenarios, sowing dates, levels of seed infection and plant densities. It gave reliable predictions for aphid arrival in lupins for all sites and years. Predictions for CMV spread were also reliable (Figure 1). Predictions for peaks in aphid population numbers during the growing season were generally good but occasionally too low and early. Predictions for yield loss from CMV infection compared favourably with historical field experiment results for different sites. The model was incorporated into the DSS for use in forecasting CMV risk. The inputs required from the user are location, lupin variety, level of seed infection, sowing date, and plant density. Predictions are given for aphid arrival date, CMV spread, potential yield losses, transmission of CMV into harvested seed and whether applying integrated control measures at seeding is warranted. Maps illustrating the risk from CMV for different areas in the WA grainbelt are produced from the DSS outputs for different localities and levels of seed infection with CMV.

Figure 1. Actual incidence of CMV in lupin field experiments compared with model predictions for incidence at Badgingarra over four years.

CMV/APHID WEBSITE AND DECISION SUPPORT SYSTEM
A general forecast of CMV risk based on DSS predictions for the coming growing season in the WA grainbelt will be made available in April through the CMV/aphid Website (http://www.agric.wa.gov.au under CMV in search), PestFax, TopLine, rural radio, etc. Forecasts will be updated regularly during the growing season using the latest climate data. The Website will provide growers and advisers with access to the general risk forecast using maps to illustrate CMV risk in different areas, and will offer personalised predictions of likely yield losses from CMV and the need for integrated control measures at seeding. These predictions will be based on climate data for the user’s location and seeding details (lupin variety, level of CMV in seed sown, sowing date and plant density). The Website also provides background information on CMV and aphids, photographs of aphids and CMV symptoms, management recommendations for CMV and aphid control and an explanation of the forecasting model and DSS. Further refinement of the DSS will provide reliable forecasts for peaks in aphid populations and the need for insecticide applications to control aphid feeding damage in spring, thereby avoiding unnecessary costs, and providing an environmentally responsible approach to control. A DSS for bean yellow mosaic virus (BYMV) in lupin is also being developed.

ACKNOWLEDGMENTS
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KEY WORDS
CMV, aphids, model, decision support system

GRDC Project No.: UWA 290
Paper reviewed by: Roger Jones and Martin Barbetti