Summary

This project has culminated in the commercialisation of Angel™ strand medic (Medicago littoralis), Australia’s first annual pasture legume cultivar with tolerance to soil residues of sulfonylurea (SU) herbicides.

SU herbicides are widely used in Australian cereal-livestock zones but their soil residues can persist into the following years. Annual medics are highly susceptible to these residues, resulting in reduced dry matter production, lower seed yields and decreased nitrogen (N) fixation.

Field experiments confirm Angel’s ability to tolerate a wide range of SU residues, in many cases outyielding its susceptible parent, Herald®, by over 100% for dry matter production, seed yield and regeneration.

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Conclusions

1. This project confirmed the ability of Angel to tolerate SU residues from a range of application rates, in some cases up to or over twice the recommended label rate, in many cases out-yielding its susceptible parent, Herald, by over 100% for dry matter production, seed yield and regeneration.

2. Notwithstanding its good tolerance to SU soil residues, trial results have also shown that Angel can still be effectively controlled to an acceptable level in-crop by a range of commonly used chemicals. These control options include both non-SU and post emergent SU applications (excluding triasulfuron).

3. In all other aspects, Angel appears to perform identically to its parent Herald. This includes its agronomic performance in the absence of SU residues (dry matter production, seed yield, hard-seed breakdown, maturity etc.). Morphologically it appears to be identical to Herald, bearing the same distinctive leaf markers and pod characteristics. Its response to aphids, Pratylenchus neglectus, boron toxicity and inoculation with commercial Group AL rhizobium are also the same.

4. The potential benefits of growing Angel compared to susceptible cultivars in the presence of SU residues include:
   a. Increased nitrogen fixation resulting in improved soil fertility and available N for following cereals.
   b. Increased seed yields, soil seed reserves, regeneration (all contributing to improved persistence).
   c. Increased legume dominance and competitiveness leading to greater pasture legume production and nutritive value.
   d. Reduced weediness resulting in less carryover of cereal diseases such as Take-all, cereal cyst nematode, Pratylenchus root lesion nematode and crown rot.
   e. More vigorous root systems resulting in: better nodulation and thus N fixation; increased tolerance of root diseases such as Rhizoctonia and Pratylenchus spp.; increased ability to extract soil moisture and nutrients; enhanced ability to take advantage of the residual weed control of SU herbicides.

5. For the first time, farmers now have a viable pasture legume alternative that can increase productivity through increased dry matter production and N fixation in the presence of SU residues but can also be controlled with commonly used in-crop herbicides.

6. Farmers will also have access to management protocols to be applied when using Angel as documented in the attached technical fact sheet (Attachment 1).

7. Angel will be released by Seedmark as Australia’s first SU residue tolerant pasture legume in 2007.

Recommendations

We recommend the use of Angel strand medic as a pasture legume for any of the following situations:

1. Low to medium rainfall (275-400 mm), alkaline loamy sands to loams (pH > 6.5), including with relatively high boron levels.
2. Where SU herbicides are used in the cropping phase.
3. Where SU herbicides are used for summer weed control prior to a pasture phase.
4. In mixtures with other medics where SU residues are not believed to be an issue.

Outcomes

Economic Outcomes

The development, commercialisation and release of "Angel" strand medic (M. littoralis), Australia's first annual pasture legume cultivar with tolerance to soil residues of sulfonylurea (SU) herbicides, should result in more productive and persistent pastures in areas with low rainfall and alkaline soils.

These are most at risk from damaging levels of sulfonylurea (SU) herbicide residues applied in previous cropping phases and are further defined below:

Target area: There are an estimated 8.2 million hectares (M ha) of soils with pH more than 7.0 and average rainfall less than 350 mm in the southern temperate cropping area: South Australia, 3.9 M ha (Upper Eyre Peninsula, Murray Mallee and Upper North); Victoria, 2.0 (Mallee region); Western Australia, 1.2 (Northern wheatbelt, Central wheatbelt and Mallee) and New South Wales, 1.1 (South-western NSW). There is also an additional 2 M ha of cropping in the summer dominant rainfall zones of Queensland and NSW with alkaline soils and growing season rainfall (April - September) of less than 235 mm where the persistence of SU residues presents a threat to pasture legume establishment, production and persistence (Lloyd, pers. comm.).

The potential benefits of growing "Angel" compared to susceptible cultivars in the presence of SU residues include:

a. Increased nitrogen fixation resulting in improved soil fertility and available N for following cereals.
b. Increased seed yields, soil seed reserves, regeneration (all contributing to improved persistence).
c. Increased legume dominance and competitiveness leading to greater pasture legume production and nutritive value.
d. Reduced weediness resulting in less carryover of cereal diseases such as Take-all, cereal cyst nematode, Pratylenchus root lesion nematode and crown rot.
e. More vigorous root systems resulting in: better nodulation and thus N fixation; increased tolerance of root diseases such as Rhizoctonia and Pratylenchus spp.; increased ability to extract soil moisture and nutrients and an enhanced ability to take advantage of the residual weed control of SU herbicides.

Some of the above benefits will translate directly into gains in grain and livestock production while others will result in reduced input costs such as N fertiliser and herbicides. Another benefit of having a productive pasture phase within a cropping enterprise (i.e. mixed farming) is the income stability and reduced financial risk profile associated with having diversified enterprises (e.g. grain, meat, wool and hay) and lower machinery and annual input costs compared to that required for continuous cropping.

A well managed pasture phase can also be an integral tool in preventing herbicide resistance in weeds by the rotation of herbicide groups and use of non chemical weed control (including grazing, spray-grazing, hay-making, green manuring and spray-topping).

Environmental Outcomes

A productive pasture, able to tolerate normally damaging levels of SU soil residues, with more ground cover, and less of an erosion risk.

Achievements/Benefits

Angel strand medic

Key messages

• Angel has excellent tolerance to sulfonylurea (SU) herbicide residues (including summer SU herbicide applications)
• Angel can be controlled in-crop by a range of commonly used herbicides
• Angel is the world's first annual pasture legume tolerant of SU residues
• Angel seed commercially available in 2007
Summary
A new annual medic, Angel, has been bred from Herald strand medic (Medicago littoralis) by John Heap, South Australian Research and Development Institute (SARDI) and Chris Preston (Cooperative Research Centre (CRC) for Weed Management Systems) using conventional mutation breeding. Extensive field testing has confirmed its excellent tolerance to a range of sulfonylurea (SU) herbicide residues. We believe it to be the world’s first annual pasture legume tolerant of SU residues.

The issue
SU herbicides such as chlorsulfuron (e.g. Glean®) and triasulfuron (e.g. Logran®) are used extensively in the cereal-livestock zones of temperate Australia. They are generally viewed as effective, cheap and safe-to-apply herbicides with useful levels of residual activity. However these residues can persist beyond the cropping year into the following year, particularly in areas with alkaline soils and low rainfall, where their breakdown by microbial action and chemical hydrolysis is significantly reduced.

Legumes (including annual medics) are extremely susceptible to even very low residues of SU herbicides which can cause severe stunting, reduced dry matter production, seed yields, persistence and N fixation. Interactions under stressful conditions are also likely to result in increased susceptibility to root diseases and nutrient and moisture stresses. However in the low rainfall alkaline soil areas of temperate Australia where residues are most likely to be a problem, annual medics still remain the best agronomically adapted pasture legume.

Scale
There are about 8.2 million hectares of soils with pH more than 7.0 and average rainfall less than 350 mm in the southern temperate cropping area: South Australia, 3.9 M ha (Upper Eyre Peninsula, Murray Mallee and Upper North); Victoria, 2.0 (Mallee region); Western Australia, 1.2 (Northern wheatbelt, Central wheatbelt and Mallee) and New South Wales, 1.1 (Southwestern NSW). There is also an additional 2 M ha of cropping in the summer dominant rainfall zones of Queensland and NSW with alkaline soils and growing season rainfall (April - September) of less than 235 mm where the persistence of SU residues presents a threat to pasture legume establishment, production and persistence (Lloyd, pers. comm.).

Research summary
Selected results are presented below to highlight key findings over the past four years of field work focused broadly upon the aims of:

1. Testing Angel’s tolerance to SU herbicide residues from previous year applications.
2. Testing Angel’s tolerance to shorter term residues (e.g. summer SU applications)
3. Assessing herbicide options to control Angel in-crop.
4. Confirming Angel’s agronomic similarity to its parent, Herald.

1. Tolerance to longer term SU residues
Trials have been conducted in South Australia, Queensland, New South Wales and Victoria to compare the relative effect of SU herbicide residues applied the previous year, upon Angel and Herald. These have all confirmed Angel’s ability to tolerate SU residues from a range of application rates, in some cases up to or over twice the recommended label rate.

One such trial was conducted on the Mallee Sustainable Farming (MSF) core site at Waikerie, SA on a Mallee sandy loam, average annual rainfall of 275 mm, pH 8.3. In May 2002, triasulfuron was applied as a pre-emergent herbicide to wheat at four rates (0, 7.5, 13 and 26 g.a.i./ha). In May 2003, Herald and Angel were sown into the remaining wheat stubble containing the herbicide residues. Dry matter production and seed yield were recorded in 2003 and regeneration in 2004 (see Table 1).

Table 1. The effect of triasulfuron applied @ 0, 7.5, 13 and 26 g.a.i./ha in 2002, upon the dry matter production and seed yield (kg/ha) of Herald and Angel strand medic in 2003 and regeneration (p/m2) in 2004.

<table>
<thead>
<tr>
<th>Triasulfuron (applied 2002) (g.a.i./ha)</th>
<th>Shoot dry weight (kg/ha, 2003)</th>
<th>Seed yield (kg/ha, 2003)</th>
<th>Regeneration (p/m2, 2004)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herald</td>
<td>Angel</td>
<td>Herald</td>
<td>Angel</td>
</tr>
<tr>
<td>0</td>
<td>3422</td>
<td>3022</td>
<td>652</td>
</tr>
</tbody>
</table>

# Refer to ‘Report Disclaimer’
Angel showed good tolerance of triasulfuron residues at all rates, maintaining stable yields for all parameters measured. However, increasing rates of triasulfuron residues reduced Herald shoot dry weight, seed yield and seedling regeneration by more than 50%.

2. Tolerance to short term SU residues

Early experimental work focused on Angel's tolerance to SU herbicide residues from the previous year (e.g. 10-12 month break). However, the question was posed, "How will Angel tolerate SU residues from a summer application?" e.g. a break of only 3-6 months. We were told that some farmers who had applied SU herbicides in summer were noticing significant damage in their regenerating legume pastures.

A low rainfall, alkaline soil site was selected at Wirrulla, Upper Eyre Peninsula, SA. Herbicide treatments of metsulfuron-methyl # and triasulfuron were applied at 3.5 and 7 g/ha and 9 and 18 g/ha respectively to simulate a summer sulfonylurea herbicide application (i.e. 50 and 100% suggested summer application rates). Herbicide treatments were applied in January and February to allow for an approximate period of 3-4 months to the normal break of the season. Angel and Herald were then sown dry on June 2, 2005 into the prepared soil residues.

Although the break to the season did not occur until mid June, the very dry soil conditions in the interim probably contributed to the persistence of SU residues in the soil. Results from Wirrulla again show the good tolerance of Angel to SU residues compared to that of Herald. In the visual assessment, Angel's production was unaffected whereas Herald was reduced by more than 80%. The later dry matter cuts confirmed these scores with Herald again reduced by 80% in the 100% treatment.

SU herbicides are commonly used to control weeds such as Lincoln weed, caltrop and skeleton weed over summer before going into either a sown or regenerating pasture phase. The ability of Angel to tolerate these short term SU residues will enable it to both survive and to take advantage of the residual moisture and nutrient benefits of weed control whether regenerating or being established for the first time.

3. Assessing herbicide options to control Angel in-crop.

Trials assessing the effectiveness of various herbicides were conducted in 2004 at Minnipa and Netherton (Bell et al, 2004).

The most effective control at both sites in 2004 was achieved by 2,4-D#, MCPA# and Dicamba® with both cultivars controlled by over 70%. The bromoxynil# treatment at Netherton also achieved effective control of over 70%. Of the non-SU herbicides tested, clopyralid# was the least effective but still gave reasonable control of 64% compared to the nil plots.

The post-emergent SU herbicide options (metsulfuron-methyl, chlorsulfuron and iodosulfuron# at half and full label rates) provided reasonable to good control of Angel in crop with a range from 48%-80% control. However while the pre-emergent SU treatments (triasulfuron) achieved control of Herald (55-83%), they were less effective on Angel (6-35%).

In 2005 at Walpeup we tested mixtures of various herbicides and included pre- and post-emergent triasulfuron treatments (Eyre Peninsula Farming Systems 2005 Summary).

All mixtures of either 2,4-D amine, dicamba, MCPA and bromoxynil provided good control of Angel and Herald in-crop ranging from 73-92% control, however the diuron#/ MCPA mixture was less effective (38-43%). The pre- and post-emergent triasulfuron achieved control of Herald (63-80% respectively), but was less effective on Angel (16-32%).

We also tested the effectiveness of metribuzin# and cyanazin# for control of Angel and Herald in field peas with both herbicides proving equally effective upon both cultivars (71-75% control).

Trial results show that Angel can be effectively controlled to an acceptable level in-crop by a range of commonly used chemicals. These control options include both non-SU and post emergent SU applications (excluding triasulfuron). Thus for
the first time, farmers now have a viable pasture legume alternative that can increase productivity through increased dry matter production and N fixation in the presence of SU residues but can also be controlled with commonly used in-crop herbicides.

4. Agronomic similarity of Angel and Herald

An experiment was sown at the Waikerie (SA) MSF core site in 2003 where the performance of Angel was compared with Herald. In the absence of SU residues, there was no difference between Herald and Angel for all parameters measured (establishment, dry matter and seed yield). The trial was left to regenerate in 2004 and there was no difference in plant establishment, indicating a similar hard-seed breakdown pattern.

Detailed Plant Breeding Rights (PBR) studies have confirmed their similarity of morphology and maturity and glasshouse studies have shown them to be both similarly tolerant of boron toxicity.

Glasshouse screening of Angel has confirmed that it has retained the same level of resistance to aphids and P. neglectus as its parent Herald. Nodulation studies also confirm its ability to form an equally effective symbiosis with the current Group AL inoculant strain. The results of these studies were published in the Technical Information Document that was sent to seed companies expressing interest in tendering for the rights to commercialise Angel.

Commercialisation

Plant Breeders Rights were successfully sought and finally granted in May 2006.

Angel was put to open tender in 2005 with Seedmark being the successful licensee.

Initial seed commercial seed production took place in 2005 in the south east of SA. Most of this was retained for further seed production in 2006 with Seedmark planning an ambitious program of over 260 ha, targeting over 100 tonnes of harvested seed.

Contingent on seasonal conditions in the seed growing areas in 2006, certified seed of Angel should be widely available to farmers in 2007.

Acknowledgments

Funding by GRDC is gratefully acknowledged, as is the valuable assistance provided by Peter Schutz, Ben Ward and Neil Cordon, SARDI; Ron Sly, Department of Primary Industries (DPI) Walpeup, VIC and David Lloyd, Toowoomba, QLD DPI.

References

Other research

Branched broomrape control

The current branched broomrape quarantine area in South Australia is about 300,000 ha with an infested area of about 30,000 ha. Existing research has shown that the Group B sulfonylurea residual herbicides, Glean®#, Ally®# and Logran®# applied at a quarter of the label rate have stopped emergence of broomrape in the year of application and reduced it the following year (Matthews 2004). Group B herbicides are also an effective means of controlling many of the preferred broadleaf weed hosts of broomrape. Current research suggests that medics are an infrequent host of broomrape and that the risk of parasitism is likely to be quite low (compared to canola, cretan weed, wild turnip or daisy weed) at the current levels of broomrape seed in the soil in the quarantine area (Virtue et al, 2002). Predominantly it is the presence of broadleaf weeds within medic pastures that host broomrape. Dense medic pastures alone have been found to reduce broomrape emergence (Matthews 2002). However, in combination with sulfonylurea (SU) herbicide residues from the previous cropping phase, the control of broomrape could be even more effective.

We believe there is an opportunity to incorporate Angel® into an integrated weed management technique that both reduces broomrape and contributes to a profitable and sustainable farming system. It would bring the added benefits of increased
pasture production in the presence of the SU herbicide residues, increased nitrogen fixation, enhanced competitiveness against weeds and an improved cereal root disease break for subsequent crops.

Broadleaf weed control in medic pastures

Linked to the above issue, but also with wider application is the issue of Angel’s tolerance to foliar applications of the imidazolinone\(^\#\) family of herbicides (e.g. Spinnaker\(^{\#\#}\), Raptor\(^{\#\#}\), Onduty\(^{\#\#}\)). This has yet to be tested but if found tolerant, would increase the options for broadleaf weed (and some grasses) control in medic pastures.

Of specific interest to commercial seed growers is whether strategic use of low rates of chlorsulfuron\(^{\#}\) can be used pre-sowing, in order to provide residual control of susceptible background medics, particularly naturalised burr medic (\低迷ago polymorpha\)), in Angel seed crops. It is becoming increasingly difficult for seed growers to find land sufficiently free of background medic for certified seed production. Burr medics typically have high residual hard-seed levels and with their staggered germination can be very hard to predict and control in certified medic seed crops. We have conducted some pilot studies suggesting the effectiveness of this approach but need to validate this further with more in-depth studies.

References


Intellectual property summary


A change of denomination from “FEH-1” to “Angel\(^{\#}\)” was accepted (27/10/2004).

A change of ownership to include Adelaide Research and Innovation Pty Ltd was accepted (31/10/2005). Plant Breeders Rights were granted on 2nd May 2006.

Additional information

Further information is provided in the attached technical fact sheet.

Relevant links to more recent research: