Identifying herbicide impacts on N fixation of pulses

Summary
The Mallee Sustainable Farming Project (MSFP) (DLW1) identified poor nitrogen (N) fixation in pulses in the Mallee and indicated that this is likely to be due to commonly used herbicides. This project has shown that a range of current recommended grass and broadleaf herbicides can reduce nodulation and N fixation by up to 50%. The herbicide impacts are stronger and more consistent in low rainfall sites. An economic evaluation has shown that reduced N input and in some cases reduced pulse yields in these environments can lead to negative returns. Crop yellowing after herbicide application is strongly correlated to nodule reduction and is a good indication of negative impacts of the herbicide.

Report Disclaimer
This document has been prepared in good faith on the basis of information available at the date of publication without any independent verification. Grains Research & Development Corporation (GRDC) does not guarantee or warrant the accuracy, reliability, completeness or currency of the information in this publication nor its usefulness in achieving any purpose. Readers are responsible for assessing the relevance and accuracy of the content of this publication. GRDC will not be liable for any loss, damage, cost or expense incurred or arising by reason of any person using or relying on information in this publication. Products may be identified by proprietary or trade names to help readers identify particular types of products but this is not, and is not intended to be, an endorsement or recommendation of any product or manufacturer referred to.
Herbicide induced reductions in nodulation and N fixation were identified as contributing to the poor success of legumes and lack of cereal yield response following legumes in low rainfall (<300mm p.a.) Mallee environments. Herbicide damage to legumes was evident across South Australia, however it was less apparent in higher rainfall areas and was seasonally variable.

Crop yellowing following herbicide applications may prove useful as an indicator of potential long term damage to the legume-rhizobia symbiosis and subsequent N benefit to the system.

Soil N, crop species or variety and spray time all contribute to the severity of herbicide induced damage to the legume-rhizobia symbiosis. Of the herbicides tested, flumetsulam™ (Group B) was the only one to consistently reduce yields across sites and seasons. Yield declines of 10-40% were also apparent following late herbicide applications (flowering).

Including the value of N from biological N fixation in the gross margin (GM) of legumes is a good way to measure their true value. In low rainfall environments, losses of biologically fixed N or reduced yields due to herbicides will have a much greater impact on the GM (10-50%) compared to higher rainfall, more productive zones where negative impacts of herbicides are well buffered and impacts on GM are less than 20%.

Recommendations

1. Growers should be aware that herbicides which cause yellowing in pulses in low rainfall cropping regions such as the Mallee are highly likely to be reducing the number of effective nodules on the plant roots and nitrogen fixation. When considering legumes as an option in low rainfall regions, growers should identify their prime reason for choosing a legume in rotation. If weed and disease control is a priority, a potential decrease in N fixation may be less of a concern. Weed management should not be compromised.

2. To reduce the risk of herbicide damage to legumes growers should;
   a. Adopt an integrated weed management approach to reduce weed populations on farm and spray strategically to reduce the number of herbicide applications required in a legume crop.
   b. Aim to control weeds early in the season with either pre-sowing or early post-sowing herbicide applications.

3. Economic evaluation of biological N derived from legumes in GM estimates would aid in on-farm decision making. In low rainfall cropping regions like the Mallee, alternative break crops such as canola may provide a greater economic return.

4. Assessment of legume varieties for herbicide tolerance should not rely solely on yield parameters, but also include a measure of N fixation, since this is a key reason for including legumes in rotation.

Outcomes

This project, to our knowledge, is the first comprehensive field based study into herbicide effects on the legume-rhizobia
symbiosis in Australia. It has therefore contributed substantially to knowledge on legumes and N fixation and their agronomic management.

Specific outcomes include:

1. Common post-sowing pre-emergent and post-emergent herbicides (broadleaf and grass) used in legumes were identified as agents which can result in crop yellowing and reductions in nodulation, N fixation, yield and N benefit to the farming system. The risk for herbicide induced damage to legumes is strongly influenced by environmental factors such as season, location and rainfall. Herbicide damage was more severe in 2003 than 2004 and most severe at the lower rainfall sites of Waikerie and Minnipa in 2003.

2. Both grass and broadleaf herbicides could reduce nitrogen fixation. A key outcome of trials at Waikerie was the strong correlation between crop yellowing and reduced nodule number per plant. This may be used as a tool by growers to identify if their crop is at risk of reduced nitrogen fixation. With the exception of the group B herbicide flumetsulam, which consistently reduced crop yields across sites and seasons, damage caused by herbicides was highly variable. Consequently no clear spraying guides for growers can be provided.

3. Based on results from field trials over four sites, agronomic factors such as variety, N availability and spray time can significantly affect the potential for herbicide damage to legumes. Application of N following herbicide application lowered nodulation and in the presence of herbicides, lowered N fixation. Herbicides were less likely to cause reductions in N fixation when applied pre-sowing compared to post-sowing applications. Late applications of grass and broadleaf herbicides close to or during flowering had little impact on N fixation but significantly reduced crop yields (10%-40%).

4. The economic ramifications of herbicide damage to legumes vary with location. In marginal cropping regions such as Waikerie, there is little room for losses in the crop gross margin. In 2003, losses in N from N fixation caused by a single herbicide application effectively reduced returns (gross margin+$N benefit) by 38-50%. In comparison there were only small losses in N fixation observed at Minlaton, where GMs are significantly higher and therefore able to buffer incurred losses.

5. A MSFP (Mallee Sustainable Farming Project) Farm Talk article, GRDC Updates and Farm Magazine articles will make growers aware of the potential for herbicide damage to N fixation and aid in their on-farm decision making.

Achievements/Benefits

Early observations from the Mallee Sustainable Farming Project (DLW1) showed a lack of rotation response in wheat following pulses or legume rich pastures. A lack of inherent root diseases and low levels of nitrogen (N) fixation were identified as contributing factors. Controlled environment experiments and field trials at Waikerie, South Australia, identified common pre-sowing and in-crop herbicides as detrimental to N fixation.

The aim of this project was to assess the impact of common herbicides on N fixation by key pulses in southern Australia, considering the effect of environmental and agronomic variables and providing an economic evaluation of results. The project was successful in achieving all contracted outputs.

Initially, controlled environment experiments were conducted to develop a rapid screening method to assess herbicide effects on pulses that reflect those seen in the field. Results from these experiments were highly variable within and between experiments. Nodulation was clearly the parameter most sensitive to herbicide applications, with reductions evident in peas and vetch grown in two test soils. However, following extensive work, a soil based controlled environment assay was found to be unsuitable for studies into herbicide effects on the legume-rhizobia symbiosis, as it significantly underestimated the herbicide impact when compared to field evaluations. The results indicated a strong environmental influence over herbicide effects on N fixation by grain legumes.

Field trials were conducted over two years across SA (Waikerie, Avon, Minnipa and Minlaton) in collaboration with MSFP and the South Australian Research and Development Institute (SARDI). The trials assessed the effect of commonly used post-emergence herbicides (Group A, B, C and F) on the growth and N fixation by legumes (peas, lentil, vetch, medic). Soil types ranged from alkaline sands to sandy loams and annual rainfalls from 250-450mm. The key trial site was at Waikerie in the Murray Mallee where herbicide effects on N fixation were initially identified as a constraint.

In 2003 at Waikerie, five out of six of the post-emergent herbicides (broadleaf and grass) tested reduced nodulation of peas. There was a significant relationship (P<0.001) between effective nodule number and yellowing of the youngest fully expanded leaf three weeks after herbicide application ($R^2 = 0.57$). Crop yellowing following herbicide application is a tool which could be used by growers to identify possible herbicide induced damage to the legume-rhizobia symbiosis.

# Refer to ‘Report Disclaimer’
Early post-emergent herbicide treatments generally had no significant effects on above-ground dry matter production. Flumetsulam was the only herbicide to significantly reduce crop yield. However, three of the herbicides tested at Waikerie significantly reduced the percentage N derived from the atmosphere (Ndfa) and N benefit to the system, with the remainder showing non-significant reductions. Generally, agronomic studies designed to test legume sensitivity to herbicides in the field focus predominately on dry matter and yield, however project results show that this can be misleading. Yield and dry matter do not indicate the source of crop N. A reduction in N fixation can be compensated for with an increase in the uptake of mineral N from soil, ultimately affecting the N benefit to the system from the legume crop. The effects of herbicides on the legume-rhizobia symbiosis were not limited to peas. The negative effects of herbicides were also seen on various parameters in vetch and medic at Avon and Minnipa respectively in 2003.

The magnitude of herbicide effects on the symbiosis was influenced by edaphic and environmental variables. In this study, three of the four sites showed significant reductions in nodulation early in the season however, % Ndfa was only affected at the lower rainfall sites of Waikerie and Minnipa. In addition, herbicide effects were more pronounced in 2003 than in 2004 and over the two year period, herbicide effects were most severe at Waikerie. Factors contributing to severity of herbicide damage include herbicide uptake (highest in an actively growing plant), metabolism by the plant and availability in the soil post-spraying. Where there are sufficient resources (nutrients and water) available and plant growth is not limited, the crop can recover from any damage more rapidly than in a stressed environment.

In 2004 trials, effects of various agronomic parameters were assessed for their impact on herbicide induced reductions in N fixation.

A brief summary of results include:

Nitrogen: Applications of granular nitrogen immediately following herbicide applications reduced nodulation and N fixation in the presence of herbicides.

Variety: The susceptibility of three pea varieties (Kaspa, Parafield and Sturt) was assessed at Minlaton in 2004. Varieties varied in their susceptibility to herbicides. Sturt peas showed damage early in the season, but recovered quickly with no negative effects on N fixation observed. In contrast, Kaspa and Parafield varieties showed significant reductions in N fixation following some herbicide applications.

Application Time: The effect of timing of herbicide application (post-sowing pre-emergent (PSPE), post-emergent or start of flowering) was assessed over three sites. PSPE applications were less harmful to the symbiosis than post-emergent applications. Late herbicide applications (flowering) caused no significant reduction in N fixation but resulted in significant yield penalties.

Sulfonylurea (SU) Herbicide Residues: SU residues (one year after application) did not interact significantly with ‘in crop’ herbicide applications in peas grown at Waikerie. Detrimental effects of SU residues on the legume-rhizobia symbiosis were greater than those of in-crop herbicides.

Financial ramifications

Nitrogen fixation by the legume-rhizobia symbiosis has been estimated to account for 80% of the nitrogen found in Australian grains (Howieson and Herridge, 2005). With a steady rise in the price of oil, the rising cost of N fertiliser will surely follow, placing an even higher value on symbiotic nitrogen fixation. Economic analysis showed that crops in higher rainfall regions are able to buffer herbicide effects compared to those in low rainfall regions, where small changes in N benefit will result in an unprofitable crop. The direct cost of herbicides reducing % Ndfa and N benefit in locations such as Waikerie in SA needs to be weighed up against the positive benefits from improved weed control. Reduced productivity due to weeds either in the legume crop or the following cereal could compensate the losses in N from reduced N fixation. Our advice to legume growers, particularly those in low rainfall regions (<300mm p.a.), is to be ‘alert but not alarmed’ with regard to herbicide impacts on the legume-rhizobia symbiosis, recognising that they may be overestimating N benefits from legumes in some years. The extent of crop yellowing following herbicide application can provide a useful indication of reduced N benefit.

Other research

One alarming outcome of this study is that a single herbicide application can result in such large decreases in N benefit (i.e. reduction in fixed N and loss of soil N). A single herbicide application to a legume crop is most unlikely in a cropping situation
with growers applying anywhere between two and six herbicides to the one crop from pre-sowing to harvest. Further research is required to determine if several herbicide applications can have an additive negative effect on N fixation or if the majority of damage occurs following the initial application and subsequent applications have a lesser impact on the symbiosis.

Due to the complexity of environmental (rainfall, soil type) and agronomic (N, variety, spray time, crop health) factors that determine the severity of herbicide effects on the legume-rhizobia symbiosis, no clear rules can currently be given to growers regarding spray options. Complex herbicide trials over several years would be required to achieve this. Initially it is suggested that current trials which screen for legume tolerance of herbicides should include some measure of nitrogen fixation and not rely solely on yield measurements.

Australian soils are inherently low in nutrients essential for crop growth. With a steady rise in fuel prices and an ever increasing demand for sustainable farming biological N fixation will continue to be a vital component of Australian agriculture. It is therefore essential that the parameters that can affect this phenomenon are understood. A more detailed understanding of the mechanisms behind herbicide induced damage to the legume-rhizobia symbiosis (in particular multiple herbicide applications) and factors which influence this will contribute to better predicting legume susceptibility in the field. This will ultimately lead to increased N benefits in the field, particularly in low rainfall cropping regions.

Additional information
Conference Proceedings


