

**POTENTIAL FOR SITE SPECIFIC
MANAGEMENT OF *Lolium rigidum* (annual ryegrass)
IN SOUTHERN AUSTRALIA**

Samuel P Trengove

Thesis submitted for the degree

of

Master of Agricultural Science

In the

Faculty of Sciences

School of Agriculture, Food and Wine

Discipline of Plant and Pest Science

The University of Adelaide

9 December, 2013

Contents

Abstract.....	5
Declaration.....	8
Acknowledgements.....	9
1 Literature Review.....	11
1.1 Australian agricultural trends.....	11
1.2 Australian weed issues.....	16
1.2.1 Cost of weeds.....	16
1.2.2 Annual Ryegrass (<i>Lolium rigidum</i>).....	17
1.3 Temporal and Spatial Population Dynamics of Weeds.....	26
1.3.1 Spatial distribution of weeds.....	26
1.3.2 Patch stability.....	27
1.4 Decision Making for Variable Rate Herbicide Applications.....	32
1.4.1 Crop competition with weeds.....	32
1.4.2 Herbicide dose response.....	33
1.4.3 Economic thresholds.....	34
1.4.4 Models.....	35
1.5 Benefits of Precision Weed Management.....	37
1.5.1 Herbicide savings.....	37
1.5.2 Improved weed control.....	39
1.5.3 Reduced phytotoxicity effects on crops.....	41
1.5.4 Herbicide efficacy targeted to soil conditions.....	42
1.5.5 Environmental and food safety concerns.....	43
1.6 Patch Detection Methods.....	44
1.6.1 Manual detection.....	44

1.6.2	Spectral reflectance techniques.....	45
1.6.3	Machine vision.....	51
1.6.4	Chlorophyll fluorescence	56
1.7	Resolution, Interpolation and Map Production	58
1.8	Research Aims.....	63
2	Mapping <i>Lolium rigidum</i> Patches Using Spectral Reflectance Sensors.....	64
2.1	Introduction	64
2.2	Materials and Methods.....	65
2.2.1	Stationary sensor measurement.....	67
2.2.2	Replicated plot trial in wheat.....	76
2.2.3	Paddock scale sensor measurements with point assessments.....	77
2.2.4	Aerial imagery from unmanned aerial vehicle (UAV)	81
2.3	Results.....	82
2.3.1	Stationary sensor measurements	82
2.3.2	Replicated plot trial in wheat.....	105
2.3.3	Paddock scale sensor measurements with point assessments.....	107
2.3.4	Aerial imagery from unmanned aerial vehicle (UAV)	111
2.4	Discussion.....	114
3	Patch Stability in <i>Lolium rigidum</i> Populations.....	123
3.1	Introduction	123
3.2	Materials and Methods.....	124
3.3	Results.....	130
3.4	Discussion.....	136
4	Post Emergence Herbicide Efficacy Dependence on <i>Lolium rigidum</i> Density	140
4.1	Introduction	140

4.2	Methodology	140
4.3	Results	142
4.4	Discussion.....	146
5	Herbicide Treatment Options for Patch Management of <i>Lolium rigidum</i> and their Economic Implications.....	148
5.1	Introduction	148
5.2	Methodology	149
5.2.1	Post emergence herbicide trials in lentils	149
5.2.2	Pre-emergence herbicide trials in wheat	153
5.3	Results.....	156
5.3.1	Post emergence herbicide trials in lentils	156
5.3.2	Pre-emergent herbicide trials in wheat	160
5.4	Discussion.....	175
6	Conclusions	183
6.1	Mapping <i>Lolium rigidum</i> Patches Using Spectral Reflectance Sensors .	183
6.2	Patch Stability in <i>Lolium rigidum</i> Populations.....	185
6.3	Post Emergent Herbicide Efficacy Dependence on <i>Lolium rigidum</i> Density	186
6.4	Herbicide Treatment Options for Patch Management of <i>Lolium rigidum</i>	186
6.5	Future Research Directions	187
7	References.....	188

Abstract

Weed spatial distribution is typically patchy and *Lolium rigidum* (annual ryegrass) distribution is no exception. The potential for site specific management of annual ryegrass was assessed to increase farmers' financial returns through reduced herbicide costs while maintaining weed control in commercial paddocks near Bute and Tarlee, SA. Commercially available sensors N-Sensor, Greenseeker, Crop Circle and digital RGB camera were assessed for their ability to detect annual ryegrass patches in growing lentil, pea, canola and wheat crops at various growth stages. The best platform for annual ryegrass detection was the digital camera with an Excess Red – Excess Green algorithm applied to the image to delineate plant matter from background soil. The best relationship for this system was an R^2 of 0.85 and 0.86 in Ronnies and Stones North paddock respectively when the lentils and peas were at the 10-12 node stage and the annual ryegrass was at early-mid tillering.

The N-Sensor was used to map annual ryegrass in lentil, pea and canola crops with R^2 values from 0.15 to 0.88. Poor correlations were related to misclassification due to the presence of other weed species or variability in crop growth. When these effects were accounted for, the correlations improved with R^2 from 0.27 to 0.86.

Four paddocks were monitored in three seasons between 2006 and 2009 to determine stability of annual ryegrass populations at fixed locations. Annual ryegrass populations were relatively stable with high density locations typically staying high between seasons and low density locations typically staying low. The

relationships between seasons ranged from R^2 0.53 to 0.94. Of the locations that changed ranking from being relatively low density to relatively high between seasons many could be explained by their proximity to the patch boundary.

Herbicide efficacy dependence on population density was assessed by counting a wide range of annual ryegrass densities and recounting the surviving plants after the application of herbicide. It was found that efficacy of clethodim, imazapic and imazapyr was independent of annual ryegrass density between zero and 1600, 2000 and 6000 annual ryegrass plants m^{-2} in three respective paddocks. However, there were more plants surviving at the high density locations, due to the higher initial population. This greater number of survivors is likely important for patch persistence.

Small plot herbicide trials were targeted at high and low density annual ryegrass sites in lentils and wheat to assess the potential for variable applications of clethodim in lentils and pre-emergence herbicides in wheat. Economic returns from variable rate applications over a uniform application cannot exceed the cost of the herbicide used uniformly at the maximum rate unless it causes yield loss due to phytotoxic crop effects. The maximum herbicide saving that could be achieved with clethodim in lentils was $\$5.42 \text{ ha}^{-1}$ and this declined as high density patch area increased. The value of applying pre-emergence herbicides site specifically was much greater, reducing herbicide costs by $\$14.60$ and $\$15.30 \text{ ha}^{-1}$ in two paddocks where high density weed infestations affected 30 and 35% of the paddock respectively. This is including additional application costs of $\$7.50 \text{ ha}^{-1}$ for variable rate applications. Savings increased as high density patch area decreased. Targeting patches reduces the risk of return from high cost treatments

and makes it economic to treat smaller patches, as low as an infestation level of 5.6% of the paddock. Where cheaper herbicides or nil treatments were applied to low density sites there were no significant differences in annual ryegrass densities in the year of application or the following year.

Site specific management of annual ryegrass has merit with pre-emergence herbicides. The patches are able to be mapped in crop and patch stability means the map can be used in subsequent seasons to target pre-emergence herbicides.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library Search and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Signed: Sam Trengove

Date:

Acknowledgements

This thesis would not have been possible without the support and contribution of many people. To Chris Preston my principal supervisor many thanks and gratitude for your guidance and feedback throughout this study. Thank you for the time dedicated to helping me finish, reviewing drafts and guidance in analysis and interpretation of results. My deepest thanks to Allan Mayfield for first encouraging me to embark on post graduate study, and encouraging my interest in the topic of site specific weed management. The importance of Allan and Sue Mayfield's support and understanding as my full time employer while I was undertaking part time study cannot be overstated, not only with my study but also with the opportunities for me to travel and learn from others during this time. As my supervisor Allan's guidance and drive were motivational, particularly in the early years of field work, and I thank Allan for continually pushing me to finish. John Heap has been a terrific sounding board throughout this study and his ideas and suggestions are always well considered. I have enjoyed our discussions about new and emerging technologies and the potential for these technologies and the findings herein to have application in the field. Many thanks John!

Thank you to Mark and Nola Branson, Max, Ros, Bill and Michelle Trengove and Jamie Smith, the farmers that allowed me to conduct trials on their properties, hopefully without too much disruption of your day to day activities.

Many thanks go to Stuart Sherriff for your assistance in the field. Together we counted 65,790 ryegrass plants, 48,104 wheat plants, 32,672 ryegrass heads,

6,169 wild oat plants, 1,326 wild oat heads, 665 snail medic plants and a handful of brome grass, lentil, pea and canola plants. Your good company and sense of humour mean these tasks that might be considered repetitive and boring are remembered with a sense of enjoyment.

Thank you to Mum and Dad for your love and support during this time, including helping me peg trials, do plant counts and finding a lost clipboard. Thanks Ben and Lauren for opening your home (and fridge) to me when I needed a base in Adelaide in the early years. Finally, thanks Veronica for your love and support in the latter years, your understanding is always appreciated!