final report

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A Coordinated Approach to Minimising the Impact of Annual Ryegrass Toxicity (ARGT) in Agriculture

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Abstract

Annual ryegrass toxicity (ARGT) is an acute and often-fatal neurological disease caused by consumption of annual ryegrass (*Lolium rigidum*) seed heads infected with the bacterium *Rathayibacter toxicus*.

The aim was to reduce the cost of ARGT to agriculture, currently estimated at $40 million/year in Western Australian alone.

The project undertook to and succeeded in

- improving ARGT research and extension coordination
- developing better adoption and greater effectiveness of current knowledge and practices for reducing the risk of ARGT
- undertaking multiple on-farm demonstration studies to examine the use of Safeguard ryegrass - a variety that will not cause ARGT
- promoting greater uptake and effectiveness of twist fungus for biological control of ARGT. Successful establishment was shown to reduce the levels of deaths by 97% and monitoring required by 70%.
- implementing an effective ARGT surveillance system in order that changes in the incidence of ARGT and causative organisms can be monitored.

Using combinations of these factors throughout the project, influence was acknowledged in 2006 by 18% of livestock producers in WA & SA, which translates into a cost saving to industry of approximately $5.9M. It is expected this figure is even greater since the project conclusion.

Executive Summary

Annual ryegrass toxicity (ARGT) is an acute and often-fatal neurological disease caused by consumption of annual ryegrass (*Lolium rigidum*) seed heads infected with the bacterium *Rathayibacter toxicus*.

The project focused on ARGT and its management relevant to the farming systems in South Australia and Western Australia. Management systems developed, ensuring close ties between researchers, farmer groups and industry bodies. Strong collaborative links were fostered with the South Australian Research and Development Institute (SARDI) and other related projects, to enhance the development of management options. This cooperative contribution delivered information to enable landholders to explore various options available to them to manage ARGT in an economical and sustainable way.

The project focused on

- improving research and extension coordination
- developing better adoption and greater effectiveness of current knowledge and practices for reducing the risk of ARGT
- undertaking multiple on-farm demonstration studies to define the optimal use of a new ryegrass (Safeguard) that will provide equal or better nutritional value to that of naturalised Wimmera ryegrass but will not cause ARGT
- promoting greater uptake and effectiveness of twist fungus for biological control of ARGT
- implementing an effective ARGT surveillance system in order that changes in the incidence and impact of ARGT can be monitored.

The ability of the combination of these factors to reduce the cost of ARGT to agriculture, estimated to be approximately $40 million/year in Western Australian alone, was examined.

Project Achievements

- The project team formed a Reference Group of key individuals in ARGT research and development, industry and regional representatives that met bi-annually to ensure guidance to project plans and activities.
- Six Demonstration Sites, taking into account rainfall and season length variation, were set-up spanning the Agricultural region in the south-west of WA. The sites were chosen on the basis that ARGT organisms were either, confirmed as present, or extremely likely to exist based upon previous evidence but where Twist Fungus inoculum had not previously been applied. The sites allowed this biological control agent to be tested across a wide range of environments and in conjunction a comparison of Safeguard with background ryegrass. The demonstrations highlighted the same difficulties that producers have experienced with establishing and maintaining these controls, indicating that they are not as robust as originally thought.
- A comprehensive Information Package was developed from information gathered from a multitude of sources including published and unpublished written materials, and from personal communications with researchers and farmers, including case studies in both WA & SA. Information generated from data collected during the progress of this and associated projects, was also included. The package was continually promoted, in various forms, throughout the project via presentations to growers, media releases, radio broadcasts, presence at major agricultural field days and functions (e.g. crop & livestock updates), Agricultural Memos, and magazine articles. The Department of Agriculture and Food WA will continue the maintenance and promotion (in WA) of this work, until future plans are developed by NATCAT.
- A variety of monitoring and surveillance methods were examined. Some were utilised to try to capture the spread and impact of ARGT, including the causal organisms. The

detection of causal organisms in WA and the Eyre Peninsula region of SA showed that the distribution is far greater than originally expected. This information has been used to warn producers to implement control measures prior to suffering ARGT outbreaks. Cost prohibited the monitoring of the impact of ARGT through the ABS Agricultural Census.
- Information has been collected and complied to help develop a risk management strategy that will lead to a predictive service for producers of the likely severity of ARGT outbreaks on a regional basis.

Extrapolation from the project demonstrations indicates that successful establishment of twist fungus can reduce the levels of deaths (by 97%) and monitoring required (by 70%). Utilising combinations of the factors above throughout the project, influence was acknowledged in 2006 by 18% of livestock producers in WA & SA, which translated into a cost saving to industry of approximately $5.9M.

It is expected that this influence expanded throughout the continuation of the project until its conclusion in 2008, and also beyond, resulting in an even larger value to the grazing industry.

Conclusions & Recommendations
- Both Safeguard ryegrass and Twist fungus have their place in contributing to ARGT control, but that they are not as robust, as originally thought. Further evaluation of these techniques should take into account the site preparations required to best benefit these controls individually and should explore strain variations in twist fungus for adaption to drier areas.
- The pursuance of non-toxigenic Rathayibacter strains, as an additional management control option, is recommended to compliment both Safeguard and Twist fungus and help to provide a more robust, integrated ARGT control. It is likely that they may have better adaptation in drier areas and seasons than twist fungus.
- Both the non-toxigenic Rathayibacter strains and the vaccine appear likely to provide the next most beneficial advances in ARGT control management options.
- The information package developed by the project team is a giant leap forward from where it was in 2005 when the project commenced. The materials produced, the extension campaign, and the continued updating by DAFWA have all contributed to changing the status of ARGT, by giving producers a more simplified, but complete picture of the ARGT story.
- Major advances have been made in this project in mapping the distribution of the causal organisms, but more work is needed to understand the total ecology of the nematode, bacteria and plant (including their interaction with climatic affects), before accurate prediction of toxicity can be considered.
- Risk prediction is currently limited to gross seasonal characteristics and pre-disposition based upon previous paddock histories that contribute to the build-up of organism populations.

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1 Background

Annual ryegrass toxicity (ARGT) is an acute and often-fatal neurological disease caused by consumption of annual ryegrass (*Lolium rigidum*) seed heads infected with the bacterium *Rathayibacter toxicus*.

This project was originally focused on ARGT and its management relevant to the farming systems in the Central and Northern agricultural areas of Western Australia. Management systems were to be developed, ensuring close ties between researchers, farmer groups and industry bodies. Strong collaborative links were required with the South Australian Research and Development Institute (SARDI) and other interstate projects with the development of management options. Sharing of common work experiences sought to allow delivery of information to enable landholders to explore various options available to them to manage ARGT in an economical and sustainable way.

The project focused on

- improving research and extension coordination
- developing better adoption and greater effectiveness of current knowledge and practices for reducing the risk of ARGT
- undertaking multiple on-farm demonstration studies to define the optimal use of a new ryegrass (Safeguard) that will provide equal or better nutritional value to that of naturalised Wimmera ryegrass but will not cause ARGT
- promoting greater uptake and effectiveness of twist fungus for biological control of ARGT
- implementing an effective ARGT surveillance system in order that changes in the incidence and impact of ARGT can be monitored.

The ability of the combination of these factors to reduce the cost of ARGT to Australian agriculture, currently estimated at $40 million/year in Western Australian alone, was examined.

2 Project Objectives

2.1 Reference Group

Management program implemented. A reference group of key ARGT stakeholders and researchers formed to provide critical review and direction on ARGT issues and opportunities and to ensure coordination of ARGT research and communication.

2.2 Management options

Create a minimum of 2 robust and effective management options for the control of ARGT that takes into account the whole farming system.

2.3 Information package

Deliver one generic, high quality information package that will be made appropriate at district level on best agricultural practice for managing ARGT. The package will enable farmers to improve profitable and sustainable outcomes.

2.4 Monitoring & Risk Management - Compile information to develop:

2.4.1 Monitoring methodology

A methodology to monitor the distribution and economic consequences of ARGT.

2.4.2 Risk management strategy

A risk management strategy that enables the development of a predictive tool for ARGT occurrence.

3 Methodology

3.1 Reference Group

A Reference Group of key individuals in ARGT research and development, industry and regional representatives was formed and scheduled regular meetings to ensure guidance to project plans and activities. The group met bi-annually, face to face and/or through tele- and video-conferences. Interim decisions were made through circulated emails.

3.2 Management Options

There was a wide range of management options considered, and after taking into account previous research work, it was determined that further investigation of Safeguard ryegrass and Twist fungus would provide the most benefit towards generating more robust management options. To assist in efficient use of resources, the design of these sites included both management options, individually and in combination. Additional detail of the methods is available in Appendix 1.

3.2.1 Safeguard Ryegrass

A series of six demonstration sites, taking into account rainfall and season length variation, were set-up spanning the Agricultural region in the south-west of WA. The sites were chosen on the basis that ARGT organisms were either, confirmed as present, or extremely likely to exist based upon previous evidence. Five other sites, where a comparison of Safeguard with background ryegrass was possible, were also monitored. In accordance with established knowledge of seeding rate (8kg/ha) and management, the six new sites were prepared and planted in May 2005.

3.2.2 Twist Fungus

A series of six demonstration sites, taking into account rainfall and season length variation, were set up spanning the Agricultural region in the south-west of WA. The sites were chosen on the basis that ARGT organisms were either, confirmed as present, or extremely likely to exist based upon previous evidence but where Twist Fungus inoculum had not previously been applied. The site distribution allowed this biological control agent to be tested across a wide range of environments. Previous and concurrent work (Allen, 2008) demonstrated difficulty in obtaining establishment in some environments. The inoculum was applied at a rate of 2 kg/ha (10 times recommended) to try to eliminate the normal lag phase of 3 to 5 years for influential establishment with the aim of demonstrating the effectiveness after successful establishment.

3.3 Information Package

3.3.1 Development

Information was gathered from a multitude of sources including published and unpublished written materials, and from personal communications with researchers and farmers, including case studies in both WA & SA (Appendix 2). Information that was generated from data collected during the progression of the project was also included.

3.3.2 Promotion

The information package has been continually promoted in its various forms throughout the project via presentations to growers, media releases, radio broadcasts, presence at major agricultural field days and functions (e.g. crop & livestock updates), Agricultural Memos, and magazine articles.

3.3.3 Succession Plan

A plan is in place for Department of Agriculture and Food WA to continue the maintenance and promotion of work from this project until the next phase of development is decided by a meeting of NATCAT.

3.4 Monitoring & Surveillance

3.4.1 Road Side Surveys

Roadside surveys took place in areas of Western Australia, South Australia and western Victoria where ryegrass is known to occur. Strategic sampling, based upon catchments and sub-catchments, was conducted along roadsides, using visual recording at the time of sampling and then confirmed by follow-up testing in the laboratory.

3.4.2 Farmer Surveys

<u>Face to face farmer survey</u>: The surveys were carried out at all the major field days attended by the team and also many meetings and seminars where presentations were given. They were designed to give an insight into the prevalence, severity and level of reporting of ARGT outbreaks, farmer knowledge of management options and to get contact details for the case studies and provision of additional information to those who requested it. A copy of the survey form is attached in the appendices.

<u>MLA Feedback Magazine survey</u>: This survey was included in the MLA Feedback magazine June 2006 issue, to be returned by fax or reply paid envelope. It was designed to take the place of the ABS survey, on a voluntary basis through Feedback readers, to give an insight into the prevalence, severity and level of reporting of ARGT outbreaks, farmer knowledge of management options and get contact details for the case studies and provision of additional information to those who requested it. A copy of the survey form is attached in the appendices.

3.4.3 ABS Census & Surveys

In the original proposal, asking questions in the census of the Australian Bureau of Statistics (ABS) was planned to be the way to monitor the distribution and economic consequences of ARGT. This would be a consistent form of monitoring that could be used into the future to keep a track of ARGT. An approach was made to ABS to include a series of questions into the 2006 Census.

3.5 Risk Management Strategy

3.5.1 Risk Prediction Modelling

The requirement of this project was to compile information to develop a risk management strategy that enables the development of a predictive tool for ARGT occurrence.

3.5.2 Risk Prediction Analysis

Finding a percentage of the export hay testing positive to get a prediction on severity of season for likely ARGT outbreaks. This was not a part of the original proposal, but a preliminary analysis was conducted to see if a relationship between the percentage of positive hay tests and ARGT severity of season could be found. The main obstacle was obtaining an assessment of ARGT severity, as cases are not consistently reported.

4 Results and Discussion

4.1 Reference Group

Group Membership

ARGT Reference Group			
First Name	**Last Name**	**Organisation**	**Position**
Jeremy	Allen	Dept Agriculture & Food WA	Principal Toxicologist
Barrie	Bywater	Farmer Ryegrass Action Group	Chairman
Frances	Cassella	Dept Agriculture & Food WA	Biosecurity
Donald	Coles	Valley Seeds Pty Ltd (VIC)	Safeguard seed production
Alex	Douglas	Dept Agriculture & Food WA	Manager, Weeds
David	Kessell	Dept Agriculture & Food WA	Project Development Officer
Linda	Leonard	Dept Agriculture & Food WA	Project Manager
Alan	McKay	SA Research & Development Inst	Manager, Plant Diseases
Clinton	Revell	Dept Agriculture & Food WA	Manager, Pastures
Ian	Riley	SA Research & Development Inst	Research Leader
Greg	Shea	Dept Agriculture & Food WA	WA Central Ag Region Rep
Glenda	Smith	Dept Agriculture & Food WA	Project Technical Officer & EO
Don	Telfer	Dept Agriculture & Food WA	WA Northern Ag Region Rep
Sandy	White	Dept Agriculture & Food WA	WA Southern Ag Region Rep
George	Yan	BART Pty Ltd	Twist fungus production

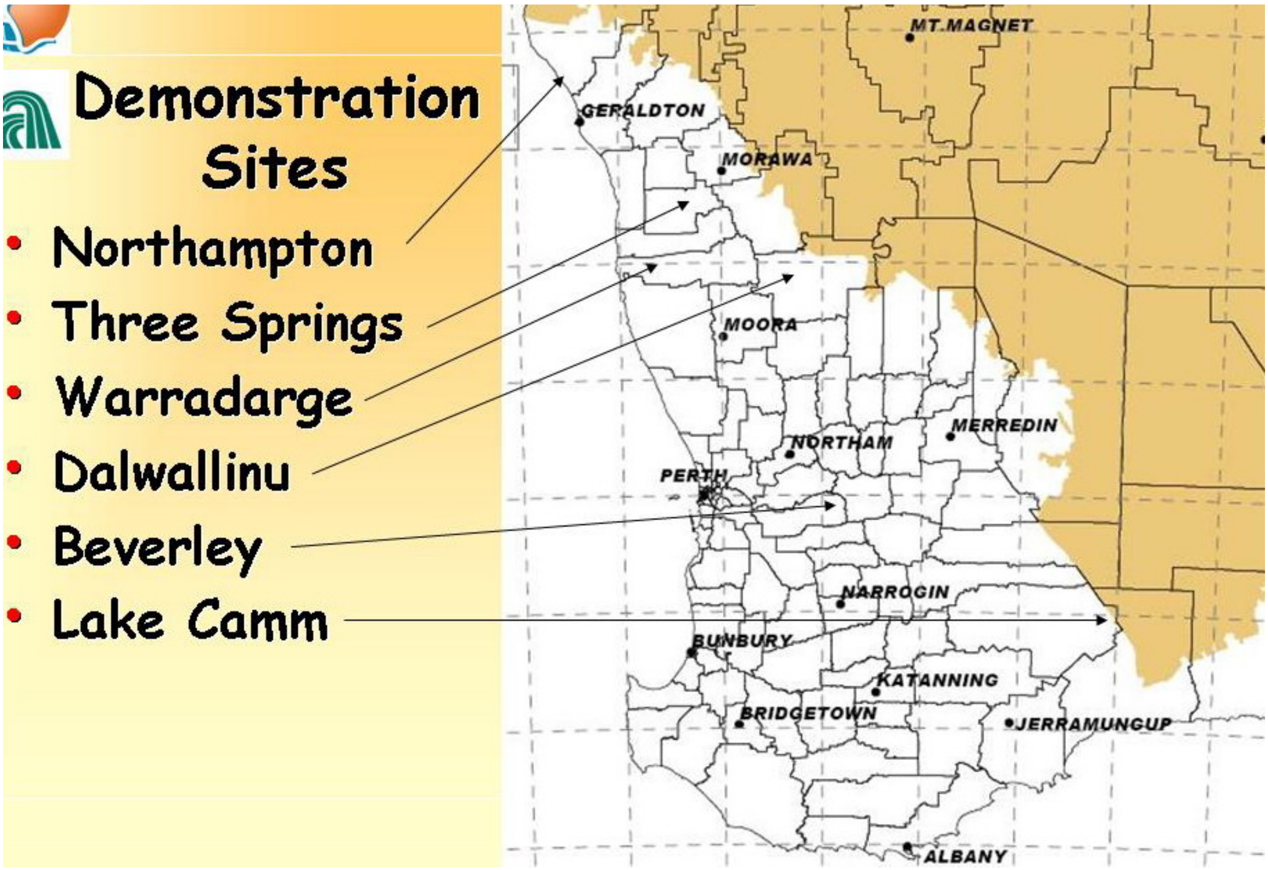
Table 4.1: Reference Group members

Group Meetings
Meetings were held at the South Perth office of the Department of Agriculture and Food WA on
10 March 2005,
3 August 2005,
6 April 2006,
19 September 2006,
except 5 June 2007 as a video conference.

4.2 Management Options

Demonstration sites

Six sites were established spanning the Agricultural region in the south-west of WA that took into account rainfall and season length variation. The sites were located at (from north to south) Northampton, Three Springs, Warradarge, Dalwallinu, Beverley, and Lake Camm. They were chosen on the basis that ARGT organisms were either, confirmed as present, or extremely likely to exist based upon previous evidence, but where Twist Fungus inoculum had not previously been applied.



Site details and plans, including aerial photographs, are included in Appendix 3

Plant counts

Site	Treatment	Mean	LSD 5%	Ratio
Beverley	Control	149		
	Safeguard	289	47	1.9:1
Dalwallinu	Control	384		
	Safeguard	434	352	1.1:1
Lake Camm	Control	94		
	Safeguard	182	66	1.9:1
Northampton	Control	498		
	Safeguard	537	518	1.1:1
Three Springs	Control	167		
	Safeguard	238	195	1.4:1
Warradarge	Control	924		
	Safeguard	1242	359	1.3:1

Table 4.2: Plant establishment counts in 2005 (plants/m^2)

The plant counts in Table indicate that none of the demonstration sites were able to be established properly to achieve the 3:1 ratio required for the proper introgression of Safeguard. However, all sites had sufficient plant numbers to allow successful establishment of Twist fungus. The Dalwallinu, Warradarge and Three Springs sites were planned to be re-seeded in 2006, but because of the dry season only the Warradarge site was able to be seeded. The resulting establishment was very poor due to the lack of rain.

Gall counts

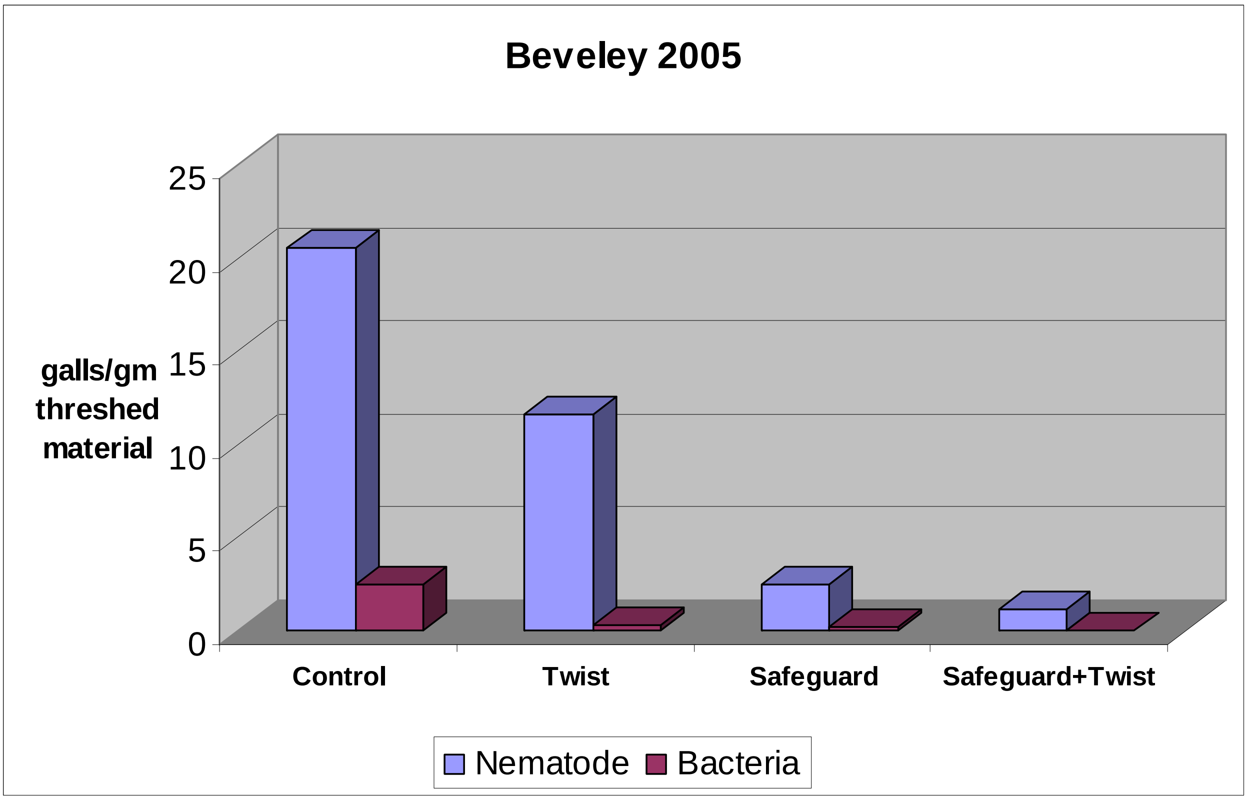


Figure 4.1: Gall counts from the Beverley site in 2005

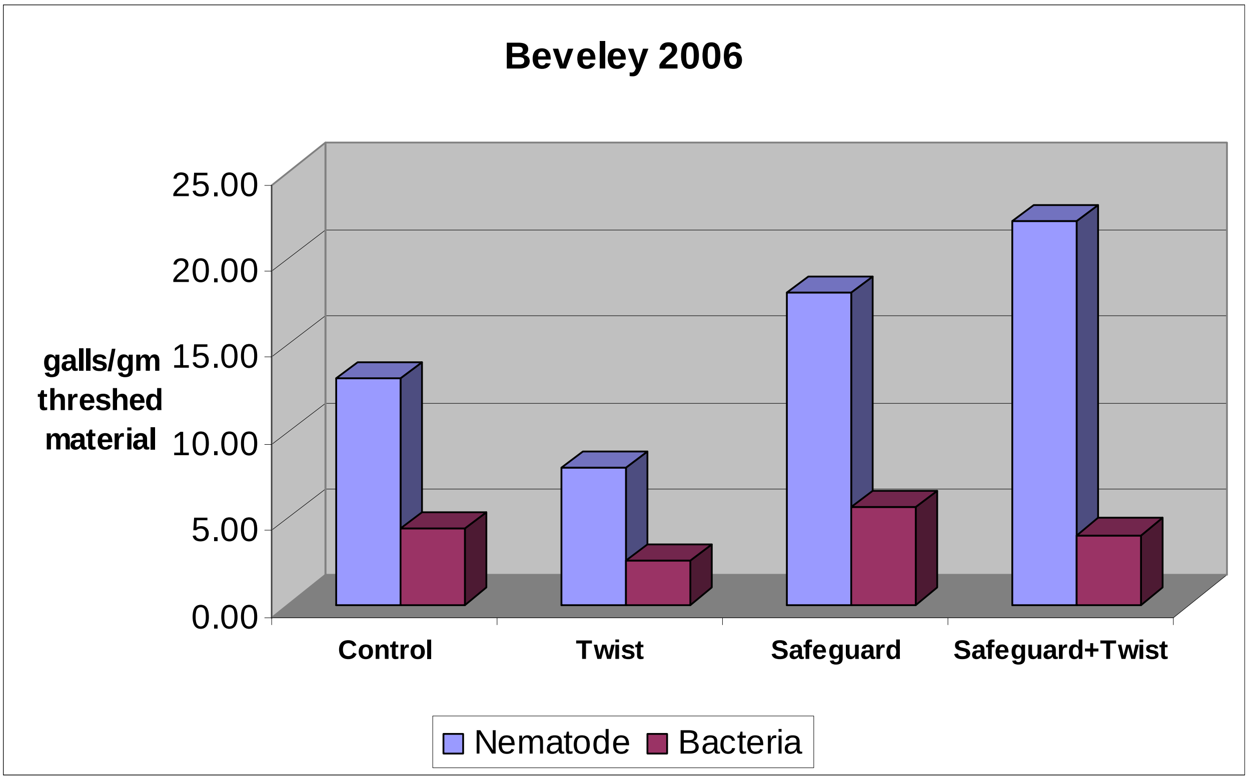


Figure 4.2: Gall counts from the Beverley site in 2006

Comparing the plots for the two seasons shows a completely different result. In 2005 (a wetter year) the result trend showed what would be expected from synergistic actions from the control mechanisms of both Safeguard and Twist fungus. In the following year 2006, there was no logical explanation of the gall count differences based upon the treatments. High nematode and bacterial gall counts were seen in both the Safeguard and Twist treated areas (including the farmer's paddock surrounding the demonstration site, which had both treatments in 2005)

The ELISA test results from the surrounding paddock (Table 4.3) also show that there was a large increase in the bacterial gall level in 2006.

	2004	**2005**	**2006**
	(bacterial galls/kg)		
Untreated	> 1000	>1000	> 1000
Safeguard + Twist fungus		8 (3 - 31)	454 (324–695)

Table 4.3: Bacterial gall levels in the paddock surrounding the Beverley demonstration

The most likely cause of this change is due to the dry weather conditions during the 2006 season.

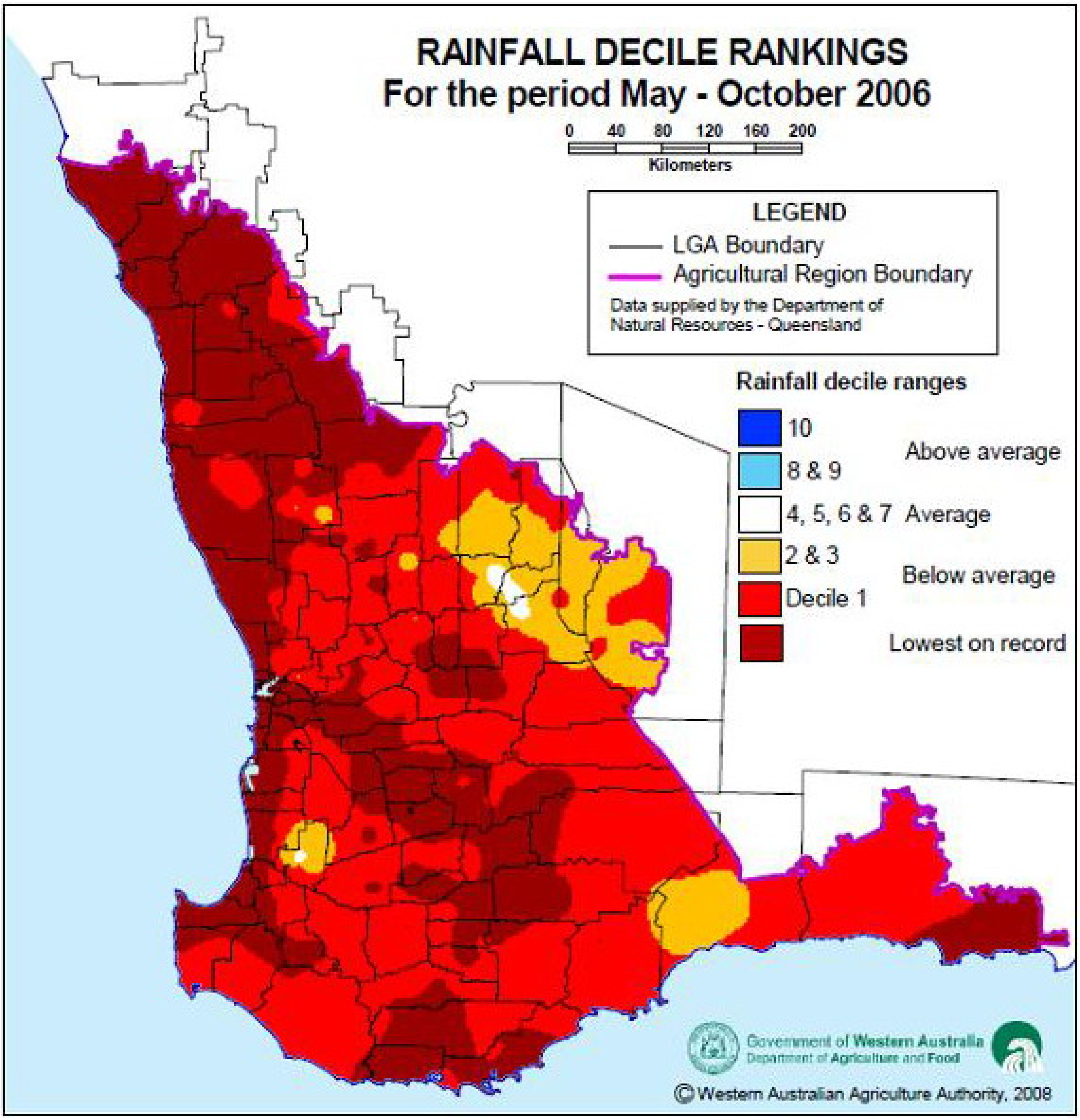


Figure 4.3

Figure 4.3 shows the growing season (May – Oct) rainfall decile rankings for the Agricultural zones of WA for the 2006 season. The map demonstrates that this was the driest season on record for all sites except Beverley and Lake Camm, which were both Decile 1. This and similar maps for the project period 2005 – 2008 are presented in Appendix 4.

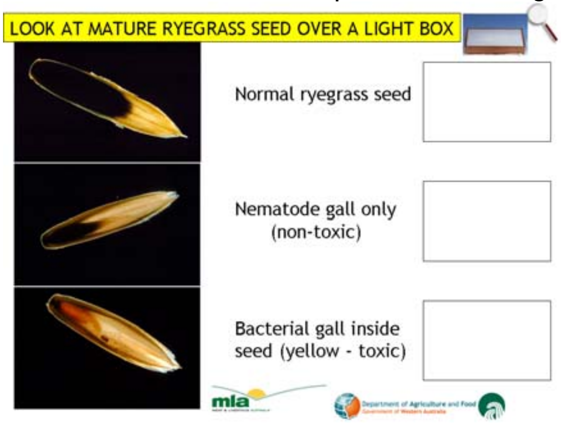
Contributing factors are:

- The local ryegrass ecotype set a lot of seed and the plant count ratios (Table 4.1) support that there was little or no introgression of Safeguard genes in spring 2005.
- Safeguard may have been preferentially grazed during summer 2005, leaving the Safeguard proportion present in 2006 very low (evidence of this exists from the Newdegate demonstration site)
- Dormant local-ecotype ryegrass seed was present and emerged in 2006.
- The 2006 season of a late start and early finish promoted the production of nematode and bacterial galls, however it is difficult to understand how the nematodes were so successful in 2006 given the low rainfall and their low numbers at the end of 2005.

4.3 Information Package

4.3.1 Package Development (printed items are included in Appendix 5)

- **Gall identification display card for light box:** This is a detection aid that has laminated windows containing normal seed, nematode and bacterial galls, teaching the user to distinguish between them when the aid is placed over a light box or against a window.

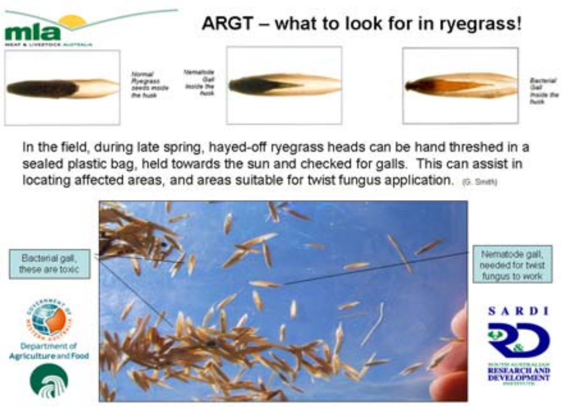


- **Test Kit:** The test kit includes sampling bags, some ARGT background information, detailed sampling & submission instructions, a laboratory submission form, a courier despatch envelope, a twist fungus Farmnote, and a Safeguard ryegrass management guide. (Appendix 5.2)

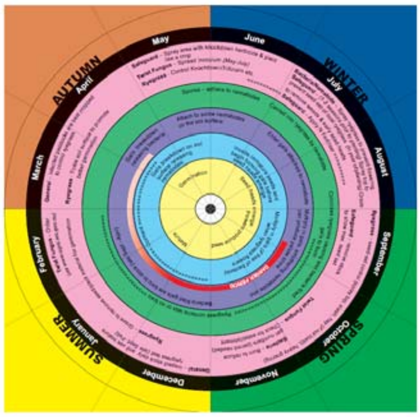
- **Powerpoint presentations:** A range of powerpoint presentations were developed over the life of the project, for various audiences, and were updated as additional information became available.

- **Farmnotes:** Three farmnotes were published and then updated during the project. The titles are: **1**. ARGT – Current situation (#417 - updated Feb 2010) (Appendix 5.3) **2**. ARGT – Control through management of annual ryegrass pasture (#258 – updated Sep 2008) (Appendix 5.4) and **3**. Twist fungus reduces the risk of ARGT (#416 – updated Feb 2010) (Appendix 5.5). These are available in printed format and also PDF format from the Department of Agriculture and Food WA website under ARGT

- **ARGT What to look for brochure:** This was developed to be included into the kits to assist growers in identifying areas that would be suitable to apply twist fungus inoculum.



- **Lifecycle wheel:** Although not part of the proposed project, this was developed by David Kessell to bring together all of the information on ARGT and organism life cycles throughout the year and highlight the timing for the various points of intervention that managers can influence their risk of ARGT outbreaks occurring. (Appendix 5.7)



- **Video material for DVD:** New and historical video material has been collected, to make a DVD to represent visual aspects of outbreaks, to aid in identification of the disease by producers. It was proposed to include other materials such as the publications and presentations developed in this project so that it formed a complete information package, but a request for additional funding was not met.

- **Website:** http://www.agric.wa.gov.au/PC_92800.html?s=1370329285 Web pages have been developed and updated to include the latest information as the project progressed. The text is linked to the project publications. It is planned to include the ARGT prediction forecasting system, being developed by Drs Baker, Purser & Salam, into this site when it is complete. The only additional item that should be included is a reporting facility that can be accessed by producers and department SARDI and DAFWA staff to report outbreak information.

4.3.2 Promotion

- **Press releases:** A series of releases were issued during the project and since to alert producers of situations such as outbreaks in new areas, making application for twist inoculum, etc.

- **Radio interviews:** A series of radio interviews were conducted, mostly through ABC Rural in WA along the same lines as the press releases and also to promote the project during major and minor field days.

- **Magazine articles:** Articles were presented in a range of locations e.g. Kondinin Group “Farming Ahead” and MLA “Feedback”

- **Agriculture Memo articles:** These articles were produced to be timely reminders for management options that producers could use to manage or minimise their risk of an ARGT outbreak. The Agricultural Memo is distributed throughout the agricultural areas and coastal zones of WA by various offices of the Department of Agriculture and Food WA.

- **Presentations:** Many presentations were given at grower group meetings and organised seminars & updates of DAFWA and Agribusiness.

- **Displays:** At major rural field days in WA and many other events (2005-2008) the project presented displays of what the project was doing and gave an opportunity for producers and the public to become more aware of ARGT organisms and their management.

A summary of the project's promotion activities is presented in Appendix 6.

4.3.3 Succession Plan

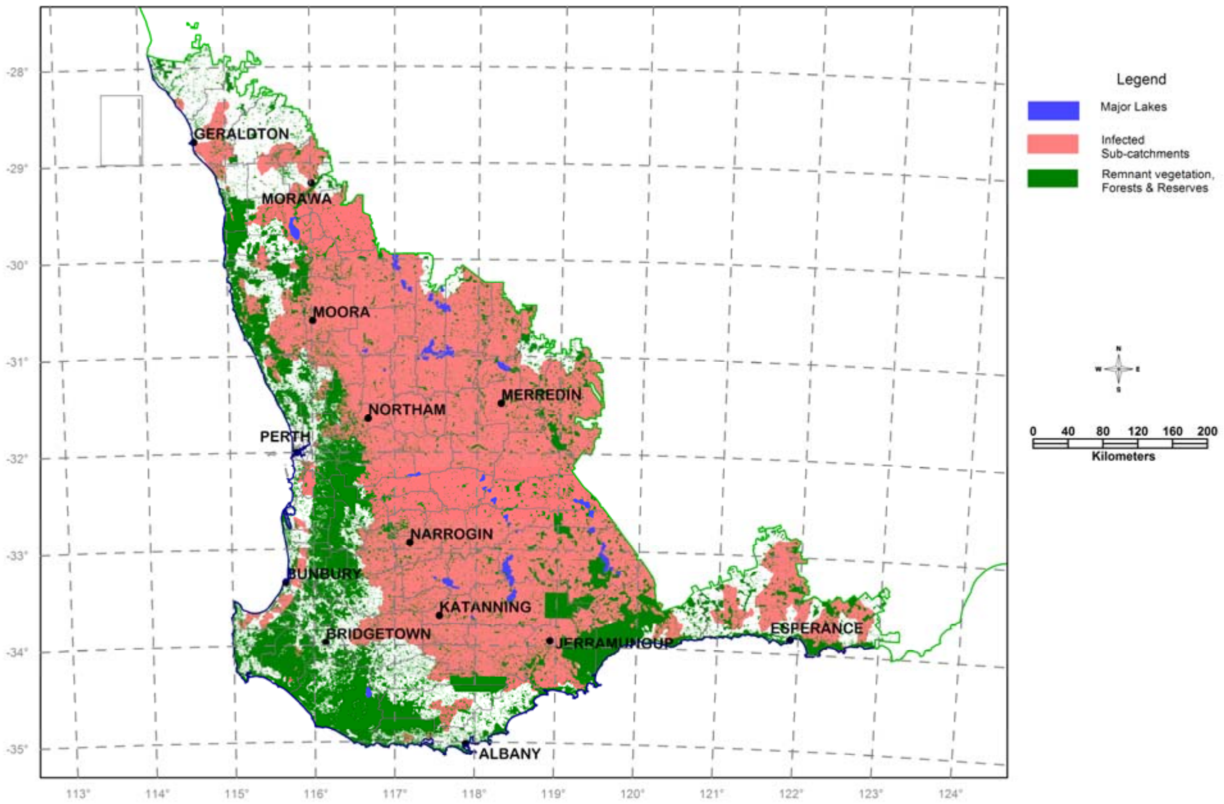
Currently the Department of Agriculture and Food WA provides a commitment of 1 FTE for 10 days/yr to maintain the information package and test kits. The information and presentations generated by this project can be used to deliver to farmer groups requiring information on ARGT.

4.4 Monitoring & Surveillance

4.4.1 Road Side Surveys

In Western Australia, the surveys were carried out using a catchment and sub-catchment approach, as the organisms are easily moved along waterways. This also applied to some areas in South Australia and western Victoria, but there are many areas in NW Victoria and South Australia where internally drained alkaline soils limit spread by this means, so the sampling approach was less efficient/reliable. (Appendix 7)

Sub-catchments where ARGT organisms have been detected



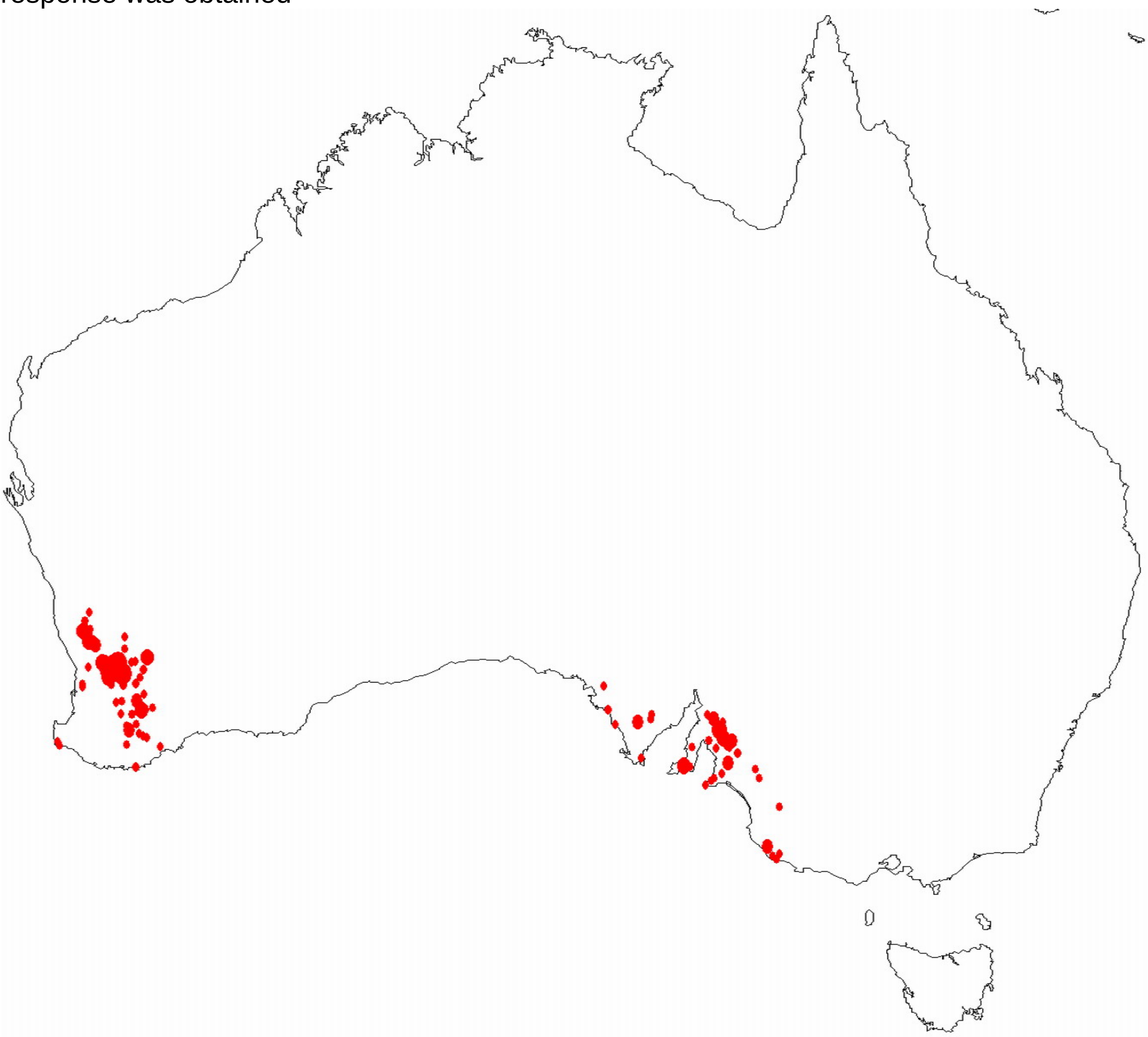
4.4.2 Farmer Surveys

Face to face farmer surveys
278 farmers responded to the questionnaire at many venues across WA during 2005/6. 46% of the survey participants had confirmed or suspected ARGT of killing livestock on their properties and all were using spray-topping or spray-top-grazing to help control the disease in their pastures. 38% have used heavy spring grazing to lower the toxic potential of their pastures, 53%

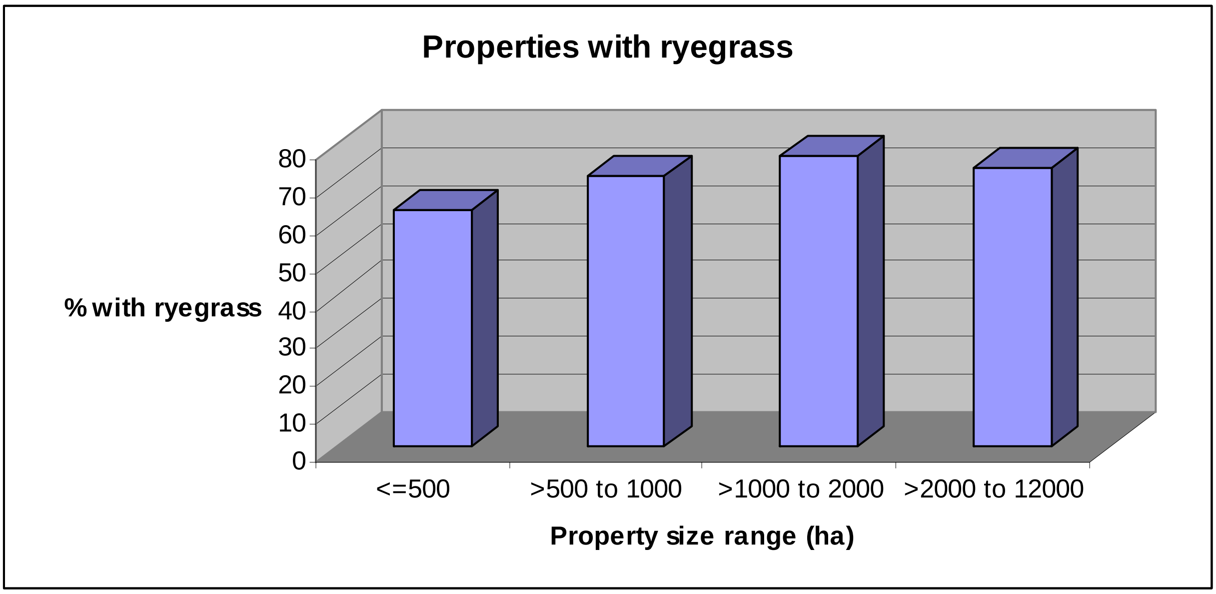
have spread twist fungus and 10% have seeded Safeguard ryegrass. Together, the affected respondents have lost a total of 29511 animals, of which sheep formed 98%.

MLA "Feedback" magazine surveys

The survey was sent to approximately 4000 livestock farmers in WA & SA. There were 674 responses approximating a 17% return rate. This is considered a good response level for this type of survey. The distribution frequency of respondents who said yes to having confirmed ARGT causal organisms or ARGT outbreaks is mapped below. This corresponds very well with the results of other surveys and known outbreak reports, indicating that a representative response was obtained



The property size distribution of the respondents was also examined to confirm that there was no bias on this basis. The respondents who have annual ryegrass on their properties (Mean = 70%) is plotted below.



The properties that have had ARGT or bacterial galls in feed, amounted to 27% of the properties that have ryegrass present (area = 28%). This also confirms that the survey response was not biased towards those who have had ARGT. Based upon the roadside distribution work (section 4.4.1), this would indicate that at the time of the survey (Jun – Aug 2006), there were still a lot of producers who were unaware of the extent of the spread of the causal organisms, particularly in WA.

On the properties that have ryegrass, 66% of those with no record of ARGT were undertaking actions to control/prevent ARGT.

A representation of the most popular techniques used for ARGT control is provided in the table below. The 495 respondents often used a number of techniques and the proportion of those using each technique is shown.

Technique	**Count**	**%**
Spray-top	287	58
Spray-top-graze	289	58
Heavy crash grazing	187	38
Twist fungus	68	14
Safeguard	30	6
Other	97	20

A range of other techniques (83) were used. These have been categorised into groups based upon the type of technique and their level of popularity within the alternative techniques is presented in the table below.

Technique	%
Cutting	34
Pasture manipulation with chemical	30
Biosecurity	19
Cropping with ryegrass herbicide	9
Burning	6
Regular testing	2

Together, the respondents had lost a total of 18622 sheep and 304 cattle. The reporting rate was 9% for sheep and 20% for cattle. These levels are similar to those found in the ABS survey in 1989. The reporting procedures for producers wishing to report losses need to be re-established and advertised each season so that some sort of record is maintained. The website reporting that was set up by George Yan was hardly used and most reporting seemed to be to DAFWA, SARDI and private veterinarians. At least using this method there can be comparisons made between years and using the estimate of 10% ARGT cases reported an estimate on the value of livestock deaths is possible.

4.4.3 ABS

As previously reported, it was not possible to undertake the planned ABS survey because the quote from ABS was $40,000 (for only two questions) which exceeded the budgeted cost by $36,000. It should also be noted for future reference that the ABS now only undertakes a full census every 5 years (2006, 2011 etc) and a partial (20%) survey in the intervening years ($22,000 for two questions).

4.5 Risk Management Strategy

Risk Prediction Modelling

Model creation and testing was unable to be completed because the principal modeller Moin Salam was taken seriously ill for an extended period and was not able to undertake his part in the project before it finished.

However, as per the requirements of the project, the background information was collected for the modelling purposes and is included here to assist any future attempts at this exercise. Moin is currently assisting Drs Sue Baker and Barrie Purser in their work using hay industry and weather records to attempt ARGT risk prediction. It is anticipated that their work will result in a risk prediction system that will be made available on the WA Department of Agriculture and Food’s website.

Ryegrass phenological information for WA and SA was sought, but no known source was uncovered through this project. This information is required to generate the growth phases of a ryegrass plant in a given environment utilising temperature and day-length information. In the absence of this information, a decision was made to use APSYM with a short-season wheat such as Westonia or Wilgoyne as the plant growth driver. The tiller response to additional spring rainfall is likely to be the greatest variant.

Anecdotal evidence shows seasonal factors to be important in the setting up and occurrence of ARGT. Seasonal factors influence the survival and prevalence of the causal organisms, particularly the nematodes. Noted seasonal influences are

- Early break – causes attrition of nematodes

- Late break – favours ryegrass, always a good year for nematodes
- Early finish – bad years for ARGT
- Winter rainfall – need enough for galls to decay and for nematodes to invade ryegrass (this is not necessarily a lot of rain e.g. WA in 2006)
- Droughts - affect (decrease) the population density of nematodes
- There may be a temperature trigger for emergence of A. funesta as they don't seem to emerge after summer storms where moisture has remained sufficient for gall wall decay.
- 1991 was a bad year for ARGT deaths in both SA & WA
- Short seasons (late break & early finish) are worst for ARGT deaths
- Re-wetting in spring, after gall production is complete, appears to promote further toxin production

A list of known and likely model drivers was assembled and a season break calculator was developed in Excel.

Model drivers (known & likely critical factors)

1. Rainfall/moisture requirements
    - Germinate ryegrass seed
    - Break-down nematode & bacterial gall walls
    - Requirement for nematode & bacteria survival
    - Allow twist fungus spore production
    - Allow nematode movement
    - Requirement for bacterial adhesion to nematode
    - Requirement for twist spore adhesion to nematode
    - Allow nematode infestation process of ryegrass
    - Spring amount and duration for dilution of infected seed-heads
2. Temperature/day length factors
    - Break-down nematode & bacterial gall walls
    - Nematode infestation must occur prior to stem elongation
3. Threshold presence of organisms
    - Ryegrass density (minimum)
    - Nematode density (minimum)
    - Bacterium density (minimum)
    - Twist density (minimum)
4. Management:
    - Winter grazing pressure. Hard grazing in winter can cause increased proportion of ryegrass infested with nematodes.
    - Spring grazing pressure. Hard grazing (30+ DSE/ha) in spring, after seed-head emergence and before senescence, will remove 80%+ of infested seed-heads.
5. Paddock History:
    - Previous year's history is very important in setting up populations of nematodes and bacteria. Paddocks in crop or left un-grazed through spring allow build up in nematode and bacteria numbers.
6. Identify high risk paddocks based upon history, management and environmental conditions.

5 Success in Achieving Objectives

5.1 Reference Group

The project team was successful in establishing a reference group of experienced individuals who helped to guide the stages of the project as it progressed. Perhaps a greater level of interaction that would encourage more critical review and guidance is required for this group to operate more effectively. Distance (cost) and the frequency of meetings were issues that were resolved in the end, but formal reference group meetings via tele/video conference on a quarterly basis would have been more cost effective and served the project better.

5.2 Management Options

The Demonstration/Trial design was reviewed by many experienced researchers who provided valuable comments and suggestions that were included in the final document.

The results suggest it was probably a mistake to try to test both Safeguard and Twist fungus jointly within the same experimental design as the preparation required for each is entirely different. It was demonstrated on these sites, and also by numerous farmer attempts, that Safeguard requires at least one, if not two prior seasons of preparation to minimise ryegrass plant numbers so that when establishment takes place, the Safeguard will not be “swamped out” by the background ryegrass. This preparation however is almost the opposite for what is required for successful establishment of Twist fungus, as it would reduce the nematode numbers (and bacteria) to very low levels, making twist establishment and sampling to measure success almost impossible. The site preparation used at all sites was to control only that ryegrass that had emerged at the time of sowing and ignored the dormant seed that was no doubt present.

To this end, the technique employed that tried to demonstrate possible interaction when using both Safeguard and Twist fungus, failed in all 6 out of the 6 sites.

In two (Beverley & Lake Camm) out of the six sites, the first year did allow for an assessment of the benefits of Safeguard and Twist fungus. All six sites chosen were suitable for the establishment of Twist fungus.

The project successfully showed that the two proposed “robust” control measures demonstrated were clearly not as robust as first thought. This was supported by numerous farmer experiences and the Twist fungus project work of Dr Jeremy Allen (2008).

The pursuance of other management options such as the vaccine and also the non-toxigenic Rathayibacter should be continued to address additional solutions that can be integrated with those currently in use.

5.3 Information Package

The information package developed by the project team has met and exceeded the objectives of the project. In addition to the original objectives, an additional Farmnote was produced, an additional diseased material brochure was produced, an organism lifecycle and management wheel was developed and produced, and material for a DVD has been amalgamated.

The promotion of this material and the project has increased the awareness of producers to the disease and its management particularly in WA and the Eyre Peninsula area of SA where the disease is still spreading.

The succession plan that has been put in place by DAFWA will continue this until a new strategy is prepared by NATCAT.

5.4 Monitoring & Surveillance

5.4.1 Road Side Surveys

The map generated from laboratory analyses of farmer submitted samples and roadside inspections has highlighted the broad-scale of spread of the causal organisms across WA, and has been used through the project promotion to warn farmers of the impending likelihood of losing animals to ARGT if they don't take management steps towards control soon. The production of this map has been influential in motivating producers to test their pastures and make these management decisions prior to ever seeing livestock deaths on their properties.

5.4.2 Farmer Surveys

The survey return level of 18% was considered a success for this type of survey, which usually yield in the 15 – 20 % range. A baseline has now been put in place to compare future surveys of a similar nature to. The surveys highlighted that many producers in 2006 were not aware of the extent of spread of the causal organisms.

5.4.3 ABS

This was not able to be achieved due to budgetary restrictions as discussed previously. (see section 4.4.3)

5.5 Risk Management Strategy

Risk Prediction Modelling

The objective of compiling information to develop a risk management strategy to enable the development of a predictive tool for ARGT occurrence was achieved. However, it was the desire of the project team to take this to the next level and actually produce a predictive tool. This was not able to be achieved as explained in section 4.5.

6 Impact on Meat and Livestock Industry – now & in five years time

Most members of the reference group are still involved in similar industry areas and continue to have influence on industry. If not available, a similar group of individuals could be assembled to continue to progress matters related to annual ryegrass toxicity.

The impact of Safeguard ryegrass appears to have only limited application to areas suited to grazing rather than dual purpose areas due to farmer's hesitation to plant ryegrass because of potential herbicide resistance issues for those in the crop/pasture areas. There is also a hesitation due to seed cost, but this was not as big an issue as the herbicide resistance potential.

The impact of twist fungus to present, has no doubt been a major contributor to the reduction of ARGT related livestock deaths as evidenced in the gall contamination levels of grains (McKay et.al., 2001) which had only had the influence of naturally spread twist fungus. Over the next five years, assuming there are some good seasons for establishment, twist fungus should continue to reduce livestock deaths from ARGT. There are however limitation to its establishment (in the northern and eastern Wheatbelt of WA) that are not completely understood, but are suspected to be environment related and the possibility of finding more suited strains may offer a solution.

As the causal organisms continue to spread into new areas, it follows that more livestock will be exposed and therefore affected by ARGT. Given the current spread in the Northern Agricultural Region of WA, and assuming average rainfall seasons over the next 5 years, the organisms are likely to reach detectible levels across all of the agricultural zone of WA. This assumes that weather events that result in strong winds and rainfall runoff occur throughout this period and will result in the further spread of the galls containing the causal organisms and the causal organisms themselves. The Eyre and Yorke Peninsulas are also likely to have been mostly infested, leaving the Agricultural zones of both SA & WA, that support annual ryegrass, almost completely infested by the causal organisms.

If producers are not continually encouraged to take management steps, using the information package developed from this project, to minimise the spread and the exposure of their livestock to the disease using the products developed by the project team, and spread continues as assumed above then it could be assumed that more livestock will die from ARGT.

This will also have impacts on the production and availability of "safe" hay for livestock production

At present, the impact of the risk management strategy is only sufficient to warn of major seasonal conditions that will contribute to a high potential for ARGT outbreaks, which is more than has been available previously, having no formal warning observations available. At present, this is promoted through the rural media in WA, via DAFWA press releases. If future modelling is successful then by 2011, a web-based warning system could be operational.

7 Conclusions and Recommendations

7.1 Reference Group

The contribution of the Reference Group to this project is gratefully acknowledged. A greater level of interaction that would encourage more critical review and guidance is required for this group to operate more effectively. Travel costs created budget issues for the project and the frequency of formal meetings of the reference group via tele/video conference on a quarterly basis would be more cost effective and serve the project better.

7.2 Management Options

Both Safeguard ryegrass and Twist fungus have their place in contributing to the control of ARGT, but this work shows that they are not as robust controls as originally thought. However, these, together with the other techniques for controlling ARGT, contribute a valuable benefit to minimising the effects of ARGT to agriculture.

Further evaluation of these techniques should take into account the individual site preparations required to provide the best benefit for these controls.

Pursuance of the non-toxigenic bacteria control as an additional management option is recommended, for while both Safeguard and Twist fungus provide a valuable contribution to ARGT control, they are not sufficiently robust to ensure ARGT control.

An examination of the performance of other twist fungus strains may provide material that is more suited to the areas where it is difficult to establish the current strain.

The non-toxigenic Rathayibacter and the vaccine appear likely to provide the next most beneficial advances in ARGT control management options.

7.3 Information Package

The information package, now available, is a giant leap forward from where it was in 2005 when the project commenced. The materials produced from this project, the extension campaign that was a main part of this project, and the updating continuance of the material from DAFWA, all contribute to having changed the status of ARGT, particularly in WA where it still has the greatest potential increase and is causing the greatest losses to agriculture. The package has amalgamated all of the past research knowledge, added-in the latest information and some innovative new material to give a more simplified, but complete picture of the ARGT story. The generic nature of the information makes it applicable throughout Australia.

7.4 Monitoring & Surveillance

ARGT Surveillance

The project required the development of methodologies:

- To monitor the distribution of ARGT quickly and accurately, in an ongoing way
- To measure the economic consequences of ARGT

and in so doing, help evaluate the effectiveness of ARGT management strategies

- The ABS approach to include questions on ARGT in its censuses and surveys seems expensive but may be realistic, depending on the cost of alternative resources in order to achieve the same level of coverage and depth of information.
- Individual farmer surveys have some useful components, but do not address the issues of representativeness (if that is important), or provide objective evaluation of control strategies. The surveys can only provide a partial definition of the distribution of ARGT.
- The MLA Feedback survey (response rate of about 18%) provided some useful information, but again does not address the issue of representativeness, will be biased to those who have an interest in ARGT, and those who receive and read the "Feedback" magazine.
- The GRDC funded survey of grain samples, conducted over several years, and has yielded an approximate distribution of toxicity. This method is expensive, but has the potential to identify properties on which toxic ryegrass exists, but its success will depend on the level of ryegrass control in crops. As more grain cleaning is undertaken by producers, this method of ARGT detection will become less reliable.
- Sampling ryegrass along roadsides was undertaken in the past, and was repeated with strategic sampling in this project. This method only provides information on the distribution of toxic ryegrass.

The challenge of all the methods is that

1. they represent a snapshot, or point in time estimate, requiring a repetition of the survey, or ongoing sampling to provide current and/or comparative information;
2. the representativeness can be questionable, so the validity of extrapolating findings may be low;
3. they measure toxic ryegrass, not toxicity in grazing animals;
4. economic parameters are likely to be poorly defined; and
5. quantification of control strategies is complex and difficult to determine through survey methods.

What's needed?

Although it seems to be obvious, toxic ryegrass is only of significance to livestock if it is eaten – either by direct grazing, or through consumption of toxic hay[1]. So if a paddock is highly toxic, but not fed to stock, the problem for the owner or manager is non-existent. Thus it is conceivable that toxicity may be widespread at a high level, but be of no consequence because no stock is grazing the ryegrass. In addition, experience over many years indicates that a paddock that has enough toxic ryegrass to kill stock in one year may not be so toxic the next. Clinical experience

[1] A separate issue surrounds impacts of toxicity on human food products, or the export of toxic hay and other agricultural produce.

suggests that 80% of paddocks toxic one year are not toxic the next. Toxicity is affected by cropping rotations, with toxicity in the year following cropping often being very high. Soil type and season are also considered to influence the development of toxicity, but the interaction of these variables has not been precisely quantified. Clearly, more work is needed to understand the total ecology of the nematode, bacteria, and plant, before accurate prediction of toxicity can be considered.

Being sporadic in nature, an occurrence of ARGT disease will heighten an affected producer's awareness of the situation, but this awareness will decline over time (this phenomenon is sometimes referred to as the "primacy-recency effect" whereby a significant incident ("primacy") or an event in the immediate past ("recency") is uppermost in a person's mind, and this will colour their perception of its importance). This in turn affects the responsiveness of a person to questioning about an incident or situation, in this case, ARGT disease. It will also affect the diligence with which strategies to manage or prevent further occurrences of the disease will be applied. A similar situation occurs with other livestock diseases, such as enterotoxaemia ("pulpy kidney"). In the season or two following an outbreak, a producer is often diligent in applying a preventative vaccination strategy. However, following the vaccination strategy which requires two doses of vaccine frequently becomes attenuated to one dose only, and is often ultimately dropped from management altogether, until the disease reappears.

What is needed is a rapid, economical, easily repeatable method of detecting toxic ryegrass across the relevant target area (of Western Australia), that is sufficiently quantitative to objectively determine the risk of livestock toxicity (or grain or hay contamination).

In addition, a method of determining (quantitatively) the management strategies applied to control or prevent ARGT is needed. The determination of management strategies directed against ARGT is also complicated by the need grain producers have to manage ryegrass *per se* in order to optimize cropping, and also to manage herbicide resistant ryegrass likewise. In the mind of producers, ARGT may not be a consideration when managing ryegrass under these circumstances, but such management will impact on the disease.

Thirdly, a mechanism is needed for integrating information about toxicity (in its fullest ecological sense as mentioned above), management, economics, and the actual outcomes on farm. Epidemiological and risk modelling may be of assistance here.

Some further issues that need to be addressed.

- What strategies in relation to ARGT control are we interested in quantifying? Can we put an economic parameter on each of these?
- How will the benefits of management be measured? (Are we looking at declining numbers of outbreaks, declining numbers of deaths, or something else?)
- What costs will be attributed to an episode of ARGT? Deaths are the tip of the iceberg, but how much of the iceberg is unaccounted for in each case?
- Frequency of measurement – how often do we want to repeat the evaluations?
- Sample size – what is necessary when dealing with a sporadic disease? What can be afforded?
- Sample representativeness – can this be assured in any way? How might this be done?

Ways forward

The way forward is not crystal clear. However, some possibilities come to mind.

1. Bring together relevant people to thrash out the issues facing the distribution and economics questions. A panel might include past and present researchers into ARGT; an economist; an epidemiologist; a risk analyst; a sociologist; and a wild-card type person, such as a fish

pathologist, who faces the challenge of disease in shifting populations. Such a group could come up with suitable ideas for further research.

2. Pursue the theoretical epidemiological approach, and put on a PhD student to develop an integrated risk-based model of ARGT. I suspect that there is sufficient information already available to develop a model, from which parameters with high sensitivity to small changes in inputs would yield the greatest returns from subsequent investigation.
3. Review and reassess the impacts of ARGT from an industry perspective. Being cognizant of the primacy-recency effect mentioned before, request industry (sheep, cattle, equine etc.) to reassess the *relative* importance of ARGT (i.e. determine the place of ARGT in the big picture of livestock production, export etc.), and on this basis evaluate further research activities. It may be that, like enterotoxaemia in sheep (which is significant to the affected producer at the time of an outbreak), ARGT can be dealt with in a similar way.
4. Using existing knowledge of the distribution of ARGT, select study properties (sentinel properties) at the forefront of the distribution for detailed study. This could be of two broad forms: just monitor what happens over several successive seasons, knowing that ARGT may not occur on all or any of the properties (a longitudinal study); or apply control strategies to a subset of farms, and evaluate the differences in occurrence of ARGT in the two groups over several seasons. In this latter case (a cohort study), large numbers of properties in the "treatment" and "control" groups will be needed because of the variability and sporadic nature of disease. Such an approach needs to be carefully planned.

A sporadic disease is very difficult to research in the field. If I have to make any specific recommendations, it would be to pursue points 1, 2 and 3 above.

(Chris Hawkins 9th August 2007)

7.5 Risk Management Strategy

Drivers for the modelling requirements of ARGT have been identified in Section 4.5. Whilst it was not a part of this project, an attempt was made to begin to model the risk prediction of ARGT using seasonal factors in alignment with other disease monitoring that DAFWA carries out on an ongoing basis. Due to unforseen circumstances, this was unable to progress very far, but Dr Moin Salam (modeller) is now working with Drs Baker and Purser on a technique that has shown promise for prediction, and it is envisaged that if successful, will be made available on DAFWA's website

8 Bibliography

Allen J (2008). Evaluation and further development of biocontrol for the ARGT causal organisms. GRDC Project Report DAW699.

McKay A, Allen J and Correll R (2001). Survey levels of diseased ryegrass in Australian grain. GRDC Project Report DAS272, DAW570, CSU4

9 Appendices

9.1 Appendix 1: RQMS Document 05NO36

9.2 Appendix 2: Farmer Case Studies

9.3 Appendix 3: Demonstration site details

9.4 Appendix 4: Growing season rainfall decile maps 2005 – 2008

9.5 Appendix 5: Information package items

9.5.1 Light box display

9.5.2 ARGT sampling and submission instructions

9.5.3 ARGT – Current situation (Farmnote 417)

9.5.4 ARGT – Control through management of annual ryegrass pasture (Farmnote 258)

9.5.5 Twist fungus reduces the risk of ARGT (Farmnote 416)

9.5.6 ARGT – What to look for brochure

9.5.7 ARGT – Lifecycle wheel

9.6 Appendix 6: Summary of project promotion & communication

9.7 Appendix 7: Sub-catchments in WA where ARGT organisms have been detected (updated Aug 2009)