Proceedings of the national workshop on footrot, Perth 19-21 August 2003

R K. Mitchell
A R B Higgs
A R. Mercy

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PROCEEDINGS OF THE NATIONAL WORKSHOP ON FOOTROT

PERTH
19-21 August 2003

EDITED BY:
R.K. MITCHELL, A.R.B. HIGGS and A.R. MERCY
Department of Agriculture Western Australia
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FOREWORD

The financial support of Australian Wool Innovation Ltd (AWI) made it possible for representatives of a range of organisations from across Australia to meet and review ovine footrot. This national workshop held in Perth in August 2003, was the first of its kind for several years and brought together senior researchers, policy makers and producers from all States.

The workshop provided an opportunity for the varied approach to footrot control across Australia to be considered in terms of a national approach to footrot control and also for individual States to review their current strategies in the light of experiences in other jurisdictions.

This workshop was designed to assemble a wide range of policy, research and field expertise to achieve the following six objectives:

1. Review recent footrot research activities.
2. Identify priorities for future research.
3. Review State footrot programs and resourcing.
4. Identify key differences in policy and strategy, and to identify opportunities for harmonisation.
5. Examine the feasibility of a national program for the control or eradication of virulent footrot.
6. To advise AWI on appropriate investment of producer levies in footrot research, development and innovation.

This report is a compilation of papers presented at the workshop plus summaries of formal discussion sessions. The discussion session summaries were collated in an ‘Outcomes Report’ prepared following the workshop by Bevan Bessen, of Bessen Consulting Services, who was engaged to facilitate the workshop. Substantial parts of the latter ‘Outcomes Report’ are included in these workshop proceedings.

All participants are to be congratulated for their full and open participation in the workshop, particularly in the discussion sessions where the greatest value was achieved in looking ahead to possible future footrot activities in Australia.

Bob Mitchell is gratefully acknowledged for his work by convening what was a successful and enjoyable workshop, for ensuring that attendees had every opportunity to make their contribution and for his tenacity in pulling together the papers for these proceedings.

Ashley Mercy
MANAGER
ANIMAL HEALTH
DEPARTMENT OF AGRICULTURE WESTERN AUSTRALIA
EXECUTIVE SUMMARY

A national workshop involving representatives from State Departments of Agriculture, Universities, sheep industry organisations, CSIRO and Australian Wool Innovation Ltd (AWI), was held to review footrot research, identify gaps in footrot knowledge, review state footrot programs, consider industry commitment to footrot control and formulate advice to AWI on future investment in footrot research, development and innovation.

The workshop combined formal presentations of papers with group discussion and workshop sessions to consider a range of issues.

Key outcome from the first part of the workshop was a list of gaps in the collective knowledge about footrot. The three highest impact gaps in our knowledge were identified as:

1. Defining the virulence boundaries for eradication purposes. Activities identified to progress this issue were:
   i) validation of the Cheetham Test;
   ii) validation of the livestock production significance of *D. nodusus* strains in the field.

2. Understanding the genetic control of virulence in *D. nodusus*.

3. Use of the national collection of isolates to ‘standardise’ research using fully characterised strains to make research comparable across States.

While it is not a research activity, producer support and acceptance of any strategy was noted in the latter session as an essential component of any control efforts.

With regard to the issue of a national approach to footrot control, it was acknowledged that there is great diversity in the prevalence of footrot and control activities across Australia. In effect there is a range from no control to significant progress towards eradication. Each situation requires a different approach, just as has occurred with other successful disease control programs.

The workshop acknowledged that Western Australia’s approach to eradication was appropriate given the prevalence of the disease in this State.

There was general agreement that virulent footrot is not something that any regional sheep industry wants to live with but there needs to be a combination of key strategies in place to enable effective control to occur.

The workshop concluded that a national footrot control/eradication program was not appropriate at this stage but national harmonisation of footrot diagnosis is needed. The prevalence of virulent footrot varies considerably between States as does the support from the respective sheep industry organisations.

The outcomes of the workshop were combined into the final advice to Australian Wool Innovation Ltd (AWI) for considering the appropriate investment of producer levies in the following footrot research, development and innovation areas:

- Vaccine research.
- Molecular pathogenesis research.
- Better diagnostic tests.
Definition of control/eradication targets.
Research collaboration and linkages.
Producer support.
Economic analyses.
Regional strategies.
Funding requirements.
Increased communication.
Government support.
**LIST OF PARTICIPANTS**

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<tr>
<td>Dr Bruce Allworth</td>
<td>Australian Wool Innovation Ltd</td>
<td>NSW</td>
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<td>Dr Graham Bailey</td>
<td>Regional Veterinary Laboratory, Orange</td>
<td>NSW</td>
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<td>Mr Will Banks</td>
<td>Queensland Agricultural Force (AgForce)</td>
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<tr>
<td>Dr Kevin Bell</td>
<td>Australian Wool Innovation Ltd Board</td>
<td>WA</td>
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<td>Dr Neil Buchanan</td>
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<td>Ms Nicky Buller</td>
<td>Department of Agriculture</td>
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<td>Dr Brian Cheetham</td>
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<td>Mr Jim Cooper</td>
<td>Tasmanian Farmers and Graziers Association</td>
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<td>Dr Tony Higgs</td>
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<td>Dr Ruth Kenman</td>
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<tr>
<td>Dr John Larsen</td>
<td>Melbourne University, McKinnon Project</td>
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<td>Mr James Maslin</td>
<td>Footrot Steering Committee</td>
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<td>Dr Ashley Mercy</td>
<td>Department of Agriculture</td>
<td>WA</td>
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<tr>
<td>Dr Mick Middleton</td>
<td>Department of Primary Industries Water and Environment</td>
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<td>Dr Bob Mitchell</td>
<td>Department of Agriculture</td>
<td>WA</td>
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<tr>
<td>Mr Mike Palmer</td>
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<td>WA</td>
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<td>Mr David Pitman</td>
<td>National Footrot Reference Laboratory</td>
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<td>Dr Barry Richards</td>
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<td>Mr Chris Richardson</td>
<td>Footrot Eradication Campaign Advisory Committee</td>
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<td>Mr Mike Riley</td>
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<td>Prof. Julian Rood</td>
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<td>Dr Dan Salmon</td>
<td>NSW Rural Lands Protection Board</td>
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<td>Dr John Seaman</td>
<td>NSW Agriculture</td>
<td>NSW</td>
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<td>Dr David Stewart</td>
<td>CSIRO</td>
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<td>Mr John Symons</td>
<td>Sheep Advisory Group</td>
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<td>Prof. Richard Whittington</td>
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<td>Dr Scott Williams</td>
<td>Australian Wool Innovation Ltd</td>
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PROGRAM
NATIONAL WORKSHOP ON FOOTROT
19 and 20 August 2003 at Broadwater Pagoda Hotel, Como, and
21 August 2003 at Department of Agriculture
South Perth, Western Australia

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2. An overview of the EC488 Footrot Project. Bob Mitchell
3. Discussion: Footrot - the definitions (footrot, virulent footrot, benign footrot) and main diagnostic methods for D. nodosus. CHP94 conclusions and protease monoclonal (MAb) ELISA. Barry Richards and David Stewart

**THEME B: RESEARCH UPDATES, LABORATORY TESTING AND IDENTIFICATION OF RESEARCH GAPS**

5. DNA analysis of virulent and benign strains of D. nodosus. Brian Cheetham
6. Eradication of virulent footrot by specific vaccination with new approaches to diagnosis. Richard Whittington, John Egerton and Om Dhungyel
7. Molecular epidemiology: Relationship between virulence and clonal strains of D. nodosus in ovine footrot. Nicky Buller
8. Breeding for resistance to footrot in sheep (Raadsma and Egerton). The Hickford NZ test development: Application to control of footrot. John Egerton and Scott Williams
9. Foot bathing; footrot ecology and dominance in mixed D. nodosus infections. Demonstration of aspects of the Footrot Database. Laurie Depiazzi
10. Laboratory testing for D. nodosus, quality assurance, maintaining the National Collection of pen tested strains (and others). National Footrot Reference Laboratory. Mike Palmer and David Pitman
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OFFICIAL WELCOME TO ALL PARTICIPANTS

Charlie Thorn, Executive Director
Animal Industries Department of Agriculture Western Australia

Charlie Thorn, Executive Director, Animal Industries, Department of Agriculture, Western Australia, welcomed all participants, especially those from interstate. He commented on the timeliness of bringing footrot researchers, regulatory authorities and sheep producers together to consider a national approach to footrot.

Mr Thorn wished all participants well and hoped the workshop would achieve consensus in its deliberations, and that positive outcomes would follow.
THEME A

OBJECTIVES, OVERVIEW AND FOOTROT DEFINITIONS

(TOPICS 1-3)
TOPIC 1

PURPOSE AND OBJECTIVES OF THE WORKSHOP

Scott Williams
Australian Wool Innovation Ltd
Parkville, Victoria

Changes in government attitudes towards financial support for agricultural organisations has led to closer scrutiny of the activities administered by the various State departments using the drafting gate of public versus private benefit.

Ovine footrot control has repeatedly received a low public benefit rating from economic analyses and hence industry generated support has become an important part of coordinated programs.

In pursuit of alternative funding support for the footrot eradication project in WA, Australian Wool Innovation Ltd (AWI) was approached to consider possible contributions (see Topic 3 for details). One of the outcomes of discussions with AWI was agreement to convene a national workshop that would include representatives of key players in industry, government, universities and CSIRO with the following proposed objectives:

1. Review recent footrot research activities.
2. Identify priorities for future research.
3. Review State footrot programs and resourcing.
4. Identify key differences in policy and strategy, and to identify opportunities for harmonisation.
5. Examine the feasibility of a national program for the control or eradication of virulent footrot.
6. Advise AWI on appropriate investment of producer levies in footrot research, development and innovation.

The Workshop participants were asked to consider these objectives and they were collectively accepted.

Dr Scott Williams wished attendees well in their pursuit of achieving these objectives.
TOPIC 2

AN OVERVIEW OF THE EC488 FOOTROT PROJECT

Bob Mitchell
Department of Agriculture
South Perth, Western Australia

The issue of the feasibility of footrot control and eradication is intrinsically connected to industry support and co-ownership of responsibility for funding.

In May 2002, the Department of Agriculture in WA again approached the sheep industry producer organisations for funding for approximately half the costs of the footrot eradication project. In June an initial Footrot Research submission was developed for consideration by AWI. At a July 2002 meeting with WA Farmers, the case for exploring other sources of funding was presented, requesting a decision by September 2002. The then Managing Director of AWI stated they would fund the lot.

After two months of further negotiations, the offer was firmed up as $3m from AWI over five years, with the Department to contribute $2m over five years. The media publicity produced a range of reactions; some stakeholders were highly supportive, some asked AWI for similar funding for their own activities, and others voiced opposition.

The new Board of AWI revisited the decision and asked further questions. In November 2002, Dr Scott Williams came to WA, attended a Footrot Eradication Campaign Advisory Committee (FECAC) meeting, and from there a revised proposal was prepared for funding of the WA program. The proposal gained support and is now AWI project EC488. This led to WA obtaining $412,000 over 1.5 years to March 2004 (some retrospective funding was included because of commitments associated with earlier expectations).

One essential component is this National Workshop on Footrot (budget provision $45,000), while other funds have been directed to:

1. Enhanced Producer Assistance (to achieve on-farm eradication success).
2. Improved surveillance, detection and diagnosis; and
3. Research, with three sub-modules:
   A. Virulence and epidemiological markers.
   B. Footrot research database; and
   C. Production effects of D. nodosus reference and benchmark strains.

The National Workshop aimed to bring together 35 people with a range of experiences with footrot. The presentations and discussion sessions are very important, but it is even more important to willingly share facts and hypotheses, to develop and refine opinions about footrot, to listen to the broad range of concerns of other participants, and to contribute to informed debate and develop workable recommendations for further action.

The organisers tried to maintain a balance in the potential input between research leaders, regulatory authorities, laboratory specialists, field operatives, sheep industry producer representatives and funding bodies.
The single most interesting feature of *D. nodosus* (and the disease footrot in sheep and goats, with a wide range of clinical expressions) is that some strains can justifiably be targeted for control/eradication, but other strains (benign strains) do not produce significant disease and are commonly carried by cattle. The classical interaction triangle exists between organism (strain of *D. nodosus*), environmental factors, and host factors. One of the greatest resources available is the National Collection of 9,000 freeze dried isolates, including approximately 100 isolates that have been extensively characterised (79 as part of CHP94, and others pen tested in WA).

There is no single simple answer or solution to the many important questions about footrot. Using a spoked wheel analogy: the pivotal 'central hub' role of Footrot Research is acknowledged, but the 'rim' or point of actual action (progress) is based on Farmer Vigilance and Cooperation, and Industry Support. The wheel will not progress without each of the various spokes being strong enough and positioned correctly. The spokes include Proactive Surveillance and Detection, Laboratory Diagnosis, Methods of Treatment, Procedures for Eradication from Individual Flocks, Legislative Framework, Biosecurity Measures, Interstate Cooperation, Acceptable Movement Controls, Funding, Effective Extension, and several other important spokes. A successful campaign requires that no spoke can be very much weaker than the adjoining spokes.

The future of EC488 beyond March 2004 is uncertain. Provided there are successful outcomes from the National Workshop, it is likely that proposals for some longer term footrot funding could be viewed favourably by AWI. A national approach is desirable. Some States may go ahead at a faster rate, while others can learn from the collated information and examine both good and bad examples. The willingness of all stakeholders, especially producers, to contribute funds is likely to influence the rate of progress in each State.
WHEEL ANALOGY USEFUL FOR FOOTROT ERADICATION PROGRESS
TOPIC 3.1

FOOTROT: THE DEFINITIONS

R.B. Richards
Manager, Animal Health Laboratories
Department of Agriculture, South Perth, Western Australia

Scientific definitions

Defining footrot from the scientific viewpoint is relatively straightforward. Footrot is the process of destruction of the superficial and deeper layers of the ovine hoof associated with a mixed bacterial infection of which *Dichelobacter nodosus* is the major transmissible agent. Much can be said about the tissue destructive roles of the various bacterial species that make up the footrot microflora and it is probable that other species, notably *Fusobacterium necrophorum*, contribute to lesion development. However, *D. nodosus* truly deserves attention as the primary pathogen, because to eliminate this organism is to eliminate footrot. *D. nodosus* exists with a destructive potency (virulence) that varies from mild to severe. Numerous critically controlled experiments have demonstrated that the organism displays a more or less continuous range from mild to severe virulence. Those strains of *D. nodosus* at the mild end of the virulence spectrum are associated with a disease called *benign footrot*, where tissue destruction is generally limited to the interdigital skin and adjacent soft horn of the sole, causes little underrunning, and seldom results in lameness, production loss or concern over animal welfare. At the other end of the scale, highly virulent strains of *D. nodosus* are often associated with severe destruction of the horn of the sole and heel and may progress through to shedding of the hoof. The disease is called *virulent footrot*. Obviously, lesions this severe cause profound lameness, significant production loss and unacceptable stress in the animal. Between these extremes, all variations are possible and the term *intermediate footrot* has been used to loosely describe a disease that cannot be conveniently labelled as either benign or virulent.

In addition to virulence of the pathogen, lesion (disease) expression is known to be modified by the innate resistance of the host, and the environment. Hence, strains of *D. nodosus* that are capable of ‘producing’ severe disease in some sheep (e.g. Merinos) may ‘produce’ only mild disease in other sheep (e.g. British Breed sheep) under the same environmental conditions. Even within a genetically similar line of sheep, the same organism may ‘produce’ disease of different severity. More importantly, highly virulent strains of *D. nodosus* may ‘produce’ severe disease when environmental conditions are favourable, and mild disease when they are not. It is important to note that mild strains of *D. nodosus* will rarely be associated with severe disease expression even when host susceptibility and environmental conditions are optimal for lesion development. However, virulent strains of *D. nodosus* may produce mild disease when these two factors are not conducive to lesion development. Although these phenomena of disease expression are well understood and create no special problems in a scientific sense, they have a significant effect when it comes to deciding on control and eradication strategies.
Regulatory definitions

From the disease eradication point of view, there are essentially two forms of footrot: those that qualify for eradication and those that don’t. If it is accepted that eradication of footrot means eradication of the pathogen, then the issue becomes identification of the organisms to be targeted. In Western Australia, since 1974, eradication has targeted those strains of *D. nodosus* capable of producing severe disease when host and environmental conditions are not limiting (those strains with a high maximum potential virulence (MPV)) and for convenience we have labelled these the *virulent footrot strains*. No action is taken on those strains with a low MPV, which we have called *benign footrot strains*. Deciding which strains are which has always been difficult and is frequently impossible based on field assessments alone. In WA we have chosen to use the protease thermostability test to assist this decision making.

Hence, in WA, stable (S) strains are subject to eradication and unstable (U) strains are not. While all studies conducted here and elsewhere have supported the concept that the S/U division is appropriate, there are exceptions to the rule and we have discovered rare U strains capable of producing severe disease. Fortunately, these strains have had a specific zymogram profile (U5) so alternative policies are applied when these are found. Because the spectrum of virulence is probably continuous, the difference in MPV between mild S strains and ‘hot’ U strains (U5s excluded) can be minor. As the eradication campaign over many years has gradually eliminated the more severe S strains and ignored the U strains, the distinction becomes even more difficult. What is needed is a more precise test of virulence, one that is capable of assisting regulatory decision-making and enhancing eradication prospects.

In a regulatory sense the definitions of virulent (subject to eradication) and benign (not subject to eradication) footrot may be quite different from the scientific definitions. Where to locate the cut-off point is an economic/political decision for each jurisdiction to consider. Clearly, the better the virulence tests available in the laboratory, the better the decision will be. It is important, in this workshop, to accept that scientific definitions of virulent/benign footrot may be quite different from the regulatory definitions so that meaningful debate on eradication is possible.
TOPIC 3.2

PROTEASE MONOCLONAL (MAB) ELISA

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Background

The protease MAb ELISA diagnostic test was developed at CSIRO Livestock Industries (CLI) and successfully evaluated in Project CHP94. The test is an antigen capture ELISA in a microtitre plate format for the detection and discrimination of proteases from virulent and benign *Dichelobacter nodosus* in either broth cultures or from swabs obtained directly from infected feet. The advantages of the swab protease MAb ELISA include: culture is not required thereby reducing the cost of laboratory diagnosis; potentially the test provides a rapid flock test within one to two days for detecting the presence of thermostable strains of *D. nodosus* and potentially a rapid diagnostic and monitoring test for field and abattoir surveys. The monoclonal antibodies are able to distinguish subtle antigenic differences between the proteases produced by either virulent or benign strains. The results demonstrated a high degree of agreement between the results for the protease MAb ELISA and gelatin gel test. There was also excellent repeatability between laboratories for the protease MAb ELISA.

Available reagents

Virulent monoclonal antibody.

Horseradish peroxidase (HRP) conjugated monoclonal antibody.

These two reagents have been successfully produced under subcontract by a commercial company and are available for testing of broth and swabs.

This single step conjugate replaces the two-step procedure, the latter consisting of a polyclonal anti-protease isoenzyme antisera and an anti-sheep immunoglobulin antisera used in Project CHP94. Besides simplifying the ELISA, this may increase the sensitivity of the test by reducing any background created by the polyclonal sheep antibodies.

Difficulties have been experienced in the commercial production of the benign monoclonal antibody and consequently the latter reagent is currently not available.

Cost

With a completed Biological Research Materials Agreement in place, CLI will provide sufficient virulent MAb and HRP-conjugated MAb for initial testing with the protease MAb ELISA to undertake some surveillance and research work. Since there is a cost for subcontracting a commercial company to produce these MAb reagents, a fee will be charged for providing the reagents once this initial requirement is met.

If commercial use of the protease monoclonal antibodies in diagnosis of footrot is intended at a later date, a licence from CLI will be required.
Reference

THEME B

RESEARCH UPDATES, LABORATORY TESTING AND IDENTIFICATION OF RESEARCH GAPS

(TOPICS 4-12)
TOPIC 4

GENOMICS, GENETICS AND PATHOGENESIS OF 
DICHLOBACTER NODOSUS

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In nearly all bacterial infections, a detailed knowledge of the mechanism of pathogenesis of the disease is required if an effective control strategy is to be developed. In this modern molecular era pathogenic mechanisms are generally elucidated by using what is known as a reverse genetics approach, whereby putative virulence genes are inactivated and the ability of the resultant mutant to cause disease is determined in an animal model, fulfilling what is known as molecular Koch’s postulates.

Until relatively recently such studies were not possible in *D. nodosus*. However, we now know that many *D. nodosus* strains are naturally transformable and that it is a relatively straightforward process to construct chromosomal mutants of virulent strains of *D. nodosus* (1, 3). We have used this technology to construct defined genetic mutations in the fimbrial subunit gene fimA, Analysis of the resultant mutants in vitro and in sheep virulence trials demonstrated that the type IV fimbrial subunit gene was essential for virulence, protease secretion and genetic transformability (3). We have also shown that it is possible to genetically alter the fimbrial serogroup of a *D. nodosus* isolate by natural transformation, providing evidence that antigenic variation in these fimbriae could occur after natural transformation and subsequent homologous recombination (2). More recently, we have constructed mutants in each of the *D. nodosus* protease genes and have determined their relative contribution to the overall elastase and protease phenotype of a virulent isolate of *D. nodosus*. We have also characterised a functional Fur iron regulatory protein and used proteomic analysis to identify Fur regulated proteins.

In addition, in collaboration with The Institute for Genomic Research (TIGR) and the University of Arizona, we are currently sequencing the *D. nodosus* genome. This project is progressing very well and will be completed later this year. These data have enabled us to identify every gene on the *D. nodosus* genome. Already we have used this information to identify genes that are involved in fimbrial biogenesis, to construct mutations in those genes and to determine their role in the regulation and assembly of the fimbriae of *D. nodosus*. We will be constructing a *D. nodosus* microarray that will enable us to identify *D. nodosus* genes that are only expressed in a footrot lesion and also has the potential to revolutionise the epidemiological analysis of field isolates of *D. nodosus*. Finally, by use of modern bioinformatic tools we will be able to identify genes whose products are potentially surface exposed or secreted. These products represent potential vaccine candidates and need to be investigated for their vaccine potential. The *D. nodosus* genome project therefore has rekindled the hope that we may be able to develop a vaccine that can be used for the control and eventual eradication of ovine footrot.
References


Initial work - Monash University

Virulent strains of *D. nodosus* cause more severe infections of the hooves of sheep than do benign strains. Some factors which are involved in this process have been identified. For example, the proteases secreted by virulent strains of *D. nodosus* are more stable when heated than the proteases from benign strains. In addition, virulent strains have greater twitching motility, generated by appendages known as fimbriae. The differences in properties between virulent and benign strains may be due to differences in gene content, i.e. benign strains may lack some genes found in virulent strains (or vice-versa). Alternatively, these differences in properties may be due to altered gene regulation in benign and virulent strains. Margaret Katz, working with Prof. Julian Rood at Monash University, began investigating DNA differences between virulent and benign strains in 1988. This work was funded by the Woolmark Corporation, and led to the identification of two DNA regions, designated the vap region and the vrl, which were associated with virulent strains. The vrl sequences were analysed at Monash, and the vap regions were further characterised at the University of New England.

Characterisation of the intA genetic element

Brian Cheetham and Margaret Katz continued these studies on moving to the University of New England in 1991, and have carried out an active footrot research program, funded by University Research Grants and small ARC grants, for the past 13 years. Our first major finding was that the vap region was part of an integrated genetic element, containing an integrase gene. We call this set of genes the intA element. The intA element is present in all virulent strains which we have analysed, but is also found in about 30 per cent of benign strains. Analysis of the genes of the intA element did not reveal any similarities to genes involved with virulence in other bacteria.

Identification of the intB, intC and intD genetic elements

We subsequently identified three more integrated genetic elements. The intB element, or part of it, is found in all strains which we have analysed. The intC element is found in most, but not all strains, and the intD element is found in only a minority of strains. However, none of the four genetic elements identified so far is found only in virulent strains and not benign strains, or vice-versa.

Identification of two putative virulence regulatory genes

We found that these four integrated genetic elements integrate into two different tRNA genes in the *D. nodosus* chromosome. One of these tRNA genes is immediately downstream from glpA, which is highly related to rsmA from the plant pathogen *Erwinia carotovora*. This gene encodes RsmA, a global repressor of virulence in *E. carotovora*. RsmA is an RNA-binding protein which prevents the translation of specific mRNA molecules.
The second tRNA gene is located immediately downstream from pnpA, which encodes polynucleotide phosphorylase. This is also an RNA-binding protein, and is responsible for cleavage and degradation of RNA molecules. Thus, the two integration sites for the intA, intB, intC and intD elements are downstream from genes encoding RNA-binding proteins. We believe that glpA and pnpA encode virulence regulators in \textit{D. nodosus}, and that their products, GlpA and PnpA, affect the expression of virulence factors, such as thermostable proteases, by binding to the mRNAs that code for these factors.

A model for control of virulence by integrated genetic elements

We found that the location of the intA, intB, intC and intD elements in virulent and benign strains was non-random. All virulent strains have the intA or intC elements next to glpA, and the intA element next to pnpA. Benign strains usually have the intB element at one of these positions. We also found that loss of the intC element from a virulent strain resulted in loss of thermostable protease activity, a virulence factor. When the intC element was lost from this strain, the intB element became located next to glpA.

We propose that integration of these elements next to glpA or pnpA alters their expression by altering their mRNA transcripts, which alters the activity of GlpA and PnpA in the strain. This in turn alters the expression of virulence factors. In support of this model, we have shown that transcription of glpA and pnpA extends into the integrated genetic elements. We are currently constructing knockout mutants of \textit{D. nodosus} in which glpA or pnpA are inactivated, to further test this hypothesis.

Identification and characterisation of a bacteriophage from \textit{D. nodosus}

Integrated genetic elements may be derived from bacteriophages, plasmids with integrase genes, or conjugative transposons. To investigate whether the intA, intB, intC or intD elements were derived from bacteriophages, we attempted to induce bacteriophages from a range of \textit{D. nodosus} strains. We were successful in the induction of a bacteriophage, DinoH1, from one \textit{D. nodosus} strain. However, this bacteriophage is not derived from one of the four integrated genetic elements. It carries its own integrase gene, intP, and integrates at a different site in the \textit{D. nodosus} chromosome. DinoH1 may have a role in the transfer of other integrated elements between strains of \textit{D. nodosus}.

Footrot diagnosis

In the course of our work, we have identified a number of genes which may be involved in the regulation of virulence in \textit{D. nodosus}. We have recently applied this information to the diagnosis of footrot. This work is funded by Australian Wool Innovation, and is described in the accompanying paper.

Footrot publications


TOPIC 5.2

DNA ANALYSIS OF VIRULENT AND BENIGN STRAINS OF
D. NODOSUS

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Introduction

Different strains of D. nodosus cause disease of different severity, ranging from benign to virulent. The severity of the disease is also affected by environmental factors such as temperature and rainfall, and by the breed of sheep. In the early stages of infection, it is often difficult to distinguish between benign and virulent footrot by examination of the hooves of affected sheep. However, early diagnosis is important because sheep affected by virulent, but not benign, footrot are subject to quarantine.

A variety of laboratory tests have been used for the diagnosis of footrot. The gelatin gel test, which measures the stability of proteases produced by the bacteria, is used routinely in NSW to distinguish between virulent and benign footrot. The proteases of virulent strains are more stable when heated than the proteases of benign strains. Using this test, strains are classed as stable, and considered to be virulent, or unstable, and considered to be benign. Some strains give intermediate results in the gelatin gel test, and are classed as equivocal. The gelatin gel test has been highly effective in the management of footrot in NSW. However, it has become apparent that there are some strains of D. nodosus which produce stable proteases, but do not cause virulent footrot in the field. We have termed these strains 'gel-stable, field benign'.

At the University of New England, we have been using DNA analysis to investigate genes involved with virulence of D. nodosus. The major aim of this work is to find differences between the genes of virulent and benign strains. During the course of this work, we have identified a considerable number of genes which may play a role in virulence, and we have proposed a model for the genetic regulation of virulence. DNA analysis of a small number of gel-stable, field benign strains showed that all of these strains were missing a gene which is present in gel-stable, field virulent strains. We have been investigating the use of this gene, designated gene A, as a DNA probe to distinguish between virulent and benign strains which are gel-stable.

Results

In a project funded by Australian Wool Innovation Ltd (EC158), we have isolated DNA from a large number of strains of D. nodosus, including both virulent and benign strains, classified as stable, equivocal or unstable using the gelatin gel test. We use a Southern blot test to determine whether gene A is present in DNA from these strains. If the gene is present, a dark band or bands will appear on the Southern blot, and if the gene is absent, there are no bands. A sample of this data is shown over the page (Figure 1A). To confirm that DNA from all strains is present on the blot, we probe the same blot with a gene which is present in all strains (Figure 1B). Thus, there should be bands in lanes containing DNA from all strains in
Figure 1B. Our hypothesis is that gel-stable strains which have bands in Figure 1A are virulent, and gel-stable strains which do not have bands in Figure 1A are benign.

Figure 1. DNA from 17 strains of *D. nodosus*, analysed with probe A or probe B.

The results from DNA analysis of 179 strains isolated from sheep with different types of footrot are summarised in the table below. Note that properties with stable footrot can have mixed populations of bacteria, some of which are stable and some benign.

<table>
<thead>
<tr>
<th>Footrot type</th>
<th>No. of properties</th>
<th>Type of isolate</th>
<th>No. DNA positive</th>
<th>No. DNA negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable benign</td>
<td>15</td>
<td>Stable</td>
<td>2</td>
<td>46</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equivocal</td>
<td>0</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unstable</td>
<td>4</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>Stable virulent</td>
<td>&gt; 8</td>
<td>Stable</td>
<td>37</td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equivocal</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unstable</td>
<td>9</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Unstable benign</td>
<td>&gt; 6</td>
<td>Stable</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equivocal</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unstable</td>
<td>12</td>
<td>26</td>
<td>38</td>
</tr>
</tbody>
</table>

For stable and equivocal isolates, there was a very strong correlation between benign footrot and a negative DNA test, and virulent footrot and a positive DNA test. However, unstable isolates from benign strains gave a mixture of positive and negative results.

**Conclusions**

These results strongly suggest that the DNA test can be used to distinguish between benign and virulent footrot when isolates are stable or equivocal in the gelatin gel test. Thus, the DNA test could be used in conjunction with the gelatin gel test, in cases where the gel result indicates virulent footrot, but the field observations suggest benign footrot. From the data above, 15 properties with benign footrot were classified incorrectly on the basis of the gelatin gel test alone. The results do not support the use of the DNA test alone, as the results for unstable isolates are mixed. We are currently seeking further samples to continue the evaluation of the DNA test.
TOPIC 6

ERADICATION OF VIRULENT FOOTROT BY SPECIFIC VACCINATION AND NEW APPROACHES TO DIAGNOSIS

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Summary
In this paper we present findings from several decades of research and conclude that virulent footrot (VFR) can be eradicated from sheep by specific vaccination. The disease is caused by particular strains of *Dichelobacter nodosus* that possess virulence factors including proteases and fimbriae. Sheep can be immunised against experimental and field challenge with footrot by vaccination either with fimbriate *D. nodosus* cells or with isolated fimbrial preparations either native or recombinant. The fimbriae are responsible for the serological K-agglutination reaction which has been used to classify field isolates into nine major serogroups. The range of protection conferred by vaccination is largely restricted to the serogroup involved, but antigenic competition precludes effective vaccination with multivalent vaccines. However, vaccination with specific fimbrial vaccine led to eradication of virulent footrot from small ruminants in Nepal and Bhutan. We have developed rapid PCR tests to determine serogroup, a microplate K-agglutination test to measure vaccine immunity and an ELISA test to assist diagnosis and objectively assess the effectiveness of eradication. A rapid test for to determine virulence of isolates is still required.

The first footrot vaccines
The first footrot vaccines produced in 1969 consisted of monovalent whole *D. nodosus* cells blended in oil emulsion adjuvant (11, 15). These vaccines protected sheep against homologous challenge and also had therapeutic effects in affected sheep (Tables 1 and 2). In these preliminary trials there were sheep that failed to respond to vaccination, a phenomenon noticed ever since which necessitates competent clinical examination to remove non-responders during eradication programs.

<table>
<thead>
<tr>
<th>Table 1. Therapeutic vaccination of Merinos with homologous vaccine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Vaccination</td>
</tr>
<tr>
<td>Nil</td>
</tr>
</tbody>
</table>

* Three deaths.
** Five deaths.

<table>
<thead>
<tr>
<th>Table 2. Effect of homologous vaccination during transmission in Merino/Border Leicester cross sheep (per cent affected) (11)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treatment</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Vaccination</td>
</tr>
<tr>
<td>Nil</td>
</tr>
</tbody>
</table>
A monovalent vaccine was patented by CSIRO in 1971 and by 1972 three vaccines were available commercially. Two large scale field vaccination trials were conducted in 1975 but all these vaccines performed poorly, so the vaccines were withdrawn from the market in 1976 (22). The low level of protection observed was attributed to the use of alum adjuvant in the commercial products.

Diversity in \textit{D. nodosus} antigens

Initially at least two distinguishable serogroups of \textit{D. nodosus} were identified based on agglutination tests using antisera prepared in rabbits (10). A bivalent vaccine including these two serogroups was prepared and field trials were conducted. Field trial results of this vaccine were highly variable although vaccinated sheep generally had less severe infections of shorter duration (11, 14).

By 1974 it was recognised that many antigenically distinguishable strains of \textit{D. nodosus} existed and that whole cell vaccines were rarely protective against heterologous serogroups (9, 10).

Studies conducted later indicated that there were eight major serogroups (A, B, C, D, E, F, G and H) of \textit{D. nodosus} in the Australian environment and that multiple serogroup infections were common within a flock and even within sheep (5, 6). This grouping was later extended to nine serogroups with the incorporation of serogroup I (4). Within these serogroups additional heterogeneity was observed in the form of serotypes (3, 34). An additional serogroup, serogroup M has been identified in Australia and New Zealand (2), and in Nepal (18). These antigenic variants of \textit{D. nodosus} have been identified in all major sheep growing countries.

Multivalent whole cell footrot vaccines

The first experimental multivalent footrot vaccines contained whole cells of five major serogroups which were representative of most field infections. These vaccines were protective against homologous challenge but protection was not afforded against serogroups not contained in the vaccines (5, 24, 29). Vaccines containing nine serogroups A-I in oil adjuvants were released commercially. However, sheep vaccinated with these multivalent commercial vaccines were not protected for more than 12 weeks (20, 23, 28) in contrast to at least 16 weeks protection against homologous challenge provided by conventional monovalent vaccines (32, 35). Under severe challenge multivalent vaccines only partially protected sheep for a short period (30) (see antigenic competition, below).

Fimbriae as the key immunogen

Fimbriae are filamentous projections concentrated at the ends of the bacterial cell. They are believed to be involved in twitching motility, protease secretion and attachment to epithelial cells (21, 25). Fimbriae are major protective antigens (31).

Development of recombinant vaccines

\textit{D. nodosus} is a fastidious anaerobic bacterium and fimbrial expression is highly variable in liquid cultures. In order to overcome problems of mass production of fimbriae for vaccine preparation, the genes encoding the fimbrial subunit of \textit{D. nodosus} were cloned into the Type 1 fimbriate bacterium \textit{Eschericia coli} and subsequently into Type 4 fimbriate \textit{Pseudomonas}.
aeruginosa (1, 16, 25). Recombinant P. aeruginosa produced fimbriae which were identical to those produced by D. nodosus. The protective and curative efficacy of recombinant fimbrial vaccines was similar to that of whole cell or fimbrial D. nodosus vaccines (12, 33).

Antigenic competition in multivalent footrot vaccines

The average antibody titres in sheep vaccinated with multivalent footrot vaccines were only 25 per cent of those recorded in sheep vaccinated with a monovalent or bivalent vaccine (27). The agglutination titre associated with protection against homologous challenge with serogroup A is 3,200 (35). This level did not persist for more than three months in sheep vaccinated with multivalent vaccines (30). Antibodies against individual serogroups decreased linearly with the increase in number of D. nodosus strains in the vaccine, and this decrease in agglutinating antibodies was directly associated with a similar linear decrease in protection in sheep (Figures 1 and 2) (28). A monovalent vaccine was shown to induce a high antibody titres and these lasted for two to three years (13, 26).

Reduced antibody production against individual components of a multivalent vaccine is believed to be due to the phenomenon of antigenic competition (20, 28, 30). Antigenic competition is predominantly due to the presence of a family of immunologically related antigens rather than interference by extraneous proteins. However, the actual mechanism of antigenic competition is still not fully understood.

Figure 1. Relationship between log2 (K-agglutinating titre 10-1) and number of D. nodosus fimbrial antigens present in D. nodosus fimbrial vaccine preparation at: (a) three weeks post primary; (b) three weeks post secondary; (c) five weeks post secondary; and (d) eight weeks post secondary vaccination, for serogroup A (○), and serogroup B (●) (28).
Evaluation of specific footrot vaccination in Nepal

VFR was probably introduced to Nepal by four imported Polwarth rams. It became established in migratory flocks in two districts in the Western Region and was characterised by extremely high within-flock prevalence (up to 90 per cent), strong seasonal trends in occurrence and significant economic losses. Intensive programs based on identification and treatment of cases and the culling of animals refractory to treatment had failed to eradicate the disease from Nepal over a period of 25 years or more. Consistently, mixed flocks of sheep and goats, apparently free of footrot at the conclusion of these annual programs, became re-infected during their routine summer transhumance migration to alpine pastures.

From 1993-1996 specific vaccination was tested for its potential to contribute to the management of footrot in the endemic region. A survey was undertaken to determine which serogroups of *D. nodosus* were present on the hypothesis that the few rams implicated may have introduced a limited number. Initially all of 208 isolates were identified as serogroup E and shown to be gelatin gel positive. A preliminary treatment trial of affected animals was conducted in order to identify additional low prevalence virulent strains. A virulent strain of serogroup B was identified in sheep in which infection persisted after treatment with serogroup E vaccine (Table 3). Serogroup E could no longer be isolated from vaccinated animals but the presence of antigenically distinct benign strains became apparent also.

Forty mixed-species flocks of sheep and goats (approximately 9,500 animals) were included in a trial to compare three vaccination regimes for their capacity to protect animals from VFR during migration. Eleven flocks were treated with two doses of specific vaccine (Group A), nine with commercial multivalent vaccine followed by specific vaccine (Group B) and ten with two doses of commercial vaccine (Group C) in March-April 1993 prior to the annual migration. Ten flocks remained unvaccinated (Group D). There was also rigorous clinical examination of every foot of every animal on three occasions before migration.

Only sheep and goats free of signs of footrot were allowed to migrate. Nevertheless, VFR recurred in many flocks three months later during the wet season while on migration to alpine pasture. However, prevalence was significantly lower in Group A compared with the other three groups combined.

As a result of the beneficial effect of specific vaccination in Group A and for ethical reasons, Groups A, B and C all received specific bivalent serogroup E and B vaccine prior to migration from 1994-1996. Group D remained unvaccinated. There was no recurrence of virulent
footrot after November 1993. After the first season the virulent strains of *D. nodosus* used in the specific vaccine could no longer be isolated although the antigenically distinct, benign strains of the organism persisted.

The annual program of inspection, identification and treatment of cases continued for seven years. Vaccination ceased after four years and there were three more migrations under close clinical and bacteriological surveillance.

**Table 3. Results of a treatment trial with monovalent vaccine isolates in serogroups E and B were virulent (17)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>Culture positive animals</th>
<th>Total isolates</th>
<th>Identity of isolates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccinated</td>
<td>Day 0</td>
<td>18</td>
<td>47</td>
<td>E B C UT</td>
</tr>
<tr>
<td></td>
<td>Day 60</td>
<td>4</td>
<td>21</td>
<td>47 - - -</td>
</tr>
<tr>
<td>NIL</td>
<td>Day 0</td>
<td>8</td>
<td>34</td>
<td>34 - - -</td>
</tr>
<tr>
<td></td>
<td>Day 60</td>
<td>7</td>
<td>53</td>
<td>52 1 - -</td>
</tr>
</tbody>
</table>

**Evaluation of specific footrot vaccination in Bhutan**

The first cases of footrot in Bhutan were reported in the flock at the National Sheep Breeding Centre (NSBC) in Bumthang in 1990 after the importation of sheep from Australia. This centre supplies breeding animals to village flocks throughout Bhutan. Despite the presence of footrot at NSBC, the distribution of sheep continued. In 1998 research was aimed initially at identifying the strains of *D. nodosus* responsible for the disease at NSBC. Forty isolates were cultured from cases in that flock. All isolates were identified as belonging to serogroup B. Vaccine was prepared from these isolates and shown in a controlled trial to accelerate cure of cases and to prevent infection at a time when the disease spread in unvaccinated animals (Table 4). The same vaccine was used to treat all sheep at NSBC for two successive years. After the first year no further cases of footrot were seen at NSBC in spite of close surveillance for two more years after the withdrawal of vaccine (19).

**Table 4. Results of a vaccination trial with specific monovalent vaccine in Bhutan (19)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number affected weeks post vaccination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 0</td>
</tr>
<tr>
<td>Vaccine</td>
<td>n = 16</td>
</tr>
<tr>
<td>Nil</td>
<td>n = 16</td>
</tr>
</tbody>
</table>

No other strains were ever found in this flock. Application of monovalent vaccine to the whole flock, without other treatment, resulted in eradication in one year.

**Specific vaccination pilot trial in Australia**

In March 2002, 660 adult ewes were purchased from Armidale and transferred to a farm near Taralga, NSW. This property had been destocked of sheep for three months. Within two weeks of the arrival of these animals lameness was noticed. To investigate the lameness a random group of 45 ewes was inspected. Within this group 20 animals (44 per cent) were affected (score two or more). All 26 isolates of *D. nodosus* from these cases were of serogroup F. Isolates tested for in vitro virulence by elastase and gelatin gel tests (n =13) were all found to be virulent.
A representative isolate of this serogroup F was selected and a whole cell vaccine was prepared. All animals in the flock were vaccinated with two doses of vaccine in August-September 2002. On serological testing the geometric mean titre at 12 weeks post vaccination was 6738 (see Figure 3 also). Foot scoring of the whole flock was done on three occasions in January, February and April 2003. On the first inspection 13 animals with footrot were identified. These were all treated with antibiotics. On the second inspection eight animals were found with suspected footrot lesions and they were culled from the flock. All of the isolates of \textit{D. nodosus} isolated from the infected animals found on both these inspections were found to be serogroup F. On the third inspection all the animals were found to be free of foot lesions. Lameness has not been noticed in any animals since then, although environmental conditions have not been conducive to transmission.

![Figure 3. Serological (K-agglutination) results of the specific vaccination trial at Taralga.](image)

**Serogroup specific multiplex PCR with pre-enrichment culture for identifying strains of \textit{D. nodosus} in sheep with footrot prior to vaccination**

The identification of the serogroup(s) of \textit{D. nodosus} present in a flock is a prerequisite to specific (autogenous) vaccination. Conventional methods of identification of the serogroup present in a population requires that the organisms be isolated, identified visually in mixed culture on streak plates, subcultured to purity and subjected to antigenic analysis. This process takes at least three to four weeks. However, a simple and rapid serogroup specific PCR test on enrichment cultures has now been developed (7). The fimbrial gene region confers serogroup in \textit{D. nodosus}. A common forward primer was designed from the conserved amino-terminal region of the fimbrial gene (fimA) and nine (A-I) serogroup specific reverse primers were designed from the carboxy-terminal regions of fimA. Single tube multiplex PCRs with the common forward primer and groups of three, four or five reverse primers were designed so that amplicon size for each reaction product was different. It is possible to amplify DNA of isolates from all the relevant serogroups present in the reactions (example in Figure 4). These PCR tests on mixed colonies from four-day-old cultures on 4 per cent hoof agar medium have practical value by reducing the time to confirmation of serogroup.

There is great need for a simple rapid virulence test to combine with this test for serogroup.
Anamnestic ELISA for the diagnosis of virulent footrot

The immunological memory (anamnestic) responses in sheep recovered from virulent footrot can be aroused by subcutaneous injection of outer membrane protein (OMP) and fimbrial antigens of *D. nodosus* (8, 37). The magnitude of this response is directly correlated with the severity of lesions and the highest antibody response attained during infection; memory lasts at least a year after recovery from virulent footrot (36). The primary and anamnestic responses to OMP and pilus antigens were similar but the response to pilus was highly specific (38). The sensitivity of the procedure for detection of sheep with a history of virulent footrot was approximately 80 per cent. Anamnestic challenge with 10 µg pilus was used in the specific vaccination and virulent footrot surveillance program in Nepal (8). Conventional diagnostic methods could not be applied during the disease transmission periods in these flocks because of the migration to alpine pastures far away from human habitation. The results of the study supported clinical and bacteriological findings suggesting that virulent strains of *D. nodosus* had apparently been eliminated from these flocks in Nepal. These tests have been developed in Merino sheep in Australia and are likely to be supplementary tests that can be used for surveillance of virulent footrot in conjunction with specific vaccination.

Prospects of specific vaccination in Australia

Based on research in Nepal and Bhutan we believe virulent footrot can be eradicated from sheep flocks in Australia by following the procedure described below:

1. Identification of the serogroup(s) of *D. nodosus* that are present in a flock and that are associated with virulence. This is achieved by collection of lesion material then rapid testing by enrichment culture and PCR, and virulence tests.
2. Production of specific fimbrial vaccine containing no more than two of the fimbrial antigens appropriate for the flock.
3. Whole flock vaccination with two doses of specific vaccine.
4. Culture of non-responders to identify additional serogroups
5. Culling of vaccine non-responders if no additional serogroups are present,
6. Re-vaccination in year two with bivalent vaccine to eradicate the remaining virulent strains (if present). This is repeated each year until all strains associated with virulent disease have been eradicated by sequential elimination of serogroups. A maximum of four years would be required if eight virulent strains in eight different major serogroups were present.
7. Confirmation of eradication by clinical examination, bacteriology and anamnestic ELISA test.
We envisage that univalent or bivalent vaccines would be available off the shelf. A rapid test for virulence that could be included with the enrichment culture-PCR for serogrouping would be an asset.

Faculty of Veterinary Science technology package

The Faculty of Veterinary Science has developed and applied a package of technology for control of virulent footrot:

- Reference laboratory function for the serogrouping of *D. nodosus*, essential to determine which antigens to use for specific vaccine for flocks.
- A new PCR-based rapid serogrouping test.
- Conventional culture and virulence tests.
- Methods to mass-produce native and recombinant fimbrial antigens.
- Data on adjuvants required for footrot vaccines.
- Blood test (microplate K-agglutination serology) for assessment of immunity following vaccination.
- Methods to confirm that eradication of virulent strains has been achieved, including anamnestic ELISA.

Future work

Much remains to be done in Australia to achieve uniform practices for effective control of virulent footrot. Multidisciplinary research and research coordination will be valuable. Efforts within the Faculty of Veterinary Science at the University of Sydney would logically focus on:

- Further validation of rapid PCR serogrouping technology, with the need to develop a multiplex PCR incorporating virulence detection, in collaboration with other research groups.
- Development of a rapid serogrouping/virulence test kit.
- Development of an ELISA kit for immunological assessment.
- Development of commercial links for specific vaccine production.
- Evaluation of the duration of immunity and herd immunity following specific vaccination.
- Enhancement of virulent footrot control/eradication programs nationally and internationally.

References


TOPIC 7.1

FOOTROT RESEARCH BACKGROUND

MOLECULAR EPIDEMIOLOGY: RELATIONSHIP BETWEEN VIRULENCE AND CLONAL STRAINS OF DICELOBACTER NODOSUS IN OVINE FOOTROT

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Molecular typing

At present *D. nodosus* can be divided into 13 different types based on their protease thermostability and isoenzyme profile as detected in the gelatin gel test and the zymogram test, respectively. A more sensitive method of identifying different strains of *D. nodosus* was required for epidemiology and trace-back purposes.

The Pulsed Field Gel Electrophoresis (PFGE) technique is considered to be the most powerful for genetic analysis, extremely sensitive to strain variation, highly reproducible and the most widely used. The technique allows the separation of large molecular weight DNA fragments and the entire genome is analysed.

A second technique for DNA fingerprinting is the Infrequent-Restriction-Site Polymerase Chain Reaction (IRS-PCR). This technique amplifies a subset of DNA fragments of low molecular weight.

A total of 796 isolates from WA (n = 735), VIC (n = 24), SA (n = 21), and NSW (n = 16) from a total of 303 properties were analysed by PFGE. A subset of 677 was analysed by IRS-PCR. A total of 214 PFA types were identified, with 181 of these being found in WA. With the IRS-PCR method, 94 IrsT types were identified with 77 present in WA. This indicates a genetic diversity of 1:4 by the PFGE method and 1:10 (1:8 in WA) by the IRS-PCR method.

The PFGE types can be grouped into clonal clusters where isolates are genetically similar. Throughout the Australian isolates 82 clonal groups were identified (67 in WA) by PFGE, and with the IRS-PCR method 48 clonal groups (36 in WA) were recognised. Despite the small number of isolates tested from NSW, VIC and SA, six clonal groups (identified by PFGE) were common between all States indicating that similar genetic types have spread throughout Australia. In particular, the three most common clonal groups found in WA (PFA 9, 7, 11) were found in all States tested. The results with IRS-PCR supported the findings of the PFGE method.

Application of molecular typing to epidemiology of *D. nodosus* in WA

The clonal groups that were common between States were also the ones that had persisted in WA over a prolonged period despite the eradication program begun in 1974.
In particular, clonal groups seven, nine and 11 have been present on WA farms for almost 26 years, whereas other clonal groups may be detected for a short time and if not seen in later years then it can be assumed that they have been eradicated.

The genetic diversity on farms could be grouped into genetically identical, genetically similar (clonal) or genetically dissimilar. Of 133 farms that had more than one isolate typed by PFGE 30.8 per cent of these had isolates that were genetically identical, 20.3 per cent of farms had isolates that were clonal (closely related), and 48.9 per cent of farms had diverse genetic types present on the farm.

This genetic diversity was also found in an individual hoof. In 6.1 per cent (n= 15) of the 247 farms tested in WA up to three different molecular types were found in a single hoof. This occurred in 26 of the 709 animals tested (3.7 per cent). The isolates detected in an individual hoof could either be genetically diverse or subtypes of a parent strain. Protease thermostable (S) and heat-labile (U) strains could also be present in a hoof.

![PFGE gel results showing different molecular PFA types in a single hoof from Farm 44.](image)

The finding that different molecular types and in particular benign and virulent types can coexist in an individual hoof indicates that the organism is being spread from sheep to sheep and that the source of the infection may be more than one infected sheep.

These results have implications for the eradication program as laboratories must ensure they perform tests for differentiation of benign and virulent isolates from a pure culture only. It would be recommended that more than one isolated colony from each hoof be subcultured for further testing in the gelatin gel test and the zymogram.
Relationship of genetic type and protease thermostability and isoenzyme profile

The resulting molecular types obtained by both typing methods (PFGE and IRS-PCR) were analysed to determine if a relationship existed between the molecular type and protease thermostability. It is now well established that an isolate that produces a thermostable protease is capable of causing a severe lesion in the hoof under ideal environmental conditions. However, there are some isolates that do not produce thermostable protease, yet cause severe lesions. These have been tested for virulence by pen trials and therefore have been confirmed as virulent organisms. These have a zymogram profile of U5. However, not all U5 zymogram profiles produce virulent lesions, and those that do are in the minority. Most U5 types only cause benign hoof lesions. Two other zymogram profiles needed investigation, and these were the U6 type and the T zymogram types. U6 types only show one protease band in the zymogram gel. This band is fast moving under electrophoretic conditions and is common to all strains. The T strains also have the fast moving band, but in addition have weakly expressed bands normally seen in S1 strains. Both U6 and T strains are negative in the gelatin-gel test indicating they produce a thermolabile protease. Therefore all molecular types were investigated to determine if a relationship existed between protease thermostability, zymogram profile and molecular type.

Of the 735 isolates tested from 247 properties in WA, 21.6 per cent of isolates belonged to the clonal group PFA 11. 19.6 per cent of these were S strains compared to 2.3 per cent U strains. Clonal group PFA 7 comprised 18.2 per cent of all strains and 17.1 per cent of these were S strains compared to 1.0 per cent U strains. The U strains in these two clonal groups consisted of mainly U5 strains.

The major group for the U strains was clonal group PFA 9 which comprised 10.2 per cent of all isolates tested, with 3 per cent being S strains and 7.2 per cent being U strains. The other 64 clonal groups identified in WA contained less than 5 per cent of strains in each group.

When the U5 strains (n = 47, 6.4 per cent) were investigated for molecular type, the virulent U5 strains had a molecular type (PFA 11a) identical to S strains on that property. Molecular type PFA 11a consisted entirely of S strains apart from five U5 strains. One U5 isolate (PFA 18) came to WA from SA and did not spread and this is a unique molecular type for WA. The benign U5 strains had molecular types that were consistent with other U strains.

The U6 strains (n = 17, 2.3 per cent) had a molecular type that was identical to either the S strains isolated on the same property, or U strains present on the same property.

All T strains tested (n = 12, 1.6 per cent) had molecular types identical to S strains on the same property.

Conclusions

Both PFGE and IRS-PCR methods were suitable for molecular typing of *D. nodosus* and indicated that the organism was genetically diverse at a ratio of 1:4 by PFGE and 1:10 by IRS-PCR. Thus the PFGE method is twice as sensitive to detecting genetic changes than the IRS-PCR.

The typing indicated that strains had spread throughout Australia, and the common strains had persisted in WA for over 26 years since the beginning of the eradication program.
Molecular types on farms could be diverse, and this molecular diversity also existed in the hoof.

Of the molecular typing performed on U5 isolates so far, they could be divided into virulent or benign strains based on their molecular type.

U6 isolates were genetically identical to either S strains or U strains isolated from the same property, whereas all T strains had identical fingerprints to S strains on an infected property. This would indicate that thermostability of the protease may be due to a conformation change in the protein.

**Publications**

**Book Chapter**


**Journal publications**


**Conference proceedings**


**Conference presentations**


Poster presentations

Buller, N.B., Richards, R.B., Hampson, D.J. (2003). Relationship of Molecular Type to Protein fingerprint. Poster Presentation at the Australian Society for Microbiology Conference, Auckland, New Zealand October 2003.

TOPIC 7.2

INVESTIGATION OF RELATIONSHIP OF GENETIC DIVERSITY, PROTEASE THERMOSTABILITY AND WHOLE CELL PROTEIN PROFILES

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Introduction

Molecular typing has indicated that D. nodosus is genetically diverse (Buller et al. 2000) and it has been found that during a disease outbreak and after prolonged infection, subtypes of the parent strain occur.

During the course of an investigation of a flock of sheep that had been artificially infected with isolate 198A, U6 strains were detected in the zymogram test. Isolate 198A normally has a zymogram profile of S1, therefore it was of interest to compare the U6 and S1 strains to determine if there was any genetic difference that could be detected between the zymogram profiles.

Methods

Pulsed Field Gel Electrophoresis (PFGE) and Infrequent Restriction Site Polymerase Chain Reaction (IRS-PCR) were used to DNA fingerprint the isolates, and sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) was used to analyse the whole cell proteins.

Isolates recovered from sheep that had been inoculated with isolate 198A (ATCC 27521) were typed by PFGE and IRS-PCR 18-24 months after initial infection.

Results

Seven different molecular types were obtained by PFGE (PFA 4a, 4b, 4c, 4d, 4e, 4f, 4g) and three different types by IRS-PCR (IrsT 26, 26a, 26b). The mechanism for the genetic diversity appeared to be the insertion or deletion of DNA of molecular weight of approximately 25 to 45 kilobases as detected by the PFGE method (Figure 1).

Three U6 zymogram types were also isolated from the sheep that had been inoculated with isolate 198A. All three isolates had a molecular type of PFA 4b and IrsT 26, which was the most common molecular type of isolate 198A in the flock and also the same genetic types as the majority of S1 strains (Figure 1).
The isolates were investigated for whole cell protein profiles by SDS-PAGE. No difference could be seen between the different molecular types or between the S1 and U6 zymogram profiles (Figure 2).

To establish whether molecular types of the same clonal groups had similar protein profiles, other molecular types were investigated by SDS-PAGE. Isolates that formed a clonal group of PFA 11 were analysed by SDS-PAGE and were found to be similar in their protein profiles (Figure 3).
However, when isolates that were genetically dissimilar were analysed by SDS-PAGE, a number of differences were seen (Figure 4).

**Figure 3.** SDS-PAGE of whole cell proteins of genetically similar isolates.

**Figure 4.** SDS-PAGE of whole cell proteins of genetically dissimilar isolates.

**Conclusions**

An isolate may undergo genetic change in the course of an infection outbreak. These genetic changes may result in a number of closely related isolates that have similar molecular types and therefore form a clonal group. Isolates that originated from sheep that had been infected with isolate 198A for a prolonged time underwent genetic changes. The genetic difference appeared to be due to large insertions or deletions of DNA. The different genetic subtypes that originated from isolate 198A had the same whole cell protein profiles when examined by SDS-PAGE.

When isolates from other clonal groups were examined similar results were found. These isolates within a clonal group were related by their genetic type and by their whole cell protein profile. The lack of genetic and protein differences between isolates of the same genetic type or within a clonal group suggest that the differences in protease thermostability may be due to conformational changes in the protein, rather than to detectable genetic change and/or expression of different proteins. These results demonstrate that PFGE typing can be useful in predicting likely phenotypic expression of whole cell proteins. Further work is required to elucidate differences between virulent and benign strains.
D. nodosus may undergo rapid genetic change, therefore an epidemiological investigation must be undertaken as soon as possible after the disease outbreak so as to establish definite links between the outbreak case and trace-back or trace-forward properties.

**Reference**

TOPIC 8

BREEDING FOR RESISTANCE TO FOOTROT IN SHEEP

See paper under Topic 6
TOPIC 9.1

FOOTBATHING, FOOTROT ECOLOGY AND DOMINANCE IN MIXED DICELOBACTER NODOSUS INFECTIONS

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Key issues in footrot eradication have been researched over the last decade in a series of combined ecology and footbathing trials. These trials were aimed at investigating:

- effects of \( D. \) nodosus strain, environment and host resistance on persistence of footrot infections;
- the role of footbathing in ovine footrot eradication;
- dominance of individual strains of \( D. \) nodosus in mixed infections.

Influence of microbial, environmental and host factors in footrot eradication

A trial, known as the five site trial, aimed to evaluate the effect of environment and host resistance on the expression of ovine footrot caused by a single strain of \( D. \) nodosus. The trial covered three footrot transmission periods at Badgingarra, Wokalup, Vasse, Wilga and Mount Barker (Western Australia).

Footrot persisted at two sites and at Mount Barker, outbreaks flared anew each year, with up to 10 weeks of covert footrot during early winter where footrot was not detectable by fortnightly observations of every foot.

At the first transmission period, there was little evidence of well-defined host susceptibility, as \( D. \) nodosus bacteria were still in transmission from artificial to natural infection. In the subsequent two annual outbreaks, a pattern of host susceptibility was clearly established. At Mount Barker, footrot lesions ranging from severe under-running to very mild were specific to individual sheep.

Natural extinction of \( D. \) nodosus footrot infections in Merino sheep

In the five-site trial, footrot self cured at Vasse, Wilga and Badgingarra after infection was established in the first transmission period. After prolonged absence of lesions, \( D. \) nodosus-like bacteria were seen in foot smears from Wilga. However, when sheep from all three lesion-free sites were placed at Mount Barker at the third transmission period, no footrot developed.

Self-cure was associated with deep sandy soil and relatively dry climate (Badgingarra), deep sand over clay with poor pasture coverage (Vasse) and gravelly loam soil with lawn-like pasture (Wilga). Persistence of infection at Wokalup and Mount Barker was associated with loamy soil and annual rainfall above 600 mm. A greater severity and consistency of annual outbreaks at Mount Barker compared to Wokalup was attributed to better pasture coverage.
Genetic change of *D. nodosus* populations *in vivo*

In close observations of many field trials, conversion of S1 to U6 strain of *D. nodosus*, recognised by a deletion of all except one protease band, usually occurred at less than 1 per cent prevalence.

Various genetically novel strains appeared at very low rates, often self extinguished, and did not appear to dominate in mixed infections.

In all experiments there was no evidence that benign strains converted to virulent strains. T and U6 strains isolated from natural outbreaks were shown in standard pen trials to be benign.

Variation in isolation of individual *D. nodosus* strains *from mixed infections*

The probability of isolating particular strains of *D. nodosus* from mixed infections was influenced by mode of infection (natural or induced), time of year (climate, soil type and pasture) and virulence of the infecting bacterium (severity and infectivity).

*D. nodosus* strains in mixed natural infections reached equilibrium, the ratio of strains remaining constant despite changes in environment, genetic changes in S1 strains, and host resistance.

In one experiment, some individual feet yielded only S1 strains, other feet yielded S1, U6 and T strains at different sampling times. The ratio of S, U and T strains in superficial covert footrot mimicked that of visible footrot.

In another experiment, a hot U5 strain was apparently more infective than either strain 198 (highly virulent) or a mild U5 strain in natural infections, at the end of a transmission period. However, the mild U5 and hot U5 strains spread equally well, and better than strain 198, in artificial infections in the same period. Only after two transmission periods in natural field infection did the ratio of strain 198, hot U5 and mild U5 equate with the virulence hierarchy observed in standard pen trials of those strains.

Covert lesions and eradicability of mild footrot

(a) Desiccation treatment

In the Mount Barker flock of the five-site trial, footrot outbreaks cycled consistently for three consecutive seasons. Continuing from the trial the flock was sent in December to Merredin Research Station (annual rainfall 300 mm), where they remained until April, whence they were transported to green wet pasture at Wokalup Research Station. At Merredin where no rain was recorded, footrot lesions apparently healed, but reappeared at Wokalup, along with isolations of the S strain. Retrospective analysis showed that if the most susceptible 27.5 per cent of the flock had been culled before Merredin, then footrot might have been eradicated.

(b) Five day footbathing

Aging footrot affected Merino sheep from a commercial farm were partitioned into lesion and non-lesion groups, based on diagnosis by footparing every foot. The non-lesion group was subjected to five-day footbathing then placed on lush irrigated pasture at Wokalup Research
Station. At monthly inspections, no lesion were recorded until October where maximum score two lesions occurred and only U6 strains of *D. nodosus* were isolated. In contrast, only S strains were isolated from the untreated group. In the following May, treated sheep that previously had U6 strain yielded S strain from score one lesions.

These trials demonstrated in two different ways how *D. nodosus* survived in covert lesions in chronically affected sheep. In both cases, only mild forms of S strain footrot were involved. In general the most susceptible sheep were the most likely to show lesions in the transmission period, but were also most likely to have covert lesions during periods of non-transmission.

**Role of footbathing in footrot eradication**

A series of 24 controlled paddock pen trials were conducted at Mount Barker Research Station to investigate the mechanism of footbathing. Daily 10-minute footbathing with zinc sulphate/detergent resulted in cumulative destruction of *D. nodosus* cells on the surface but not in the interior of the hoof. Effectively, at least three days exposure to zinc sulphate/detergent was required to remove evidence of intact *D. nodosus* cells from the surface of the hoof. From these trials, the five-day footbathing procedure was developed.

The role of five-day footbathing in footrot eradication was investigated in four controlled field trials using a range of *D. nodosus* strains under various environmental conditions. Five-day footbathing enhanced the success rate of summer eradication of footrot associated with mild strains of *D. nodosus*, even where score 4/5 under-run lesions were involved. In contrast, five-day footbathing was spectacularly unsuccessful against footrot caused by the deeply invasive strain 198. The results were consistent with the hypothesis that mild S-strains or benign U-strains of *D. nodosus* do not readily penetrate deeply into hoof tissue.

**The significance of deep covert penetration in ovine footrot**

The post-bathing appearance of deep rotting lesions emerging from soles of feet without any interdigital involvement proved the ineffectiveness of topical treatment against footrot caused by highly virulent strains of *D. nodosus*, such as strain 198. Summer eradication, which depends in part on a desiccant treatment, was also ineffective against strain 198.

**Conclusions**

- U strains and mild S strains can be extinguished from sheep flocks by natural extinction, by summer eradication or by summer eradication/five-day footbathing.
- Destocking is possibly the only practical option for footrot eradication where highly virulent strains of *D. nodosus* such as strain 198 are involved.
- The chance of isolating a particular strain of *D. nodosus* from mixed infections in sheep flocks is affected by combinations of mode of infection, time of year and virulence of *D. nodosus*.
- Virulence evaluation based on the National Pen Trial Protocol is a valid predictor of the severity of chronic footrot infections.
References


TOPIC 9.2

FOOTBATHING, FOOTROT ECOLOGY AND DOMINANCE IN MIXED DICHELOBACTER NODOSUS INFECTIONS

Laurie Depiazzi

The aim of footrot ecology research in Western Australia was to investigate the biological basis of ovine footrot eradication. An outcome of the early stages of research was a decision to eradicate stable protease (S) strains of *Dichelobacter nodosus* as a major objective of the WA footrot eradication program. This decision was based on the observation that all highly virulent strains of *D. nodosus* were protease stable.

Methodologies for investigating survival of *D. nodosus* in the field included a five-day footbathing procedure, developed from a series of paddock-pen trials, long term field trials with intensive monitoring by direct microscopy, lesion score, laboratory culture, and tracking strain dominance in mixed infections using gene probes.

The feasibility of eradicating mild footrot was demonstrated in an experiment where ovine footrot caused by S strain AC2127 was extinguished without intervention at three of five geographical sites. In additional studies, eradication of mild S and U strains was enhanced by five-day footbathing in conjunction with environmental and host resistance factors.

In contrast, neither rigorous culling nor five-day footbathing were successful in eradicating footrot associated with the highly virulent *D. nodosus* strain 198.

It was concluded that deep penetration of *D. nodosus* into apparently healthy hoof tissue (covert footrot) was a major factor in the persistence of footrot in sheep, with or without intervention.

In some circumstances, environment and host resistance played a role in deep penetration. However, unknown or unconfirmed virulence determinants responsible for extreme survival capabilities of strain 198 need to be identified.

Two major objectives of research are:

- To confirm the exceptional properties of highly virulent S strains in the field, and to foster research that will identify a diagnostic marker for these strains.

- To develop a database to make available the extensive data from ecology and footbathing research, in the context of footrot eradication.
TOPIC 10

NATIONAL FOOTROT REFERENCE LABORATORY

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Laboratory structure

The National Footrot reference Laboratory (NFRL) is situated in the Albany Animal Health laboratories, its primary function is to provide a diagnostic service to the States Footrot Eradication Program.

The NFRL runs the quality assurance program for the ‘gelatin gel’ test, the primary virulence test for *Dichelobacter nodosus* (*D. nodosus*), on behalf of ANQAP. The NFRL also advises other laboratories on techniques involved in the growth and virulence testing of *D. nodosus*.

The National collection of freeze-dried isolates of *D. nodosus* created as a result of the collaborative study CHP94 'Validation and Implementation of New Technologies for the rapid and precise Diagnosis of Ovine Footrot' is maintained at the NFRL.

Laboratory role in footrot eradication in Western Australian

Two forms of Ovine footrot are recognised benign and virulent, flocks infected with the virulent type may experience significant production losses if the disease is uncontrolled. Both forms of the disease are caused by the bacterium *D. nodosus*, however some strains possess virulence factors which allow them to produce the more severe virulent disease. All strains of *D. nodosus* are strongly proteolytic, however the protease enzymes produced by the virulent strains are considerably more resistant to heating than those of the benign types. The 'gelatin gel' test was developed in the NFRL to measure the heat stability of protease enzymes. Flocks in Western Australia that are found in laboratory tests to be infected with Gelatin gel Positive *D. nodosus* are quarantined until the infection is eradicated from that flock.

Laboratory procedures

The basic steps in Laboratory diagnosis are as follows:

1. Lesion material is inoculated onto agar plates, to grow the bacteria present.
2. *D. nodosus* growth where seen, is re-grown on a second agar plate to obtain a pure culture, and produce protease for the virulence tests.
3. Perform virulence tests on the protease enzymes produced by the *D. nodosus* isolated.

The procedures used to grow *D. nodosus* (Pitman et al. 1994), and virulence test *D. nodosus* (Palmer 1993) in the Albany Laboratory have been previously described in detail, a brief summary follows.

Although Footrot is caused by, *D. nodosus* the bacterium is always found in association with many other bacteria in lesions. The samples submitted for culture even from an active lesion rarely contain more than 5 per cent *D. nodosus* and more usually 1 per cent or fewer. *D. nodosus* requires strict anaerobic conditions for growth in the laboratory but is not an especially fragile organism and survives exposure to air quite well.
Lesion material is submitted to the laboratory as scrapings in a modified Stuarts Transport medium with as little faeces soil, etc. as possible, swabs have been found to be less suitable. The transport medium provides a moist reducing environment and if kept cool the sample will retain a reasonable number of viable *D. nodosus* for up to a week. Samples are inoculated onto TAS medium with ground sheep hoof, on which *D. nodosus* grows as a thin spreading layer, most of the other bacteria present grow more heavily but spread less quickly. Using a stereo microscope to inspect the plates, typical growth of *D. nodosus* can be seen and sub-cultured after two days incubation. Typically, pure cultures of *D. nodosus* are available for virulence testing in four days but slower growing isolates or badly contaminated samples may occasionally increase this time. In research flocks where all lesions sampled were expected to yield *D. nodosus* the actual isolation rate is around 98 per cent.

**Virulence testing**

Two virulence tests both of which identify characteristics of the protease enzymes produced by *D. nodosus*, are performed in the NFRL, these take two days to complete.

**Gelatin gel test**

The virulence characteristic used to define a virulent strain of *D. nodosus* in Western Australia, is production of a thermostable protease, tested for using the Gelatin gel test. In the test the activity of the protease the bacteria produces is measured, firstly untreated, and then after heating to 68°C for a specific time.

Protease activity is measured using a gel diffusion technique in an agarose gel containing the protein gelatin. Gelatin gel negative protease loses its activity within 16 minutes at 68°C, positive protease still shows considerable activity at that time. A strain of *D. nodosus* classified in the zymogram as S3, and some variants of the zymogram type S1 (T strain) produce protease which is moderately thermostable and are classified as Gelatin Gel test 'Equivocal'.

**Protease zymogram**

A second test, the protease zymogram is used to further characterise *D. nodosus* protease, this test uses electrophoresis to separate the protease isoenzymes produced by an isolate. Using the zymogram isolates can be divided into 12 types three of these (S1, S2, S4) are gelatin gel positive, eight are gelatin gel negative (U1-8), and one (S3 not present in WA) is equivocal in the gelatin gel test (see Table 1).
Table 1. Virulence characteristics and distribution of Gelatin Gel and Zymogram Types in WA and National Trial CHP94

<table>
<thead>
<tr>
<th>Zymogram</th>
<th>Gelatin Gel</th>
<th>WA July 1997-July 2003</th>
<th>National trial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Per cent of isolates</td>
<td>Per cent isolates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>isolates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S1 Positive 34</td>
<td>47 Virulent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S2 Positive 3</td>
<td>4 Virulent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S4 Positive 1 case only</td>
<td>0 Virulent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S3 ** Equivocal 1 case only</td>
<td>15† Virulent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U1 Negative 54</td>
<td>20 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U2 Negative 2.7</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U3 Negative 1.6</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U4 Negative 1.4</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U5 ** Negative 1.4</td>
<td>4 Some isolates virulent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U6 Negative 0.3</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U7 Negative 1 case only</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>U8 Negative 1 case only</td>
<td>0 Benign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T ** variant of S1 Variable 0.6</td>
<td>1 isolate Clinically benign Potentially virulent ??</td>
</tr>
</tbody>
</table>

** Zymogram required to correctly classify these potentially virulent types.
† 38 per cent of isolates from Hamilton were S3.

Laboratory workload and costs

Samples

Up to 3,000 samples are processed in the NFRL each year, 75 per cent of these in the three months October to December. Between 60 and 65 per cent of samples yield growths of D. nodosus. With long incubation times, and multiple steps, keeping track of the progress of footrot samples, and reporting completed cases promptly is almost impossible to do manually. The NFRL has a locally designed computer program on which we record all case and sample details and each step of the laboratory processing as it occurs. The program then creates interim and final reports as soon as the test data is completed.

Staff

Because of the seasonal nature of footrot the laboratory staff all have duties in other areas of the Animal Health Laboratories as well as the NFRL. There are two senior staff who do the culturing and virulence tests (1.4 full time equivalents) and a support worker who prepares media (0.25 FTE). Total staff cost for the 2002/03 season was $115,000.
Major consumable materials

Culture (plates - media - gas packs - CO₂) $12,000 per year
Gelatin gel (buffer - agarose - gelatin - pipette tips) $500 per year
Zymogram (buffers - acrylamide) $600 per year

Capital equipment

Media preparation - use of balance, microwave oven, laminar flow cabinet and autoclave.

Culture - Stereo microscope - incubator - anaerobe jars (use of computer and microscope). Approximate cost $20,000.

Gelatin Gel - Water bath - pipettor - timer - illuminator - glass plates (also use of compound microscope and incubator). Approximate cost $4,000.

Zymogram - Electrophoresis unit - power supply (also use of compound microscope and incubator). Approximate cost $10,000.

Gelatin gel quality assurance program

The NFRL conducts two rounds of Gelatin Gel QA tests each year, in September, and in March, laboratories in New South Wales, South Australia, Tasmania, and the NFRL itself participate. The D. nodosus isolates used are selected from the National Footrot culture collection. Participating laboratories are requested to culture and gelatin gel test the isolates and report their result for each as Positive, Equivocal or Negative. In addition the degree of thermostability of the proteases each isolate produces is reported, this must be within the 'acceptable variation range' of the mean of the results recorded by all labs.

Results are reported to the Australian National Quality Assurance Program (ANQAP), and are published in their annual Veterinary Serology and Virology report.

Where the program indicates a laboratory has a consistent problem with the Gelatin Gel test, the NFRL works with that laboratory to assist them to identify and correct it. The Gelatin Gel QA program commenced in 1997, when a standard method for the test was introduced. Early problems due mainly to an incomplete adoption of the method by all labs, which resulted in poor agreement of results, have been fixed, and now little variation of results between laboratories occurs.

Freeze dried collection of D. nodosus

The NFRL has accumulated over 9,000 D. nodosus isolates preserved by freeze drying, since the laboratory commenced footrot culture in 1977. Included in these are 79 isolates that were extensively characterised in the national footrot trial CHP94, that comprise the National Collection.

Services available to other laboratories

1. The NFRL can advise on D. nodosus culture, gelatin gel, and zymogram testing, and has in the past provided a four day training course to laboratory workers from other States.

2. Gelatin Gel 'equivocal' or other D. nodosus isolates of interest can be zymogram typed.

3. External quality control for the Gelatin Gel test.
Supply of *D. nodosus* isolates from the WA or National collection to researchers, particularly for the assessment of new virulence tests.

A limited number of field samples could be accepted for culture and virulence testing. (We are presently providing this service to one private laboratory.)

**References**


TOPIC 11

ROUTINE LABORATORY TESTING FOR FOOTROT IN AUSTRALIA

Dr Graham Bailey
Officer in Charge, Regional Veterinary Laboratory
Orange, New South Wales

Laboratory tests are used as an aid in footrot diagnosis throughout Australia. Laboratories that provide routine diagnostic footrot testing were surveyed. These laboratories included State/Territory Government Laboratories (5) and Private Laboratories contracted to State Governments (2). Universities, CSIRO and private veterinary laboratories not contracted to supply services by State Governments were not surveyed.

Routine footrot testing

Of the seven laboratories surveyed, four provide a routine footrot diagnostic testing. Details of tests offered are supplied below. Of the remaining three, two have never offered a routine footrot diagnostic service (Queensland and Northern Territory) with the third (Gribbles Victoria) no longer perform routine footrot diagnostic testing due to low demand. If required, all three arrange for testing to be performed by outsourcing to one of the four labs conducting routine diagnostic footrot testing.

Specific test capability

The specific test capability of the four laboratories providing routine footrot diagnostic testing are provided in the table below:

<table>
<thead>
<tr>
<th>Organisation/Location</th>
<th>NSW Agriculture</th>
<th>WA Agriculture</th>
<th>Dept. Primary Industries</th>
<th>Idexx Laboratory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RVL Orange</td>
<td>Footrot Ref Lab, Albany</td>
<td>Animal Health Lab. Kingsmeadow</td>
<td>Adelaide</td>
</tr>
<tr>
<td>Smear examination</td>
<td>Y/N</td>
<td>Y/N</td>
<td>Y/Y</td>
<td></td>
</tr>
<tr>
<td>(capability/routinely performed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culture</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Protease thermostability</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Elastase</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Zymogram</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Serotyping</td>
<td>N</td>
<td>N</td>
<td>N¹</td>
<td></td>
</tr>
<tr>
<td>PCR</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Protease ELISA</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

Y Yes.
N No.
¹ Outsource to University of Sydney when required.
Further details of the laboratory tests including Collection and Transport of samples, culture of *Dichelobacter nodosus* and protease thermostability testing are provided in the following tables.

### Collection and transport

<table>
<thead>
<tr>
<th>Instructions supplied</th>
<th>NSW Agriculture</th>
<th>WA Agriculture</th>
<th>Dept. Primary Industries</th>
<th>Idexx Laboratory</th>
</tr>
</thead>
</table>

Type of sample

<table>
<thead>
<tr>
<th>No. of sheep sampled</th>
<th>NSW Agriculture</th>
<th>WA Agriculture</th>
<th>Dept. Primary Industries</th>
</tr>
</thead>
</table>

Collection to receipt in Lab (typical time)

<table>
<thead>
<tr>
<th>Culture of <em>Dichelobacter nodosus</em> and Protease Thermostability Testing</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Primary culture</th>
<th>NSW Agriculture</th>
<th>WA Agriculture</th>
<th>Dept Primary Industries</th>
<th>Idexx Laboratory</th>
</tr>
</thead>
</table>

Per cent samples from which *D. nodosus* isolated

<table>
<thead>
<tr>
<th>Samples cultured last 12 months</th>
<th>NSW Agriculture</th>
<th>WA Agriculture</th>
<th>Dept Primary Industries</th>
</tr>
</thead>
</table>

Protease reported as:

<table>
<thead>
<tr>
<th>Interpretation provided with Protease Thermostability Test</th>
</tr>
</thead>
</table>

The presentation at the Workshop will highlight similarities and differences between the laboratories. In addition general points mentioned by labs of relevance in their interaction with field staff will be discussed.

Workshop participants not listed who can offer routine laboratory testing for footrot are encouraged to contact the author (preferably prior to the Workshop). The intention is to provide Workshop participants with a comprehensive overview of Australian routine laboratory testing capability.
TOPIC 12

IDENTIFICATION OF GAPS IN FOOTROT RESEARCH
SUMMARY OF DISCUSSIONS

Bevan Bessen and Barry Richards led the workshop through a process of facilitated discussion on footrot research. Two outcomes were achieved by the conclusion of this discussion.

OUTCOME ONE: Review of research - see previous papers

OUTCOME TWO: Identify gaps in the collective knowledge

The following is an extract from the facilitator’s report (Bessen Consulting Services) summarising the discussions and prioritisation process.

Participants worked in small mixed groups on the following focus question:

“Based on the presentations from researchers, what are the main gaps in our collective knowledge on footrot?”

Responses were written onto large sheets by each group and the sheets were posted on a wall. All workshop participants then used five votes to indicate their five most important gaps.
The results are provided below:

**Identified gaps**

*Group One:*

<table>
<thead>
<tr>
<th>Main gaps</th>
<th>Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boundary – where benign/virulent line is set.</td>
<td>15</td>
</tr>
<tr>
<td>Need for improved diagnostic tests:</td>
<td></td>
</tr>
<tr>
<td>- Faster</td>
<td>9</td>
</tr>
<tr>
<td>- Cheaper</td>
<td></td>
</tr>
<tr>
<td>- Apply MAb Elisa</td>
<td></td>
</tr>
<tr>
<td>How can we put new technologies into practical tools?</td>
<td>6</td>
</tr>
<tr>
<td>Vaccine development:</td>
<td>5</td>
</tr>
<tr>
<td>- Commercialisation</td>
<td></td>
</tr>
<tr>
<td>- Registration</td>
<td></td>
</tr>
<tr>
<td>- Cost?</td>
<td></td>
</tr>
<tr>
<td>- Will producers use?</td>
<td></td>
</tr>
<tr>
<td>- Types:</td>
<td></td>
</tr>
<tr>
<td>Multivalent</td>
<td></td>
</tr>
<tr>
<td>Serogroup specific</td>
<td></td>
</tr>
<tr>
<td>(Plus costs to know groups present).</td>
<td></td>
</tr>
<tr>
<td>Animal welfare:</td>
<td>2</td>
</tr>
<tr>
<td>- Do we know what community pressures could arise if footrot is not controlled?</td>
<td></td>
</tr>
<tr>
<td>- Public perception.</td>
<td></td>
</tr>
<tr>
<td>Perspective regarding boundary differences:</td>
<td></td>
</tr>
<tr>
<td>- Regulator</td>
<td></td>
</tr>
<tr>
<td>- Researcher</td>
<td></td>
</tr>
<tr>
<td>- Producer</td>
<td></td>
</tr>
<tr>
<td>Not enough surveillance:</td>
<td></td>
</tr>
<tr>
<td>- on a property (for eradication);</td>
<td></td>
</tr>
<tr>
<td>- in a State or Region:</td>
<td></td>
</tr>
<tr>
<td>Know where footrot is.</td>
<td></td>
</tr>
<tr>
<td>What ‘type’.</td>
<td></td>
</tr>
<tr>
<td>Mutation?:</td>
<td></td>
</tr>
<tr>
<td>- After eradicating virulent strains, would other ‘benign’ strains become a problem?</td>
<td></td>
</tr>
</tbody>
</table>
**Group Two:**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of producer support and knowledge unknown.</td>
<td>17</td>
</tr>
<tr>
<td>Virulence (molecular era):</td>
<td>8</td>
</tr>
<tr>
<td>- Improve the test.</td>
<td></td>
</tr>
<tr>
<td>- Which determinants?</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td></td>
</tr>
<tr>
<td>Field behaviour West</td>
<td></td>
</tr>
<tr>
<td>Protease Tests</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td></td>
</tr>
<tr>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Role of mixed infections unknown:</td>
<td>5</td>
</tr>
<tr>
<td>- In lesion development?</td>
<td></td>
</tr>
<tr>
<td>- <em>D. nodosus</em> and <em>D. nodosus</em>?</td>
<td></td>
</tr>
<tr>
<td>- <em>D. nodosus</em> and other species?</td>
<td></td>
</tr>
<tr>
<td>Time:</td>
<td>2</td>
</tr>
<tr>
<td>- How to reduce test time?</td>
<td></td>
</tr>
<tr>
<td>- How to use direct swab tests?</td>
<td></td>
</tr>
<tr>
<td>Frequency of mixed serogroup infections unknown?:</td>
<td>1</td>
</tr>
<tr>
<td>- Within foot.</td>
<td></td>
</tr>
<tr>
<td>- Within sheep.</td>
<td></td>
</tr>
<tr>
<td>- Within flock.</td>
<td></td>
</tr>
<tr>
<td>- Within region.</td>
<td></td>
</tr>
</tbody>
</table>

**Group Three:**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>No acceptable test of virulence:</td>
<td>16</td>
</tr>
<tr>
<td>- Gelatin Gel too sensitive?</td>
<td></td>
</tr>
<tr>
<td>- U5’s (unstable strain 5).</td>
<td></td>
</tr>
<tr>
<td>- Pen-test – gold standard but more of a research tool.</td>
<td></td>
</tr>
<tr>
<td>Molecular tests still need further assessment:</td>
<td>10</td>
</tr>
<tr>
<td>- Increased collaboration required to facilitate testing (how might this be achieved?).</td>
<td></td>
</tr>
<tr>
<td>Potential of the mono and di valent vaccines for the Eastern States:</td>
<td>5</td>
</tr>
<tr>
<td>- How might this be progressed?</td>
<td></td>
</tr>
<tr>
<td>Assessment of the role of covert lesions with different treatments.</td>
<td>1</td>
</tr>
<tr>
<td>New Zealand resistance test not valid in Australia:</td>
<td>75</td>
</tr>
<tr>
<td>- Potential role?</td>
<td></td>
</tr>
</tbody>
</table>
### Group Four:

<table>
<thead>
<tr>
<th>Theme</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eradicability (virulence):</td>
<td>8</td>
</tr>
<tr>
<td>- Mild versus virulent.</td>
<td></td>
</tr>
<tr>
<td>- Cost:benefit study.</td>
<td></td>
</tr>
<tr>
<td>- Saleability to producers.</td>
<td></td>
</tr>
<tr>
<td>Validate Cheetham Test for diagnosis:</td>
<td>7</td>
</tr>
<tr>
<td>- Production.</td>
<td></td>
</tr>
<tr>
<td>- Welfare (linked to saleability to producers).</td>
<td></td>
</tr>
<tr>
<td>Virulence understanding:</td>
<td>5</td>
</tr>
<tr>
<td>- Genomics.</td>
<td></td>
</tr>
<tr>
<td>Ecology:</td>
<td>4</td>
</tr>
<tr>
<td>- Environmental selection.</td>
<td></td>
</tr>
<tr>
<td>- State-wide demographics of strains (molecular epidemiology).</td>
<td></td>
</tr>
<tr>
<td>Rapid strain characteristic and identification leading to vaccine.</td>
<td>2</td>
</tr>
<tr>
<td>Host resistance:</td>
<td>2</td>
</tr>
<tr>
<td>- Genetic markers.</td>
<td></td>
</tr>
<tr>
<td>Surveillance tests:</td>
<td>2</td>
</tr>
<tr>
<td>- MAb?</td>
<td></td>
</tr>
</tbody>
</table>

### Group Five:

<table>
<thead>
<tr>
<th>Theme</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of an effective vaccine.</td>
<td>11</td>
</tr>
<tr>
<td>Don’t know the role of putative virulence genes in the disease process.</td>
<td>10</td>
</tr>
<tr>
<td>No standardised, effective laboratory test(s).</td>
<td>1</td>
</tr>
<tr>
<td>Not enough epidemiological information on strains.</td>
<td>1</td>
</tr>
<tr>
<td>Importance of genetic variation in vivo.</td>
<td>1</td>
</tr>
</tbody>
</table>

### Identified themes

The whole group examined the weighting of responses and identified the following themes in the knowledge gaps:

- Haven’t defined the virulence boundaries:
  - Diagnosis of what’s eradicable and what’s not.
  - Cheetham Test needs validation.

- More work required on molecular tests and new technologies:
  - Understanding of science.
  - Diagnosis.
  - Surveillance tests.

- Need a better understanding of epidemiology:
  - Use of fingerprinting to improve identification in biosecurity breakdowns.
  - Mixed infections.
  - Covert lesions, with different treatments.

- Need to build producer support for eradication campaigns:
  - Acceptance.
  - Knowledge.
  - Welfare issue for producers, for community and lobby groups.
More work on vaccine development and commercialisation.

More work on host resistance and genetic markers.

Lack of linkages between research teams, across the spectrum, resulting in disparate databases across Australia.

**Gap analysis**

At the request of the workshop, a gap analysis was carried out, to match the importance assigned with the likely impact to be achieved.

The results are provided below:

<table>
<thead>
<tr>
<th>Theme</th>
<th>Gap analysis</th>
<th>Votes</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Virulence</strong></td>
<td>1. Defining the virulence boundaries for eradication purposes:</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>- Validation of Cheetham Test.</td>
<td>** *</td>
<td>Will determine future eradication success.</td>
</tr>
<tr>
<td></td>
<td>- Production validation in field.</td>
<td>** *</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Understanding genetic control of virulence (Rood project).</td>
<td>** *</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>New technologies to improve existing diagnostic tests – protease thermostability, twitching motility (MAb PCR on lesions).</td>
<td>*</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>** * **</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Will determine future eradication success.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Eradication strategy</strong></td>
<td>Can mild strains be eradicated?</td>
<td>*</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Develop test for eradication?</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategy for covert footrot?</td>
<td>*</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Producer support; acceptance; knowledge; community groups.</td>
<td>** *</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Animal welfare boundary?</td>
<td>*</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Can this be set?</td>
<td></td>
<td>Essential</td>
</tr>
<tr>
<td></td>
<td>Independent study.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dealing with mixed infections from an eradication viewpoint.</td>
<td>*</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Benefit/Cost Analysis of eradication for any new virulence boundary(ies) set.</td>
<td>**</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Can mutations occur after eradication to affect success?</td>
<td>*</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Improved methods of surveillance (abattoirs?).</td>
<td>**</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Treatment and prevention</strong></td>
<td>Potential of New Zealand resistance test (1 gene).</td>
<td>*</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Potential of specific (autog) vaccines.</td>
<td>*</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Research strategies</strong></td>
<td>More collaboration between Australian research groups to improve efficiency and facilitate field outcomes.</td>
<td>**</td>
<td>Improves efficiency and speeds progress.</td>
</tr>
<tr>
<td></td>
<td>Collective database of trial results to facilitate research outcomes and improve future trial designs.</td>
<td>**</td>
<td>Avoid duplication, enhance design.</td>
</tr>
<tr>
<td></td>
<td>Use of national collection of isolates to ’standardise’ research using fully characterised strains.</td>
<td>**</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>**</td>
<td>Makes research comparable.</td>
</tr>
</tbody>
</table>
SUMMARY OF GAP ANALYSIS

The highest impact gaps in knowledge from the above analysis were identified as follows:

1. Defining the virulence boundaries for eradication purposes:
   - Validation of Cheetham Test.
   - Production validation in field.

2. Understanding genetic control of virulence (Rood project).

3. Producer support; acceptance; knowledge; community groups.

4. Use of national collection of isolates to 'standardise' research using fully characterised strains.
THEME C

FIELD ASPECTS AND FOOTROT ERADICATION AND BIOSECURITY METHODS IN EACH STATE

(TOPICS 13-28)
TOPIC 13

FIELD ASPECTS OF FOOTROT
WHAT TO TARGET?

John Seaman
Program Leader, Flock Health
NSW Agriculture, Orange, NSW

Footrot is a contagious bacterial disease of sheep and goats, caused by the organism *Dichelobacter nodosus* in association with a number of other bacteria. With full expression, virulent footrot is a severe debilitating disease which causes severe lameness, illthrift and economic loss. Strains of *D. nodosus* vary considerably in virulence with benign strains usually associated with only mild transient disease.

The development of footrot lesions is dependent on the presence of *D. nodosus* and the complex interaction of host susceptibility, appropriate environmental conditions relating to moisture, temperature and pasture composition and the right bacterial flora in the interdigital skin of the sheep’s feet to set up conditions suitable for the establishment and development of *D. nodosus* infection.

The clinical expression of the disease depends on the time of year, the pasture conditions, animal factors and the strain of footrot organism. If environmental conditions are not suitable the prevalence of footrot lesions will be lower than under more favourable mild, moist conditions and the degree of lameness seen and production loss less. Any treatment will suppress expression and make clinical diagnosis more difficult.

Diagnosis of footrot in New South Wales

Introduction

In New South Wales, the Footrot Strategic Plan is directed at the eradication of virulent footrot. The strength of the plan to date has been the affirmative action of field staff in dealing strongly with footrot at the clinical level where underrunning has been used as the guide. When there were significant numbers of properties with clearly virulent disease this was relatively easy. As the level of highly virulent footrot has decreased, the expression of clinical disease becomes less clear and the difficulties associated with regulatory action on properties become more intense.

Note: From February 1992, following an Animal Health Committee decision, footrot has been defined as either benign or virulent. Under NSW Footrot Policy the former classification of ‘intermediate’ footrot is handled as virulent.

Diagnosis in flocks

In New South Wales the diagnosis of footrot in flocks is essentially a field diagnosis, which must involve a careful and thorough investigation of the flock and the flock history. In some flocks, one or two visits to the property may not be enough to establish a diagnosis of virulent footrot.
It is emphasised that in NSW the diagnosis of footrot in the flock is a professional task under the Veterinary Surgeons Act. Veterinarians should exercise their professional judgement and consider all information available before making a diagnosis.

Note: An exemption has been received under section 44 of the Veterinary Surgeons Act to allow accredited Livestock Contractors working under veterinary supervision to diagnose footrot in sheep through the Livestock Contractors Footrot Certification Scheme.

In a flock situation the veterinarian in the field must consider flock history, the environmental conditions at the time, the clinical lesions observed in the flock and any laboratory tests where applicable to arrive at a diagnosis. There are usually large numbers of sheep available and information on the previous history of the flock and the environment to which the sheep have been exposed should be ascertained.

Footrot can be diagnosed in a flock, on clinical grounds alone, by the examination of a sufficient number of sheep at a time when the disease has spread to a large proportion of the flock. With reference to the attached flowchart, lesions can be allocated to three groups (Virulent, Benign or Uncertain). Where Uncertain or Benign are proposed then at least 100 sheep selected at random must be examined in suspect mobs in the flock. In some mobs, it may require examination of more sheep to detect a sufficient number of affected sheep (score two or greater) to assist in establishing a flock diagnosis. Arriving at an Uncertain or Benign diagnosis by examining only five to 10 sheep is not acceptable. If the environmental conditions are not suitable to allow for the complete expression of the infection at the time of examination then it is recommended that the mob be re-examined again when conditions become favourable for expression of the disease. A report should be completed for each inspection visit with details of the prevalence of sheep with lesions of score two or greater, the prevalence of severe lesions with foot scores four or greater and progression or regression of lesions without treatment, along with the flock history and environmental conditions at the time.

Veterinarians should realise that in any flock where there is a history suggestive of infection (traceback, traceforward, saleyard detection, proximity to a known infected flock, eradication of virulent footrot within the past two to three years) and/or any sheep showing advanced lesions (Score 4 or 5), typical of *D. nodosus* infection, sufficient grounds must exist (professional responsibility) to reasonably exclude virulent footrot before a diagnosis of benign footrot can be made.

**Diagnosis in public places**

In public places Inspectors may not have access to information about the flock history on the property of origin and in most cases will not be able to examine large numbers of sheep. In this situation, the diagnosis must be based on the clinical findings in the sheep examined. Inspectors have powers to act on suspicion of footrot [Stock Diseases Act: Sections 7 and 8] but will generally require some confirmation/proof of footrot before taking action on the property of origin. Inspectors must be able to justify the diagnosis with clinical and diary records.

For regulatory purposes, in public places, any underrunning (Score 3a) of any hoof will constitute a basis for regulatory action.
Use of laboratory tests

Laboratory tests have been an integral part of successful eradication programs in other diseases. In these cases they have been mainly used to detect infection in individual animals, rather than the presence of infection in a flock or herd. In line with the 1991 National Animal Health Committee decision the Gelatin Gel test has been endorsed as the test of choice in NSW to assist the field veterinarian in establishing a diagnosis of footrot. Much discussion has centred on the validity of accepting a laboratory test such as the Gelatin Gel test as the definitive test to differentiate between benign and virulent footrot, as is the case in Western Australia. As with other tests, it is accepted that the Gelatin Gel test may not have 100 per cent sensitivity or specificity but experience gathered over many years confirms it to be a very useful test in assisting field veterinarians in establishing a diagnosis of footrot.

It must be remembered that the laboratory test involves the examination of material taken from a small proportion of sheep in the flock. It also involves the examination of a limited number of colonies that are grown on culture from the affected feet. Laboratory results should be interpreted after a thorough investigation of the flock and the full flock history. In New South Wales a laboratory test must not be used on its own to establish a diagnosis of virulent or benign footrot in a flock of sheep.

Further investigation

If the Gelatin Gel test returns a stable result (stable isolate; refer to flowchart), but the clinical picture and flock history is not typical of virulent footrot, allowance has been made for further investigation.

These options may be applicable in arriving at an initial diagnosis or where release from quarantine is proposed.

The options considered appropriate for further investigation are as follows:

- Examination of more sheep.
- Waiting for a spread or expression period.
- Placing sheep on irrigation paddock(s) or more favourable conditions ('high performance pastures').
- Examination of sheep older than lambs (a diagnosis of virulent footrot should not normally be made on lambs alone).
- The application of percentage footscores (score 4, 3c, 3b, 3a) and possible threshold levels.
- Review of flock history.
FLOW CHART FOR FLOCK DIAGNOSIS

Note on quarantine line: In a Control or Protected area all properties in the 'uncertain' category falling within the quarantine line (refer to flowchart) will need to have restrictions placed on the movement of stock off the property until a definite diagnosis has been made.
TOPIC 14

KEY PRINCIPLES OF A FOOTROT ERADICATION PROGRAM

Ashley Mercy, Manager, Animal Health
Department of Agriculture, South Perth, Western Australia

Introduction

In veterinary medicine, the most commonly used definition of the term eradication is, 'the regional extinction of an infectious agent' (Thrusfield, 1986). There are several key principles that need to be considered before undertaking a control or eradication program for any livestock disease. Failure to meet one or more of these criteria will significantly reduce the chances of successfully eradicating the disease.

A number of eradication campaigns have been commenced with good intentions and considerable enthusiasm, only to fail because one or more key prerequisites were not satisfied or in place. Policy makers need to apply a rigorous assessment of proposals to eradicate diseases to ensure that funds and effort are invested wisely and that expectations are realistic.

Knowledge of the disease

Knowledge of the history of a disease is important in order to develop the most cost effective control methods. It is important to have a good understanding of the disease including a good understanding of the causative organism, transmission, and pathogenesis. In the case of Virulent Footrot (VFR), there is a reasonably good understanding of the causative organism, the stable strains of *Dichelobacter nodosus*. There is also considerable knowledge of the virulence and ecology of the causative organism as well as the epidemiology of the disease.

Economic justification

Eradication of a disease needs to be economically justified. The benefits of eradication need to outweigh the costs. In some cases the benefits may be indirect, such as benefits to human health or to another industry.

The Department of Agriculture has conducted three Benefit Cost Analyses of the Western Australian Footrot Eradication Program (FEP) which have been subjected to external review. These analyses have all shown a positive BCA with the most recent in 2002 showing a BCA of seven to one with a $70 million benefit over 10 years (Ghose *et al.*, 2002).

Ability to diagnose the disease

A disease can only be controlled and eradicated if it can be recognised.

The key components for disease recognition are clinical signs, pathological changes, isolation of causal agents, demonstration of immune, allergic or biochemical responses and epidemiological identification of changes of a variable in a population (Thrusfield, 1986).
A prerequisite for any eradication program is the ability to accurately diagnose the disease. Whilst some diseases, such as bovine tuberculosis, have been successfully eradicated using tests with a relatively low sensitivity, diagnostic tests with high sensitivity and specificity are preferable.

The combination of clinical detection on suspicion of disease backed by the very accurate gelatin-gel laboratory test for stable strains of *D. nodosus*, provides an effective method of detection.

Effective surveillance by targeted inspections of neighbours of infected properties and abattoir surveillance are also key activities for detecting VFR in the Western Australian FEP.

**Removal of infected animals**

Ability to identify and remove infected animals from the risk population is necessary in an eradication program.

Key components of Western Australia’s FEP applied to all infected flocks are total destocking of infected mobs, undertaking an effective Summer Eradication Program (SEP) or a combination of destocking and SEP. The SEP option involves rigorous inspection of all sheep in infected flocks and culling of sheep with any suspicious lesions. The success rate of the SEP is around 50-60 per cent at the first attempt.

If destocking is not an option, then the SEP is mandatory for all infected flocks and is supervised by departmental staff to ensure appropriate inspection standards and culling procedures are followed (Quality Assurance). The SEP is underpinned by agreed Management Plans, preferably signed by flock owners.

The SEP is complemented by WA’s relatively dry climate, which results in a significant amount of ‘self cure’ in individual sheep. This reduces the number of sheep that need to be culled.

**Prevention of reinfection**

A mechanism is needed to prevent reinfection of flocks undergoing eradication. In the WA FEP, mandatory quarantine is imposed on all flocks detected with VFR. This reduces the risk of spread to uninfected flocks via livestock sales. Preventing the introduction of VFR via unwise sheep purchases or via straying stock are key risks that can be reduced by sensible biosecurity practices such as using vendor declarations and maintaining secure boundary fences.

**Sources of disease free stock**

A reliable source of disease free livestock is needed to restock flocks/herds undertaking eradication.

Approximately 99 per cent of WA sheep flocks are free of VFR, which provides a large pool of replacement VFR-free stock for producers choosing the destocking option.

**Effective animal health services**

A successful disease eradication program needs to be underpinned by an effective animal health service or veterinary infrastructure. The main requirements are: adequate diagnostic services; effective field services; research capability and administrative support.
The WA Department of Agriculture has a network of highly competent Veterinary Officers and Stock Inspectors who manage and implement a well-documented eradication program on individual properties. Statewide coordination is provided by a Project Manager and a small team of researchers undertake specific research projects on VFR. There are currently 49 departmental staff (equivalent of 13 Full Time Equivalent staff) involved in the FEP.

**Effective underpinning legislation**

Effective legislative powers are needed to ensure eradication procedures can be enforced. Without such powers, non-compliance with voluntary programs will significantly limit the chances of eradication.

The WA FEP is underpinned by strong legislation under the Stock Diseases (Regulations) Act (1968). The regulations provide the essential powers needed to enforce the key elements of the FEP—mandatory notification by owners is required, quarantine restrictions, movement restrictions, compliance with instructions from inspectors and de-stocking of remaining infected mobs in the case of prolonged quarantine.

Compensation for animals required to be destocked as part of an eradication program reduces the financial impact on owners and thus enhances producer support for the program. Compensation is not available under the WA FEP.

**Strong industry and community support**

Whilst regulatory powers provide Government with the ability to impose restrictions necessary to achieve eradication, achieving this goal is unlikely without strong backing from industry organisations and livestock producers.

Significant lack of enthusiasm and commitment to achieve eradication will severely undermine well-meaning and regulatory approaches by governments and generally result in failure of an eradication program.

In WA, formal industry input to the FEP is achieved via the Footrot Eradication Campaign Advisory Committee (FECAC). This is a Statewide industry based committee of key stakeholder groups including the Department of Agriculture. FECAC oversees the FEP in WA and provides advice to the Department on policy and operational matters.

The WA FEP has strong support from the major sheep industry organisations. These include the West Australian Farmers Federation, the Pastoralists and Graziers Association and the Stud Merino Breeders Association, all of which are represented on FECAC.

Another key element of producer involvement with the WA FEP is Community Footrot Groups. These groups have been formed in areas where there has been a significant number of quarantine flocks and have been highly successful in assisting local people to work together and help each other to eradicate VFR from their flocks and districts.

The FEP has been subjected to two independent Ministerial Reviews in 1994 and 2000. Both reviews concluded that eradication of VFR from WA was feasible and recommended the FEP continue.
Financial support

Control and eradication programs require appropriate funding. In Australia the eradication of exotic diseases is funded by contributions from Commonwealth and State Governments together with money from the affected livestock industry. Other endemic disease control/eradication programs such as bovine tuberculosis and Johne’s Disease have been financed by a mix of government and industry funds.

Up to 2002, the operational costs of the WA FEP have been funded entirely by the Government.

References


TOPIC 15.1

FOOTROT CONTROL PROGRAM IN SOUTH AUSTRALIA

Mike Riley* and Neil Buchananª

*Senior Animal Health Adviser, Primary Industries and Resources SA, Naracoorte
ªManager, Animal Health, Primary Industries and Resources SA, Adelaide

The objectives of the footrot control program in South Australia are to eradicate footrot from infected flocks, prevent spread to other properties and prevent introduction of footrot from interstate.

Footrot is a notifiable disease. Footrot or suspicion of footrot must be immediately notified to a Stock Inspector.

Infected sheep must not be allowed to come into contact with sheep belonging to other persons. Infected sheep must not be exposed in a market, public place or adjacent grounds.

Diseased sheep may not be travelled without the authority of a Stock Inspector.

Vaccines for the protection of sheep against footrot are permitted only with the written consent of the Chief Inspector of Stock. To date this has not been requested.

The role of Primary Industries and Resources SA (PIRSA) is to:

- provide advice on all aspects of footrot including diagnosis and eradication;
- inspect sheep at saleyards and elsewhere, to detect footrot;
- supervise the eradication of footrot from affected properties and prevent its spread by action in accordance with the Livestock Act;
- investigate the source of infection of affected properties and take relevant action to prevent recurrence;
- ensure that stock introduced into SA are accompanied by the necessary health certification.

Diagnosis of footrot

Diagnosis is based on clinical signs. A sufficient number of sheep are examined to be satisfied that there is at least 1 per cent Score 4 lesions in the worst affected mob. If necessary, 100 random sheep in the mob are tipped and foot scored by the national scoring system.

Where environmental conditions are not suitable for the expression of disease sheep on a property may be put under movement restrictions on suspicion of disease and the sheep re-examined at a more suitable time.

Because of the possibility of legal challenge samples are submitted to the laboratory. Submission of foot smears to the laboratory for bacteriological examination is compulsory where footrot is suspected.

Samples in Stuarts Transport Medium are submitted for culture and gelatin gel test. Information from these tests may assist an officer in his/her diagnosis.
Infected properties are placed under an Order under the Livestock Act until such time as the disease is eradicated on the property.

**Treatment**

The recommended procedure is a control phase during spring by footbathing in 10 per cent zinc sulphate or Radicate®.

This is followed by an eradication phase in the summer. Eradication choices are:

- Total or partial destocking. The property will be released from Order seven days after all of the sheep have been sold direct to an abattoir for slaughter. The inspector may reserve the right to inspect the property for freedom from sheep before issuing the releasing Order.

- If a partial destock is undertaken the Order will remain in place until other sheep are inspected for freedom of disease after a suitable transmission period.

- If an owner chooses to treat, programs are tailored to individual properties using a Property Disease Eradication Plan, agreed between the owner and Inspector.

The eradication phase occurs after pastures have dried off. Sheep are individually tipped and examined for the presence of lesions by a diagnostic paring. The use of contractors for this process is encouraged.

Following examination, infected sheep may be culled for slaughter or treated with antibiotics and footbathing.

The recommendation for 'clean' mobs is that they are re-examined every four to six weeks until they have had at least two clean inspections. Footbathing of 'clean' sheep is not recommended until the second clean inspection.

Sheep retained for treatment using antibiotics are treated, stood on gratings for at least 24 hours and footbathed out of the shearing shed. They are re-examined three to four weeks later and non-responders culled. Further inspections are carried out every four weeks until the sheep have had two clean inspections. There is no further footbathing until the final inspection.

The antibiotics of choice are Oxytetracycline LA or erythromycin, depending on the importance of cost and meat withholding period.

Release from Order is achieved by inspection of lame sheep in all mobs at the end of the spread period following the eradication program.

**Biosecurity**

Farmers have been advised for some years that they should examine any potential purchases for lameness. They are advised to footbath sheep on arrival and maintain isolation until the end of the following Spring.

Inspectors attend fat and store sales and clearing sales, where possible, in the high rainfall areas of the State to inspect sheep for footrot.

Neighbours of all infected properties are advised in writing of the imposition and release of Orders. Following a risk assessment the flocks of neighbours sheep may be inspected.
A health certificate (Form 2) is required for all sheep entering the State. This requires a declaration from the owner that:

- he has inspected the sheep and believes they are in good health;
- the flock is free from footrot or the suspicion of footrot;
- the sheep have not been in contact with sheep with footrot in the previous one year;
- the sheep have not been vaccinated against footrot.

Sheep from footrot protected areas (< 1 per cent flock prevalence) and the Mildura City Council area require an owner inspection for freedom from footrot and where benign footrot is detected the sheep to be tested negative by gelatin gel test.

Sheep from other areas of Australia require an inspection by an Inspector of Stock and if benign footrot is detected samples to be negative to the gelatin gel test.

The compliance rate with the requirement for health certification appears to be low.
TOPIC 15.2

SOUTH AUSTRALIAN FOOTROT PREVALENCE SURVEYS

M.J. Riley

A survey of 318 flocks in the higher rainfall districts of SA in the spring of 1985 (Dobson, unpublished data) detected 'clinically significant footrot' (one or more sheep in the flock with severe interdigital dermatitis associated with underrunning of the horn of the heel and sole to at least half way to the hard horn) in five (1.6 per cent) flocks (95 per cent confidence limits 0.2–3.0 per cent) while benign footrot was found in 52 flocks (16.3 per cent).

Table 1. The number of properties inspected by Region and number found to be infected with virulent footrot in the 1985 footrot survey in South Australia

<table>
<thead>
<tr>
<th>Region</th>
<th>Properties inspected</th>
<th>Properties infected</th>
<th>Per cent properties infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>South East</td>
<td>194</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>Adelaide Hills</td>
<td>99</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>Kangaroo Is</td>
<td>26</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>318</td>
<td>5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

In 1994, a prevalence survey was carried in the South East of South Australia, in areas with greater than 550 mm average annual rainfall. Seventy-four randomly selected properties were visited during the Spring.

For the purpose of this survey, virulent footrot was defined as one or more sheep in the flock affected with Score 4 footrot lesions, i.e. where underrunning extended from the medial wall of the digit to the outer edge of the sole.

Clinically virulent footrot was detected on three properties, giving an estimated prevalence of 4.1 per cent (95 per cent confidence limits 0.8-11.4 per cent). Samples from all three properties were positive to the gelatin gel test.

Clinically benign footrot was detected on 26 properties (35 per cent of total). *D. nodosus* isolates were cultured from 19 of these properties. *D. nodosus* was not cultured from five properties and two properties were not sampled. Of the 19 properties from which samples were cultured, nine were classified as gelatin gel negative, seven were gelatin gel positive and three properties had both gelatin gel positive and negative strains.

Table 2. The number of properties detected with clinically virulent and clinically benign footrot, the number of *D. nodosus* isolates and the results of gelatin gel testing during the 1994 footrot survey in the South East of South Australia

<table>
<thead>
<tr>
<th></th>
<th>No. properties</th>
<th>No. D. nodosus isolates</th>
<th>Gelatin gel test results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Clinically virulent</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Clinically benign</td>
<td>26</td>
<td>19</td>
<td>7</td>
</tr>
</tbody>
</table>

* Specimens not collected from two properties.
TOPIC 16

FOOTROT ERADICATION STRATEGIES IN WA

Tony Higgs
Footrot Project Manager
Department of Agriculture, Albany, Western Australia

The Footrot Eradication Project (FEP) is managed as a discrete project within the Animal Health Program of the Department of Agriculture. Overall responsibility for operational aspects for the FEP rests with Ashley Mercy, Manager of Animal Health and Tony Higgs, Manager of the Footrot Eradication Project.

The Footrot Eradication Campaign Advisory Committee (FECAC) oversees the FEP in WA and provides advice to the department on policy and operational aspects. This Committee includes representatives of the major sheep industry organisations in WA - WA Farmers Federation, Pastoralists and Graziers Association and Stud Merino Breeders Association, along with representatives of private veterinary and agricultural consultants and footrot community groups. FECAC is independently chaired by the Chairman of the Agriculture Protection Board in WA. FECAC has provided an excellent forum for input by industry and ensures industry support and commitment to the success of the FEP. The goal of the FEP is the eradication of virulent strains of *D. nodosus* from the WA sheep flock.

The key elements of the strategy for eradication of virulent footrot (VFR) in WA includes detection, diagnosis, quarantine, removal of infected sheep from the farm, re-inspection at the following transmission period and release from quarantine. Producers have the option of choosing to completely destock, or to embark on a summer eradication program. The WA FEP also contains a strong research component to support improved diagnosis, treatment and epidemiology.

Detection

One of the keys to successful footrot eradication is proactive surveillance, to detect new infections quickly and before major farm to farm transmission occurs. The inspection of sheep on neighbouring properties is essential and all reports of suspect footrot are checked. Abattoir monitoring, used in recent years in WA, has enhanced detection and improved the cost-effectiveness of the campaign. Samples are taken from sheep with clinical signs and submitted to the laboratory for testing.

Diagnosis

Cost-effective laboratory services that can diagnose VFR and assess virulence of strains are essential components of an eradication campaign. In WA the gelatin gel (protease) test is used to differentiate between virulent and benign strains of *D. nodosus*. Strains are further categorised using the zymogram test which electrophoretically visualises the different types of proteases produced by *D. nodosus*.

Quarantine

The policy of the WA Department of Agriculture, with support of industry, is to assist owners to eradicate virulent footrot from infected flocks. Quarantine movement restrictions are imposed under the Stock Diseases (Regulations) Act to prevent the spread of infection to
clean flocks. Sheep movements onto and off the property during the previous 12 months are traced. In a broader quarantine sense, sheep entering WA from interstate require pre-entry certification of freedom from VFR and are inspected before release from surveillance quarantine. The risk of VFR introduction from the Eastern States has been assessed as very low.

**Vendor declaration**

A footrot vendor declaration scheme was recommended in WA by a Footrot Review in 1994 and forms were distributed to stock agents with the endorsement of FECAC. The footrot vendor declaration is a signed statement by a livestock owner that the stock meet certain requirements. Uptake of the concept by WA sheep producers has been disappointingly low and so a simplified form was developed this year. The simplified form is due to be released before the coming spring.

**Eliminating infection**

There are two main options available for eliminating VFR; destocking or a summer eradication program:

(i) Destocking involves the removal of all sheep and goats, preferably before the autumn break, within 12 months of the property being quarantined.

(ii) A summer eradication program involves the elimination of the infection by culling affected animals using at least two summer inspections of all sheep in all mobs. The summer eradication program on any given property must be successful within 27 months (two summers) of the initial quarantine, or else remaining infected mobs will be compulsorily destocked.

The first summer inspection is done about two weeks after annual pastures have dried off. There must be no footbathing in the six weeks prior to this inspection. The stock inspector provides advice and assistance to farmers to recognise abnormal feet. All sheep must be examined and the owners conduct this inspection themselves, or employ a certified footrot contractor. Department of Agriculture Stock Inspectors provide advice to producers on inspection standards and they also provide some quality control by checking on those standards during the summer eradication programs.

All mobs must undergo at least two summer inspections and at least one has to indicate complete freedom from footrot lesions. Second and additional summer inspections are basically a repeat of the first summer inspection, usually carried out two to six weeks after the previous summer inspection. Footbathing is not recommended at this stage.

The monitoring period covers the time between the last summer inspection and the spring release inspection. The main points emphasised are:

1. Maintaining vigilance, checking for signs of footrot.
2. Keeping mobs separated, keeping records of mob movements during the year (paddock to paddock, very important during winter and spring when there is a high risk of disease spread); and
3. Allowing an interval of at least one week between mobs using common areas (laneways and yards).
Release from quarantine

In late spring, after the flock has been through a warm moist spread and expression period, all feet of all sheep are examined by Department of Agriculture inspectors. If all sheep are lesion free and/or no S strains are isolated, the farm is released from quarantine.

Summer eradication success rates

In the past four years, the percentage of farmers in WA who attempted summer eradication and succeeded in the first year were 52 per cent, 62 per cent, 57 per cent and 52 per cent. Most farmers who do not successfully eradicate VFR from all mobs nevertheless restrict infection in the first year to only one or two mobs and complete the eradication in the second year.

Treatment

Footbathing, especially the five-day method, usually results in a good clinical response. However, it cannot be relied upon to provide 100 per cent eradication of *D. nodosus* under field conditions. The WA policy is that footbathing will be allowed for disease reduction (animal welfare and production) purposes during winter and early spring, and, in conjunction with a prior culling of sheep with under-run lesions, may be also used in the weeks following pasture senescence in early summer.

Compliance

The owners of quarantine flocks are required to abide by a Footrot Eradication Management Plan (FEMP). The FEMP is an essential statement of planning and commitment of the involved parties. It provides a framework for a successful and smoothly run eradication program. The plan basically consists of a series of statements of when and how activities will be carried out. Compliance is assessed in relation to the FEMP.

Since 1 November 1997, all properties in quarantine have a maximum of two summers (27 months) to eradicate the disease. After two years on a summer eradication program, any remaining infected mobs and contact sheep must be destocked. A Footrot Review in 2000 recommended that an independent appeals process should be developed and this has been implemented.

Extension and communication

The importance of communication to stakeholders, so as to maintain informed industry support for the eradication objective, must be emphasised. Farmnotes are made available to all farmers, and a detailed ‘Footrot Guide’ is supplied to those farmers who have VFR in their flocks. Experience has shown that summer eradication success rates are highest when Department of Agriculture officers are able to communicate freely with producers during the eradication process. At a district level, the control of significant outbreaks has been greatly enhanced through the support of community action groups that have formed specifically for that purpose.
The footrot control program in New South Wales is based on the Footrot Strategic Plan which has been operating since 1988. The Plan is overseen by an industry based Footrot Steering Committee which is responsible for setting the direction of footrot control programs and monitoring progress.

The NSW Footrot Strategic Plan has the objective of improving the productivity and welfare of sheep and goats in NSW by the progressive eradication of virulent footrot. The Plan has both advisory and regulatory components and largely operates through Rural Lands Protection Boards to implement the eradication of footrot at the individual farm level and over time reduce the flock prevalence at the Board and State level.

To date significant progress has been made with footrot eradication such that all Boards throughout NSW have now reached Control (footrot flock prevalence 1–10 per cent) or Protected (footrot flock prevalence < 1 per cent) Area status. The number of infected flocks has decreased from over 6000 in 1991 to below 300 and all of these are subject to regulatory action. This significant progress has been largely due to the cooperative efforts of sheep producers working with Rural Lands Protection Boards and other significant industry groups including Livestock Contractors, private veterinarians, stud breeders and Stock and Station Agents.

The NSW Footrot Steering Committee has now set the target of December 2005 for all Boards to reach Protected Area status. If successful, this will mean footrot prevalence will be reduced to below 1 per cent in all Boards throughout the State. Although not totally eradicated the disease will be limited in distribution and largely under regulatory control. Sheep producers can now reliably source sheep free of footrot from the majority of New South Wales.

The success of the Footrot Strategic Plan can be attributed to many factors:

- Strong industry support for the program, with ownership of the direction of the program through the Footrot Steering Committee. Support was based on accepted economic and welfare grounds to justify eradication of footrot.
- Definition of a Statewide policy for footrot management based on techniques previously shown to be effective and the execution of this policy at Board level. Clear objectives and agreed strategies using sound scientific techniques were critical to ensure outcomes were achieved.
- Ongoing monitoring of progress of the program through regular reporting of outcomes to the Footrot Steering Committee. Early identification of issues and review of policy where needed. Auditing of progress has added validity to the program.
- Program includes both advisory and regulatory components — initial emphasis has been on advisory activity to gain industry support and achieve eradication. In the latter stages of the program regulatory aspects supported by suitable legislation (Stock Diseases Act) will become more important.
Existing Rural Lands Protection Board infrastructure was critical to run the program. Boards gave a high priority to the program and put on extra staff (Footrot Advisory Officers/Footrot Rangers) where needed. Veterinarians (both DVs and private practitioners) were involved in developing eradication programs and refining recommendations as knowledge improved.

An effective communication network with an identifiable, credible and coordinated source of information was available to producers through Boards. Facilitation of farmer footrot eradication groups was critical to the program in many areas — groups provided both technical information and social support and in many cases peer pressure to maintain direction of programs to achieve eradication. Farmers working together to ensure eradication was achieved over large geographical areas — and this success recognised at an industry and State level — has been critical to the program.

Laboratory support has been available to assist with diagnosis and provide scientific support as needed. Technical developments such as vaccines and new chemical treatments further assisted progress of the program.

Accredited Livestock Contractors provide a source of skilled labour to undertake eradication programs. Their role will become more important in the latter stages of the program as the 'more difficult' cases are handled.

Funding for the program has not been an issue as the cost of eradication programs have been funded by flock owners. Industry funds have supported research projects and NSW Agriculture has provided a coordinating role but the majority of program has been funded by individual producers.

Ongoing surveillance and awareness of strategies to keep footrot out of clean flocks are promoted to ensure progress achieved to date is maintained.

Footrot eradication and biosecurity methods

In New South Wales footrot is a notifiable disease and when diagnosed is subject to regulatory activity under the Stock Diseases Act. A review of policy has established clear guidelines to be followed to achieve footrot eradication on individual properties.

Following a diagnosis of virulent footrot and quarantine of the land, the District Veterinarian/Veterinary Officer (DV/VO) must provide the owner/manager of the sheep with written advisory material describing the various options for eradicating footrot and explain the obligations of quarantine under the Stock Diseases Act.

As part of the Undertaking in lieu of Quarantine signed by the owner/occupier under Section 11 of the Stock Diseases Act there is a requirement to develop an Approved Footrot Eradication Program. This Program is developed and agreed to by the owner/occupier and the DV/VO after taking into consideration what is likely to achieve the best results for the individual owner. The Program is compulsory, whether it be conducted by the owner (the Approved Owner Eradication Program) or according to requirements set down by the Inspector (the Approved Compulsory Eradication Program).

The following elements should be included, as appropriate, in a footrot eradication program:

- A description of the type of program to be undertaken.
- Details of all mobs of sheep on the property identifying those that are involved in the program.
The dates that the various eradication inspections are to be completed and the name of
the person who will inspect the stock.

A procedure for segregation of infected stock.

Deadlines for disposal of infected stock.

Footbathing treatments which are permitted.

Details of salvage treatments.

A requirement for clean musters.

A requirement for branding all stock at each inspection.

A requirement to advise the DV/VO of activities undertaken.

Milestones so that progress can be monitored.

Review dates.

Procedure for making changes to the program.

The owner’s acknowledgment that the program is a footrot eradication program under
the Section 11 Undertaking (to give it a legal status).

Examples of programs adapted from those used successfully by Young RLPB are attached
as appendices.

Approved owner footrot eradication programs

Encouragement and advisory support is provided to assist producers to undertake an
effective eradication program of their choice. This program must be approved by the DV/VO.
The outcome of this program must be the eradication of footrot from the flock, not ongoing
treatment to suppress the disease at a low prevalence.

Initially, owners will be given flexibility to decide on the type of eradication program that they
will undertake. For example employing an accredited contractor or doing the eradication
inspections themselves. Irrespective of the nature of this program, it must be written down
and the DV/VO must agree that the plan is technically sound. It must also contain review
dates. One review date should be set to coincide with an inspection at the anticipated end of
one eradication period. Once agreed by the DV/VO this owner program becomes the
Approved Owner Footrot Eradication Program.

The Approved Owner Footrot Eradication Program should be signed by both the owner and
DV/VO and include an acknowledgment that if reviews indicate that it is necessary, a revised
program will be developed. There is a requirement to regularly report progress and all
instances of non-compliance should be investigated and remedied.

Owners are given two years for an eradication program to succeed. Unless circumstances
beyond the control of the owner have intervened, a compulsory eradication program should
be prepared if the owner’s eradication program has not been completed within this time. The
policy also has provisions for interim arrangements and handling non-cooperators who are
unable/unwilling to undertake their own program.
Compulsory footrot eradication programs

If the Approved Owner Eradication Program fails within the agreed time frame a Compulsory Footrot Eradication Program is then developed. The compulsory program will usually require the owner to engage an accredited contractor, approved veterinarian or RLPB staff to undertake and be responsible for the inspection process. Ideally, the person used should be agreed with the owner. Costs incurred in engaging external assistance are to be met by the owner.

The apparent reasons for the failure of the Approved Owner Footrot Eradication Program need to be identified. This will allow the points of risk to be given specific attention during the Compulsory Footrot Eradication Program. In the majority of cases, failure of eradication occurs because all infected sheep are not detected and effectively removed following eradication inspections. This can be due to:

- an insufficient number of inspections;
- excessive delay between inspections;
- inadequate inspection technique;
- incomplete musters;
- poor stock control (boxing of clean and infected sheep) due to inadequate fencing or management expediency, e.g. to make it easier for shearing.
- all sheep identified as being infected are not sent to slaughter promptly.

Ensuring that eradication inspections are done properly, and infected sheep are removed from the property, are often the key issues that must be addressed in the compulsory program. Accredited Contractors provide a source of skilled labour needed to ensure the program succeeds.

The elements contained within a Compulsory Footrot Eradication Program will be similar to those contained in an Approved Owner Footrot Eradication Program. An additional element that may be included in some circumstances is an acknowledgment that an Inspector may visit the property to check on compliance with the program at any time and a higher level of supervision of the program is required.

While being referred to as a Compulsory Footrot Eradication Program, its formulation will still require significant cooperation and input from the owner/manager if they are to be committed to its implementation.

Failure of an owner to enter into or comply with a Compulsory Footrot Eradication Program will result in more formal regulatory action. Initially the NSW Agriculture Senior Field Veterinary Officer will interview the owner and if not resolved the matter will be discussed at the next meeting of the RLPB. The owner should be invited to attend that meeting to explain to the Directors the reasons for the failure of the eradication program.

Following consideration of the case, the Board may resolve to:

1. allow the owner to enter into another compulsory program; or
2. recommend the issuing of prescriptive Orders under S.8(1)(a).
Where the program has failed for reasons directly attributable to the owner (and not due to factors outside their control), in addition to taking action under the Act, then the DV/VO may take action to have appropriate Orders under the Stock Diseases Act issued to carry out eradication (including the option of destocking) and recover costs.

**Further reading**

NSW Agriculture Agfact – Footrot in Sheep and Goats  

NSW Agriculture Agnote – Vendor Declaration of Footrot Freedom of Flock  

Policy in New South Wales is that sheep moving from a Residual Area for footrot (e.g. Victoria) must be accompanied by a valid Footrot Vendor Declaration.
Footrot is eradicated by identifying and then culling all infected sheep/goats. Any program which relies on salvage - keeping sheep which had footrot but appear to be cured - has a significant greater risk of failure. No treatment will cure all infected animals.

Breakdowns in programs are not uncommon - surveillance and segregation of suspect mobs through winter/spring is essential. Lame sheep/goats should be caught and examined for symptoms of footrot and advice sought if suspect lesions are seen. Footbathing out of yards can reduce the risk of serious breakdown or cross-infection of other mobs but is no substitute for constant surveillance, especially before crutching, shearing, lamb-marking, etc.

Decontamination of yards, paddocks, lanes, etc. is achieved by seven day spelling/quarantine after infected or suspect sheep/goats have walked through these areas. Clean mobs should be moved or handled first through yards, then other categories, and infected mobs last. Footbathing is not a substitute for these precautions.

While cattle are not under any official restrictions, they can occasionally carry footrot infection between mobs/properties. Consideration should be given to keeping cattle that have been grazing with infected sheep/goats separate from clean mobs of sheep/goats during the eradication program.

The inability to achieve a clean muster is a common cause of later reinfection. Muster a paddock and then check muster.

Branding of all animals at the point of turning during each inspection will indicate the ability to achieve a clean muster. Brand infected and culls with a red brand on head/wig.

Footbathing at or between each turn should only proceed after consultation with the District Veterinarian or Footrot Ranger. This treatment can suppress symptoms of footrot and make removal of infected animals more difficult. The copper-based footbath product Radicate has been shown to be effective in treatment of infection and creating an artificial non-spread period between treatments, allowing inspections to continue irrespective of environmental conditions.

'Non-spread Period' is that period when transmission of virulent footrot will not occur due to hot/dry conditions. Commence first inspection early summer when clover has wilted.

Second and subsequent inspections (turns) should proceed at three to six week intervals, until each mob has had two totally clean turns (where no infection has been detected).

A list of Accredited Footrot Contractors is available from the RLPB office (see also NSW Agriculture Agnote at www.agric.nsw.gov.au/reader/17546).

Enter ALL mobs (indicating ewes with lambs at foot) in MOB LIST as attached. An additional MOB LIST is available for properties which run more than 20 mobs. If you are not inspecting the total flock give reasons.
Segregation of infected animals:

- **Inspect and cull program**: Infected animals and culls identified at each turn (see Branding) to be isolated from any identified clean animals or non-infected mobs until sold/destroyed (see Disposal).

- **Inspect and treat (salvage) program**: All 'cured' animals must be branded and isolated from identified clean animals – second turn onwards - and this separation must be maintained until the end of the next major spread period (usually Spring) and subsequently confirmed as cured by turning every animal and inspecting every foot. Consult with the District Veterinarian or Footrot Advisory Officer.

Additional advice on salvage programs:

At first turn infected may be treated with either:

- **Antibiotics** - Advice on type and usage MUST be obtained from DV or FR. Antibiotics can only be obtained on prescription from the diagnosing Veterinarian and can then be purchased from any Veterinary Practitioner.

- **Footbathing chemicals** - Consult DV or FAO.

At second turn - Do not re-treat any non-responders. Cull and dispose of as per 'Approved Footrot Eradication Program'.

**Disposal of infected stock**: Through slaughter only sections of saleyards or direct to abattoirs. Normally this should occur within two weeks of completion of each turn unless otherwise agreed to by DV or FAO. Contact the RLPB office for a Permit. Unsaleable animals may occasionally be destroyed on-farm.

**Record keeping**: The onus is on the Owner/Occupier/Manager to properly complete the 'Flock Status Report' supplied, and return to RLPB within two weeks of completion of a turn. **Failure to comply may jeopardise a future release from Quarantine.**

Alteration to agreed programs may be necessary due to changed circumstances. Prior agreement from DV or Footrot Ranger must be obtained. Failure to obtain prior agreement may be considered as a breach of your Undertaking.

**Protocol for release from quarantine**

- Fulfilling the requirements of the 'Approved Footrot Eradication Program'.
- In consultation and with the approval of the DV or FAO to employ an Accredited Contractor who will perform a single inspection of every foot of every animal in the flock the following summer under their supervision.
- Subjecting the total flock to a spread period without evidence of a Footrot outbreak in any mobs. This usually means Spring conditions. In circumstances where spread is not likely to occur within the next 12 months the owner may elect to have the release inspection undertaken by examining all sheep six to eight weeks after notification by the owner that an approved eradication program has been completed.
- The owner/operator/manager will inform the DV or FAO of the proposed start date of the release inspection.
- No antibiotic treatments or footbathing treatments are to be used within four months prior to the start of this release inspection.
The contractor will set aside all animals with any symptoms of infection and notify the DV or FAO so these animals can be inspected. No treatments of any sort - paring, footbathing, footsprays, antibiotic injections, etc. - are to be administered to these animals. It is also the responsibility of the owner to record details of such animals and supply these to the DV or Footrot Ranger.

Flocks released from quarantine will require a paddock inspection of all mobs following the next spread period after release. At this paddock inspection any lame sheep must be caught and examined for footrot.

Prevention

Footrot is a readily preventable disease, but requires care when purchasing and managing sheep. Boundary fences and gateways should always be kept as sheep-proof as possible. Where there is a suspicion of footrot in a district owners should not share roads or any other ground with other flock owners, unless there is at least seven days between sheep movements. Stray sheep or goats should not be tolerated - they are dangerous to road-users and neighbouring sheep flocks. Stray sheep should never be put over a fence, without the express approval of that landowner. Adjoining owners can significantly benefit each other by working together to enhance biosecurity. These measures will also greatly reduce the risk of spread of other diseases, such as sheep lice and Johne’s disease.

When purchasing sheep, including rams, owners should make every effort to minimise the chance of buying footrot, and the risk to their own sheep if footrot is bought in. Purchasers should carefully inspect sheep before purchase, question the vendor about footrot, and only purchase if the vendor provides a signed, completed Footrot Vendor Declaration. Purchased sheep should then be isolated on the purchaser’s property, until they have passed through a period suitable for spread, usually the spring, without breakdown.
RURAL LANDS PROTECTION BOARD

Address .......................................................... Telephone (02) ..........................................................
.......................................................... Fax (02) ......................................................................

Schedule of operations - Inspect and cull program

Approved footrot eradication program of .................................................. (Owner/occupier name and property name)

Total flock numbers: Sheep: ........................................ Goats: ..................................................
Breed(s): ...........................................................................................................................

1. Is the total flock to be inspected? Yes/No (Please complete attached MOB LIST)
Note: Inspection means looking at every foot of every animal.
What mobs will you NOT be inspecting?
List such Mobs as per MOB LIST numbers: .................................................................
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2. Proposed summer inspection schedule:
Please complete all dates and insert the name (under the title) of the person who will inspect the stock.

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<th>Turn</th>
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<th>Stock Diseases Inspector</th>
<th>Footrot contractor</th>
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3. Mustering
The entire paddock will be mustered each time a mob is moved to the yards for inspection. Any animals incapable of travelling with the mob should be immediately transported to the yards.

4. Branding
All stock will be branded during each inspection - see attached notes All CULLED/INFECTED stock will be marked on the head/wig with a red brand.

5. Footbathing out of yard
Clean Yes/No Infected/Culled Yes/No
Date of last footbath (prior to commencement of inspection program): / /
Chemical: Zinc Sulphate/Radicate
6. Segregation
All CULLED/INFECTED stock will be permanently segregated from non-infected stock until disposal.

Stock of a known disease status/risk (not infected, first clean turn, second clean turn, etc.) will be segregated from those of a different status.

7. Disposal of infected stock
Destroy and/or sell for slaughter only, during week commencing:
- 1st Inspection/Turn /
- 2nd Inspection/Turn /
- 3rd Inspection/Turn /
- 4th Inspection/Turn /

8. Remuneration
Owner of stock agrees to pay normal contract inspection fees directly to the Footrot Contractor if engaged.

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Any sheep or goats introduced to the property must have prior approval of the District Veterinarian/Footrot Advisory Officer.

All newly-formed mobs and their progeny must be inspected as part of the ongoing eradication program and will be subject the terms of this agreement.

I .............................................................. I being owner/occupier of ........................................

(Name) (Property)

agree to carry out this Approved Footrot Eradication Program according to this Schedule of Operations and as required by my Undertaking in lieu of Quarantine:

Signature of Owner/Occupier / / Date

Inspector - Stock Diseases Act Approved on behalf of District Vet. / / Date

111
RURAL LANDS PROTECTION BOARD

Address .................................................

...................................................  Telephone (02) ..............................................

...................................................  Fax (02) ....................................................... ..

Schedule of operations - Inspect and treat infected stock (salvage) program

Approved footrot eradication program of ................................................................. (Owner/occupier name and property name)

Total flock numbers:  Goats: .........................  Breed(s): .................................

1. Is the total flock to be inspected? Yes/No  (Please complete attached MOB LIST)
   Note: Inspection means looking at every foot of every animal.
   What mobs will you NOT be inspecting?
   List such Mobs as per MOB LIST numbers: .................................................................

2. Proposed summer (non-spread) inspection schedule
   Please complete all dates and insert the name (under the title) of the person who will inspect the stock.

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<th>Turn</th>
<th>Inspected by</th>
<th>Owner</th>
<th>Manager</th>
<th>Permanent employer</th>
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3. Mustering
   The entire paddock will be mustered each time a mob is moved to the yards for inspection. Any animals incapable of travelling with the mob should be immediately transported to the yards.

4. Branding
   All stock will be branded during each inspection - see attached notes.
   All CULLED/INFECTED stock will be marked on the head/wig with a red brand.

5. Footbathing out of yard
   Clean Yes/No  Infected/Culled Yes/No
   Date of last footbath (prior to commencement of inspection program):  / /
   Chemical:  Zinc Sulphate/Radicate
6. **First inspection**
   (a) Segregation - All 'salvage' stock will be identified and permanently segregated from 'clean' stock.
   (b) 'Clean' stock - Footbath out of Yards Yes/No
   (c) 'Salvage' stock - Treatment antibiotic Yes/No ..................................................
      Footbath Yes/No ..................................
      Drainage paring Yes/No ........................

7. **Second inspection**
   Inspect 'clean' mobs first
   (a) 'Clean' stock - Footbathing out of Yard Yes/No
   (b) 'Salvage' stock - Remove culls and infected non-responders.
      - Consult District Veterinarian/Footrot Ranger/Accredited Contractor.

8. **Third inspection**
   Inspect 'clean' mobs first
   (a) 'Clean' stock - Footbathing out of Yard Yes/No
   (b) 'Salvage' stock - Remove culls and infected non-responders.
      - Consult District Veterinarian/Footrot Ranger/Accredited Contractor.

9. **Fourth inspection**
   This may not be required on some mobs - Consult District Veterinarian/Footrot Ranger/Accredited Contractor.

10. **Segregation**
    All CULLED/INFECTED stock will be permanently segregated from non-infected stock until disposal.
    Stock of a known disease status/risk (not infected, 1st clean turn, 2nd clean turn, etc.)
    will be segregated from those of a different status.

11. **Disposal of infected stock**
    Destroy and/or sell for slaughter only, during week commencing:
        1\textsuperscript{st} Inspection/Turn: / /
        2\textsuperscript{nd} Inspection/Turn: / /
        3\textsuperscript{rd} Inspection/Turn: / /
        4\textsuperscript{th} Inspection/Turn: / /

12. **Record keeping**
    Flock Status Report form (supplied by the Board) will be completed by the Owner/Occupier/Manager after each turn and returned to the RLPB within two weeks of the turn being completed.
13. **Permission to alter program**

If this program requires alteration, prior permission (in writing) must be obtained from the District Veterinarian or Footrot Ranger.

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<td><strong>TOTAL numbers</strong></td>
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</table>

Any sheep or goats introduced to the property must have prior approval of the District Veterinarian/Footrot Ranger.

All newly-formed mobs and their progeny must be inspected as part of the ongoing eradication program and will be subject the terms of this agreement.

I .............................................................. I being owner/occupier of ....................................... .

(Name) (Property)

agree to carry out this Approved Footrot Eradication Program according to this Schedule of Operations and as required by my Undertaking in lieu of Quarantine:

```
Signature of Owner/Occupier / / Inspector - Stock Diseases Act / /
Date Approved on behalf of District Vet. Date
```
XXX

RURAL LANDS PROTECTION BOARD

Address ..................................................

.......................................................... Telephone (02) ..............................................

.......................................................... Fax (02) .......................................................

Schedule of operations - Destocking

Approved footrot eradication program of ..................................................

(Owner/occupier name and property name)

Total flock numbers: Goats: ................................. Breed(s): ........................................

(Please complete attached MOB LIST.)

1. Is the total flock to be destocked? Yes/No

   If Yes - Total Destocking will be completed by ...............................................................

   If No - Partial Destocking will be completed by ..............................................................

   Place a 'D' next to those mobs to be destocked in the designated column (D).

MOB LIST

<table>
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<tr>
<th>Mob No.</th>
<th>Description</th>
<th>Age</th>
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TOTAL numbers

2. Partial destocking

   Will be undertaken on all mobs considered to be infected Yes/No

   These mobs are identified by a 'D' coding on the above MOB LIST.

   All retained mobs will be turned/inspected by an Approved Footrot Eradication
   Contractor prior to release, after environmental conditions suitable for transmission and
   expression of Footrot have been experienced. Yes/No

3. Segregation

   All sheep/goats to be destocked will be permanently segregated from non-infected
   stock until disposal.
4. **Permission to alter program**

If this program requires alteration, prior permission (in writing) must be obtained from the District Veterinarian or Footrot Ranger.

Any sheep or goats introduced to the property must have prior approval of the District Veterinarian/Footrot Ranger.

All newly-formed mobs and their progeny will be considered as part of the ongoing eradication program and will be subject the terms of this agreement.

I ..................................................... I being owner/occupier of ........................................

(Name) (Property)

agree to carry out this Approved Footrot Eradication Program according to this Schedule of Operations and as required by my Undertaking in lieu of Quarantine:

<table>
<thead>
<tr>
<th>Signature of Owner/Occupier</th>
<th>Date</th>
<th>Inspector - Stock Diseases Act</th>
<th>Date</th>
</tr>
</thead>
</table>

Approved on behalf of District Vet.
### NSW FOOTROT QUARANTINES - 30 JUNE 2003

<table>
<thead>
<tr>
<th>SFVO AREA</th>
<th>RLPB DISTRICTS</th>
<th>TOTAL FLOCKS (&gt; 50 sheep)</th>
<th>QUARANTINE FLOCKS</th>
<th>SHEEP IN QUARANTINE</th>
<th>&gt; 3 YEARS QUARANTINE FLOCKS (No.)</th>
<th>GOATS No. Flocks Quarantine (No. goats)</th>
<th>QUARANTINE RELEASES 31/12/02-30/06/03</th>
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Flocks = 50 sheep or more  *Hume Board 29 additional flocks to be checked  INT 03/13462
TOPIC 18

POLICY AND ACTIVITIES IN RELATION TO FOOTROT - TASMANIA

Mick Middleton
Department of Primary Industries
Water and Environment, Tasmania

Policy

Tasmania has a history of quarantine/eradication programs. Those for bovine TB, brucellosis and hydatids were successful. Those for ovine lice and ovine footrot were not.

There was a quarantine and eradication program for footrot until 1975. The program did not distinguish between degrees or strains of footrot, and was discontinued due to difficulties in eradicating intermediate strains. The effects of the program on larger producers far outweighed the losses due to footrot.

The eradication policy was replaced by a policy of saleyard inspections, involving the large store sheep sales. The aim was to detect infected mobs, which were then subject to regulatory control. These mobs were permitted to be sold for direct slaughter, or had to be taken back to the property of origin.

This was a very difficult policy to enforce in the field. Problems encountered were:

- The difficulty in setting a diagnostic threshold in the field.
- The need to inspect sheep as they were unloaded to ensure timely detection.
- The false sense of security it gave buyers who could buy apparently sound sheep at summer store sales, only to have them break down with virulent footrot that autumn.
- The contamination of saleyards probably helped further spread.

This was replaced by a 'buyer beware' extension program which petered out in the early 1990s.

There was a brief flirtation with an unaudited vendor declaration scheme, which left the diagnostic and ethical dilemma with the producer, and achieved little.

In the 1990s, a voluntary footrot eradication area was established in NE Tasmania, but several large properties failed to eradicate despite repeated attempts, and the concept lost credibility. In hindsight, the NE of Tasmania (which supports non-irrigated dairying) has a climate less conducive to footrot control.

An attempt to set up a State footrot committee along the lines of the NSW model failed due to lack of producer interest.

Currently, it remains a case of 'buyer beware'. Footrot is neither a notifiable disease under the Animal Health Act 1995, nor is it the subject of an Industry Disease Control Program under this Act. Producers appear to regard footrot as just another chronic production limiting disease of sheep, which can usually be managed to minimise its impact on the health and welfare of the sheep. There is little industry interest in a regulatory control program.
The Department of Primary Industries, Water and Environment and Private Veterinary Practitioners provide advice to producers wishing to control, eradicate or prevent footrot.

The main issue of concern is the animal welfare impact of untreated cases.

Perspective

Tasmania is Australia’s most mountainous State, and sits in a moist westerly airstream. The result is a temperate maritime climate with a relatively even monthly rainfall distribution, and many wet days per month. In addition there are significant climatic differences between regions - the midlands and southeast are drier, the elevated inland areas are subject to frosts, and the coastal areas enjoy a mild, moist climate, conducive to non-irrigated dairying. In general, Tasmania’s climate probably mitigates against control methods relying on periods of low or zero transmission.

The most recent questionnaire survey (mid ‘90s) indicated that 40 per cent of Tasmanian sheep flocks were infected with what the owners believed to be intermediate or virulent footrot. The 2003 situation is likely to be similar.

The Tasmanian flock was largely Corriedale and Polwarth based up until the late 70s. There was a major shift to merino genetics in the 1980s. This coincided with a major increase in the prevalence and severity of footrot.

The midlands and southeast (the major wool producing areas) suffered a prolonged period of low rainfall (by Tasmanian standards, a drought) through the 1990s. The flock prevalence probably remained the same, but the impact was reduced.

Over the last few years, good spring rains have led to increased reports of footrot flare-ups.

Historically, a number of properties have eradicated virulent footrot, but a number have also broken down due to biosecurity problems - neighbouring infected flocks, stray sheep, purchases.

Footrot eradication and biosecurity methods used in Tasmania

Eradication

A number of individual producers have eradicated footrot using a variety of approaches.

Successful attempts, under Departmental guidance, have been associated with:

- initial inspection early in January;
- cull infected sheep early;
- concentration on re-inspection of the ’clean’ mobs;
- use of vaccine early in the program;
- use of antibiotics to salvage infected sheep;
- general management (clean musters, sheep-proof fences, loyal farm staff);
- good facilities (sheep handler, lighting);
- thorough foot examination at re-inspections.
The type of footbath used does not appear important - 5 per cent formalin, 10 per cent zinc and 20 per cent zinc/2 per cent lauryl footbathing have been used on successful properties. Successful attempts using 10 per cent copper sulphate or 'Radicate' appear to be rare.

If eradication is attempted in a dry, non-transmission period, little attention has been given to resting paddocks, bringing mobs in and out over clean ground, etc. and this does not appear to reduce chances of success.

Hospital mobs and 'cured' mobs are discouraged — all sheep are regarded as equally likely to break down and must be re-inspected thoroughly. Keeping management simple has allowed managers to focus on re-inspections.

Constant surveillance during first transmission period after an eradication attempt, with early examination of lame sheep is encouraged. Isolation of any mob which does break down has limited impact of breakdowns. Cell grazing has made eradication difficult on large properties.

Large properties, especially if they use contractors, and have a high staff turnover, appear unlikely to succeed.

Biosecurity

The main reasons for a property breaking down with footrot are:

- Neighbour infected.
- Purchase sheep from infected property.
- Stray sheep.

Good fencing is encouraged, but instances have occurred where the evidence indicated that infection was transmitted through a fence by water, flies, wildlife, etc. (i.e. no direct sheep contact). Our attempt at an area eradication scheme failed, probably because advisory support was not maintained. Producers are advised to footbath and sometimes also to inspect flocks if stray sheep are found in a clean mob.

Sheep purchasers are advised to footbath introduced sheep off the truck when they arrive, inspect all feet, isolate sheep through a spread period before mixing with their own clean sheep. Intensive introduction programs have been developed for rams which have to be mated soon after arrival.

Truck washing facilities are not available at all saleyards, and transporters do not have time to wash down trucks during busy store sale periods.

Tasmania does not have any specific footrot status requirements for sheep imported from interstate, though they must not be under any regulatory restrictions and must be healthy.
TOPIC 19

FOOTROT CONTROL IN VICTORIA

John Galvin
Manager Animal Health Operations
Department of Primary Industries, Bendigo, Victoria

Ovine footrot is a disease of significance to the Australian sheep industry, both socially and economically. Official control programs undertaken by State Governments, in conjunction with their sheep industries, aim to reduce the prevalence of virulent footrot and thus reduce the cost of footrot. The costs include lost productivity, loss of marketing opportunities and the cost of control and eradication of the disease.

From 1970 to 1995 Victoria applied a footrot eradication policy that required owners of sheep in declared areas to eradicate virulent footrot from their flocks by the use of quarantine. In 1982 the level of footrot infection in the south-western footrot control area was 0.2 per cent of flocks affected. A survey conducted in 1993 indicated that the flock prevalence in this area was around 6 per cent. Discussions with industry at that time indicated that a quality assurance program based on a more self-regulatory approach was the preferred action for dealing with footrot.

Official footrot control programs are aimed at virulent footrot. They need to be based on principles that include: (i) definition of virulent footrot; (ii) guidelines for flock diagnosis of footrot; (iii) guidelines for defining flock freedom from footrot; (iv) on-farm control and eradication procedures; (v) regulatory activities; (vi) education and extension activities; and (vii) vendor declarations.

Diagnosis of footrot

In Victoria the diagnosis of footrot is generally made on the clinical assessment of flocks. This requires the clinical inspection of a valid number of sheep in the flock, preferably during a period of the year when conditions are suitable for footrot development and spread. Under nationally agreed standards, a diagnosis of virulent footrot is made when there are 1 per cent or more of sheep with score 4/5 lesions.

In Victoria it is considered that laboratory tests may be useful in some instances, such as when seasonal conditions are not suitable for the spread and development of the disease. However, Victorian experience is that there are a number of flocks, perhaps 30 per cent or more in the high rainfall areas, where the current laboratory tests would define the footrot bacteria as virulent, while the clinical assessment indicates that the flock has benign footrot.

Legislation

Footrot is a (notifiable) disease for the purposes of the Livestock Disease Control Act, 1994. The Act provides the power to impose quarantine, develop (on-farm) control agreements and isolation orders to effect control within infected flocks, and prohibits the exposure of infected sheep in saleyards and public places.

The Prevention of Cruelty to Animals Act, 1986 provides the legislative definition of cruelty to animals. Footrot can cause major animal welfare problems, particularly if flocks are left untreated. In extreme cases, sheep are unable to forage or walk to water and often die.
Flystrike in affected hooves is common and often leads to body strike. It would be an offence under the Act if an owner failed to apply 'veterinary or other appropriate attention or treatment' to the affected flock.

The Stock (Seller Liability and Declarations) Act, 1993 could be used to underpin a market-driven quality assurance program based on vendor declaration and vendor liability. Footrot could be declared a condition for the purpose of this Act. This means that when sheep are sold with a vendor declaration, if the purchaser finds virulent footrot within (say) 14 days of purchase, the vendor would be required to take back the sheep and refund to the purchaser the selling price, plus pay any costs associated with transport, handling, veterinary fees, etc. Under this Act, an automatic liability could apply on the sale of non-slaughter such that, should footrot be detected after sale, a penalty (such as described above) would apply. This would change the focus of selling non-slaughter sheep from 'buyer beware' to 'seller guarantee'.

Footrot contractors

DPI has operated a system of accrediting footrot contractors over the past five years. To become accredited, a contractor must make application to DPI. Their competency is assessed by both a written examination and an assessment of their practical skills. The Accreditation lasts for one year, at which time it is reassessed taking into account the quality of the footrot control work they have done over the previous year. There are currently 21 accredited footrot contractors in Victoria.

Current situation

Dry seasonal conditions over the last four to five years have resulted in a low level of virulent footrot in Victoria, as measured by saleyard surveillance activities and disease notifications to DPI. DPI's major activities in footrot control include:

1. Maintaining surveillance in major store sales, taking on-farm follow-up and regulatory action where virulent footrot is detected.

2. Providing a service to diagnose footrot and classify it as virulent or benign, and develop on-farm control and eradication programs, where there are no private veterinary practitioners servicing the sheep industry.

3. Deal with situations where there is an unacceptable risk of footrot spreading to other flocks, or where there are potential animal welfare implications.

4. Maintain the training and accreditation scheme for footrot contractors.

5. Maintain training program for DPI animal health staff to ensure their competencies in footrot diagnosis and control.
Biosecurity measures in Queensland for virulent footrot rely mainly on passive surveillance, augmented by trace-forward and active surveillance following any advice of stock movements from infected properties interstate.

Foot problems are rare in Queensland sheep flocks. Owners are very conscious of footrot and maintain inspections and examination of sheep during normal management practices. Any suspect cases of disease are reported to the Department of Primary Industries (DPI). The two known infected properties in Queensland were detected this way. There is no evidence or reports of attempts to conceal the presence of footrot.

Interrogation of the DPI Laboratory On-line Information System (LOIS) data base does not reveal any other cases of virulent ovine footrot, but shows eighteen investigations of lameness in sheep in the last five years, for which specimens were submitted for laboratory examination.

Control of the disease is achieved by quarantine of the infected property and destocking, with a period of spelling prior to restocking. This process is currently in place on one of the known infected flocks in the Goondiwindi district, but is proceeding slowly due to the lingering drought which has hindered selling due to lack of saleable condition of sheep, coupled with fluctuating prices. The other property has been entirely destocked and Quarantine release is pending.

To date, confirmation of virulent ovine footrot has been via the NSW Agriculture laboratory, but it is understood that the WA Department may be able to offer this service in future.

There has been no desire expressed by the sheep industry to instigate active surveillance for footrot, or any provision made for funding of such a program. No financial assistance is available from either Government or Industry for affected producers to destock.
TOPIC 21

INTERSTATE MOVEMENTS/BARRIER SECURITY/ZONE STATUS/VENDOR DECLARATIONS/MONITORING FOR ‘FREEDOM’ FROM VIRULENT FOOTROT

Bob Mitchell
Department of Agriculture
South Perth, Western Australia

The issues of interstate movements of sheep and goats, the potential spread of ‘exotic’ strains of virulent footrot (VFR), difficulties of barrier security, issues of zone status and the usage of vendor declarations for footrot are all intertwined.

Prior to 1994 there was an Interstate Working Party on Footrot, and a series of meetings were held (generally at venues close to the NSW-Vic. border). The major motivation for such meetings was especially that NSW, Victoria and South Australia had great difficulties with stock movements across their mutual borders. The other southern States (WA and Tasmania) were eventually invited, as broad agreement was necessary between States as to with what degree of confidence each State/Region/Zone could allocate a status for ‘Relative Freedom from Footrot’.

The group actually reached agreement on the main definitions for footrot and for different zones! The subsequent interstate collaborative project CHP94 was initiated (by this and other groups) recognising that a faster, cheaper laboratory diagnostic test was highly desirable, and also to assess in controlled trials a range of atypical and reference strains of D. nodosus.

Then Ovine Johne’s Disease (OJD) became a major imperative, and the interstate working party lapsed.

Interstate movements

The producers in some States demand precautions (that to some others seem draconian) against the risk of introduction of significant animal diseases. Footrot is present in all States but the strains present and the prevalence and severity of strains varies between States.

At one end are the requirements for entry into WA. The property of origin has to be declared (by the owner) as free of virulent footrot for at least two years, and the person who wishes to import has to certify, in relation to the sheep or goats in the consignment:

- They have not been footbathed or received antibiotics for any purpose within three months prior to movement.
- They have not have been vaccinated for footrot within 12 months prior to movement.
- They have been born on the property of origin or been on the property not less than 12 months prior to movement except for temporary removal to an agricultural show where precautions of spread of footrot were taken.
- They have not have had any contact with animals affected with footrot 12 months prior to movement.
- All feet have been individually inspected by a person approved by the CVO within 14 days prior to movement and show no evidence of virulent footrot.
Where animals showing evidence of interdigital scalding or any form of footrot to have been individually tested by the protease thermostability (gelatin gel) test with no protease stable *Dichelobacter nodosus* being detected.

It is likely that these precautions (strengthened in 1994) indirectly assisted WA to keep OJD out.

When a State/Region is close to (or achieves) eradication of VFR, the need to then handle 'new incursions' will be a large issue for industry to handle and to adequately resource.

**Vendor declarations**

Voluntary Footrot Vendor Declarations (FVD) are a means whereby purchasers can buy sheep with a lower risk of them having VFR. The advantage for the vendor is that such FVD sheep should attract a higher price. NSW initially started this precaution and encouraged special Vendor Declared Sales. WA followed with a form in 1994 (with the same requirements as on the WA Interstate Movement form). A feature of these early forms was that if the purchaser found sheep to have VFR in the 14 day period following the sale, there were steps to essentially return the sheep and cancel the transaction.

Some other States have a slightly different VFVD, several printed onto the Waybill and some have made a FVD a necessary part of the interstate movement requirements.

VFVD uptake in WA was not very successful, and in 2002-03 there have been VFVD forms redrafted to take out the 14 day return period (a draft is attached). I believe there is no legal basis for such a form, other than as a civil court determines (if someone could be shown to have knowingly filled out a false declaration). The biosecurity precautions on the back of this redrafted form are primarily aimed to advise the potential purchaser.

Another draft development in WA, is the proposed policy for inspections and VFVD of sheep prior to clearing sales. In time this may be expanded to include other major spread events such as stud ram sales, ram lending schemes (mostly associated with newer breeds, especially for the live export market) and shows.

**Zone status**

At Interstate Working Party level to 1994, there was progress in relation to definition of terms 'Infected Zone', 'Residual Zone', 'Control Zone', 'Protected Zone', and 'Free Zone'. There is a need for National Standard Definitions and Rules to be formulated and accepted. The bases of zone definitions include the maximum prevalence of virulent footrot, and the action taken when footrot is detected.

At present there are differences between State definitions, and in some cases there is little real ability to make claims on maximum prevalence without a much increased proactive surveillance input.

**Monitoring for freedom**

Eventually there will be some Regions/States that need to prove that VFR has actually been eradicated. At what level of confidence? How much surveillance is enough? There is a high price for absolute proof. Statistical methods and risk analyses will be even more important tools at the end point of an eradication program.
OWNER/VENDOR DECLARATION

FOR VIRULENT FOOTROT IN WESTERN AUSTRALIA

This declaration is provided in good faith but must not be construed as a guarantee of freedom from virulent footrot.

Evidence of footrot includes inflammation of interdigital skin.

Virulent footrot (VFR) is caused by stable (S) strains of *Dichelobacter nodosus* as tested by the gelatin gel test.

Benign footrot (BFR) is caused by unstable (U) strains of *D. nodosus*.

Usage of this form is supported by the WA Footrot Eradication Campaign Advisory Committee.

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PART 1 - CORE DECLARATION

This Part MUST be completed and signed by the Owner/Vendor.

1. **I certify** that I (print name) ................................................................. of (print address) .................................................................
   am the owner/manager of (property name) .................................................................
   on ...................................................... Road in the (Shire) of ................................................................. under the Trading Name of ................................................................. Telephone No. .................................................................

2. **Based on inspections done and the property’s footrot history, I believe virulent footrot is NOT present on the above property.**

   Signed: ................................................................. Date: ........ / ........ / ........
PART 2 - OPTIONAL DECLARATION

This Part MAY be completed and signed.

3. I believe that benign footrot IS NOT present in my flock. Yes No Don’t know

4. I certify that, in relation to the SHEEP/GOATS offered for sale:
   A. They are not known to have had any contact with sheep or goats affected with virulent footrot within twelve months prior to the date of this declaration:
      Yes No Don’t know
   B. Lame animals and at least 30 other sheep in each mob have been examined within the previous 21 days prior to signing this declaration and no evidence of footrot was observed:
      Yes No
   C. They have not been footbathed for any purpose within the three months prior to the date of this declaration. Yes

5. I certify in relation to the PROPERTY described in Part 1:
   Virulent footrot in sheep or goats has not been known or suspected to have been present on the property for at least 12 months 2 years more than two years prior to this declaration.

   Signed: ................................................................. Date: .......... / ........... / ...........

Recommended biosecurity precautions by prospective purchaser:

1. Consider whether the presence of benign footrot is an important issue to you or not. Benign footrot is present on approximately 15 to 20 per cent of WA sheep and goat properties and is not subject to the WA Footrot Eradication program.

2. Read this vendor declaration carefully and ask the vendor and/or the agent for further information if required by you.


Recommended biosecurity precautions by purchaser:

4. Prior to loading the sheep/goats; Insist that the stock transport vehicle is clean.

5. Immediately after arrival on the property of destination: Inspect sheep/goats. If footrot is suspected immediately obtain veterinary or Stock Inspector advice. Keep purchased mob isolated. Place the introduced sheep/goats in clean paddocks (unstocked for at least seven days).

6. At all opportunities when yarding sheep: Inspect sheep/goats. If footrot is suspected immediately obtain veterinary or Stock Inspector advice. Keep purchased mob isolated.
Maintain isolation of each purchased mob for as long as possible, preferably until after the following spring, then re-inspect them. If footrot is suspected immediately obtain veterinary or Stock Inspector advice.

Retain a copy of this declaration.
TOPICS 22-25

No papers were prepared for these discussion, review and demonstration sessions.
TOPIC 26

SOME AVAILABLE ESTIMATES OF FOOTROT PREVALENCE AND PRODUCTION LOSSES

Bob Mitchell
Department of Agriculture, South Perth, Western Australia

Prevalence data

Some good data exists from prevalence surveys. The data from the SE of South Aust, the New England area of NSW, the SW of WA, and some other studies in other States will be presented, discussed and compared.

The relative prevalence by strain or severity of virulent footrot is important. For example the prevalence of severe virulent footrot (VFR), mild (intermediate) VFR, and for some benign footrot (BFR) strains will lead to a more accurate assessment of the scale of effects of the disease.

Prevalence surveys are just snapshots in time in a particular district/region/State. Because the farmers and regulatory authorities are doing a range of things, and because market prices dictate cycles of potential major and ongoing footrot spread events between years, actual prevalence can change quickly by the next year.

Abattoir monitoring for signs of footrot is a further tool which lead to a series of estimates of footrot. Some may be used, with caution, as a means of measuring progress by district/region.

Production losses

Production research is expensive and most of the work on production effects of footrot dates back to the 1980s and early 1990s. And in most trials only one ‘type’/strain was tested in one environment for a limited period. The main losses are; Wool Loss, Body Weight Loss, Increased Mortality, Increased susceptibility to fly strike, and Decreased (fertility) ability to rear a lamb to weaning.

In some instances the production research provides snippets which are not directly comparable, even when one attempts to allow for environmental effects on disease expression.

(As examples, four components of footrot production losses are given in more detail.)

Reduced wool production

1. Footrot leads to reduced wool production in merino sheep (Stewart et al. 1984). Marshall (1987) found in Wagga (NSW) that VFR led to a 7 per cent reduction in annual greasy wool production. This was in a flock of approx. 80 per cent prevalence, so the reduction in infected sheep was approx. 8.5 per cent. Wilkinson (1986) found in a trial in the high rainfall zone of WA that infected sheep with mild (intermediate) VFR produced 10 per cent less greasy wool than uninfected sheep.
2. Footrot also affects wool diameter. Marshall (1987) found wool from VFR infected sheep was 0.3 micron lower, or 0.38 micron when adjusted for disease prevalence. Wilkinson (1986) found 0.73 micron finer wool in sheep infected with mild VFR.

3. Assumption used in the WA Economic Model for reduction in wool production (by Zone, see map distributed): Zone 1 VFR 9 per cent, mild VFR 5 per cent; Zone 2 VFR 5 per cent, mild VFR 3 per cent; Zone 3, VFR 3 per cent, mild VFR 0 per cent.

4. Some compensatory effects occur with micron. Allworth (1988) found a 1 kg reduction in clean fleece weight is associated with a 1.5 micron reduction in fibre diameter.

Reduced body weight

1. Marshall (1987) in Wagga found that sheep infected with VFR were on average 15 per cent lighter than uninfected sheep over a 12-month period. Wilkinson (1986) found sheep with mild VFR were 14 per cent lighter over eight months than uninfected sheep.

2. Assumption used in WA Economic Model for reduction in bodyweight: Zone 1 VFR 15 per cent, mild VFR 10 per cent; Zone 2 VFR 10 per cent, mild VFR 0 per cent; Zone 3 VFR 3 per cent, mild VFR 0 per cent.

Increased mortality

1. Marshall (1987) found mobs infected with VFR (prevalence 80 per cent) had a 2 per cent higher annual mortality rate. Data from WA properties showed generally three to 4 per cent higher death rates (Mitchell et al. 1990).

2. In the WA Economic Model the increase in probability of a higher mortality rate for VFR is higher in Zone 2 than Zone 1 due to the lesser availability of water in the more inland zone. Zone 1 VFR 3 per cent increase, mild VFR 1 per cent; Zone 2 VFR 4 per cent, mild VFR 0 per cent; Zone 3 VFR 1 per cent mild VFR 0 per cent. In part these are interactions with the increased susceptibility to fly strike (body and/or foot strike).

Reduced fertility

1. This aspect is quite complicated and many factors interact. Croker and Kelly (1989) found a 2 per cent decrease in ovulations for each 1 kg reduction in liveweight before joining. Footrot affected ewes are lighter at joining and over pregnancy. This normally leads to fewer and lighter lambs being born. Thatcher and Rabbett (1977) and Kelly (1992) results were used to allow for the fact that ewes which did not lamb produce more wool of higher micron, and less feed would be required.

2. Assumption in WA Economic Model for estimated decrease in the probability that a footrot affected ewe will rear a lamb: Zone 1 VFR 8 per cent, mild VFR 5 per cent; Zone 2, 5 per cent, mild VFR 3 per cent; Zone 3 VFR 3 per cent, mild VFR 0 per cent.
TOPIC 27

ABATTOIR SURVEILLANCE FOR VIRULENT FOOTROT - A METHOD OF DETECTING NEW CASES AND A TOOL FOR ESTIMATING PREVALENCE

Tony Higgs
Footrot Project Manager
Department of Agriculture, Albany, Western Australia

The successful eradication of any disease requires a surveillance system that finds the disease faster than it spreads. For virulent footrot (VFR) the required success rate in finding infected but unidentified flocks was estimated to be at least 50 per cent per year to achieve eradication, and at least 80 per cent to achieve eradication within six years (Roberts and Higgs, 2000). In the drive to maximise the surveillance effort, the relatively inexpensive method of abattoir surveillance has become a significant tool for the Footrot Eradication Program (FEP) in WA. This paper reports on the method that is currently employed and key results from the last five years.

How does it work?

Abattoir surveillance is a non-targeted surveillance system that includes sheep sent to slaughter as part of normal commercial practice. Exactly which groups of sheep are inspected is largely dependent on when an inspector is present at the abattoir, although there is some scope to inspect specific truckloads with careful planning. The need for abattoir staff to connect the stock with a payment to the owner, and the legal requirement for stock identification, ensure that there is an audit trail to link the source farm with any surveillance information.

Upon arrival at an abattoir, the owner’s details on the waybill are transferred to the abattoir’s receival book and a lot number is allocated. The lot number remains with the line of sheep from the time they are discharged from the truck to the carcase weighing area on the factory floor.

In addition to the lot number, each individual animal should have either a legible wool brand or an eartag, with an embossed brand on it, to enable further confirmation of the ownership of the sheep.

The inspection procedure

Inspection of three feet of each animal takes place soon after slaughter when the majority of body movement has ceased. At least 90 per cent of sheep can be examined in every line. Any lesions that are considered by the inspector to be suspicious are sampled for submission to the laboratory. Inspectors are trained to complete the sampling and bottle labelling for a sampled animal before continuing with inspections. The latter is intended to minimise any risk that a sample bottle may not be labelled correctly.

A laboratory submission form is completed with the owner’s details, as provided on the kill sheet and waybill, and the samples are sent to the laboratory for processing.
Until now, feedback to producers has only occurred when there is a positive result from the laboratory. For the 2003/2004 season, feedback on all results will be provided to the owner or manager.

What are the benefits?
In comparison to traditional field inspections of sheep there are many significant advantages of abattoir surveillance:

- Improved occupational safety from reduced exposure to back strain and injury from scalpel cuts.
- Efficiency is increased as 10 or more lines can be inspected per day (the average was 8.4 lines per day in 2002/2003).
- Weather conditions have no effect on daily inspections as hooves are always clean. In effect this means that the window of time for abattoir surveillance is greater than for field inspections.
- Travel costs and time lost from travelling is reduced. No appointments need to be made with farmers, no long distance travel is required and there are no cancellations from bad weather.

What are the limitations?
Abattoir surveillance is not a complete substitute for field surveillance but when considering any complementary surveillance that should be conducted the limitations of the method should be considered:

- Significant numbers of sheep are exported by ship from WA. Apart from some rejects that are sent to slaughter, these sheep can not be inspected for footrot in an efficient way.
- In order to maintain the efficiency of the method, only the major abattoirs with high throughput are suitable. Small local abattoirs are too slow and slaughter too few sheep.
- The distribution of source farms is entirely dependent on the buying patterns for the abattoir and may not include areas that are at higher risk for VFR.
- Approximately 1 per cent of lines are not traceable to the source because of inadequate documentation.

While not necessarily a limitation of the method per se, the cooperation of abattoir management and staff is paramount to being able to conduct the surveillance. To date cooperation in WA has been excellent and it has been appreciated by those involved in the FEP.

How much does it cost?
Based on a daily cost for an inspector of $250, including operating expenses, the average cost per line is approximately $30 (at the 2002/2003 average of 8.4 lines per day). The latter figure compares to $125 per property, plus travel expenses, for a field inspection taking half a day.
What are the results so far?

After a successful pilot year in 1997/98, when the method was tested for efficiency and accuracy, the FEP has used abattoir surveillance as a key part of the surveillance effort. The method has identified 116 new VFR cases since it started and has included sheep from all the sheep raising areas of the agricultural area of the State. Commencing in 2003/2004 feedback will be provided to all owners/managers of sheep inspected at abattoirs.

Another key issue in any disease eradication program is monitoring progress. Traditionally, the number of quarantine properties and the number of stock on those properties have been used. However, with the FEP, changes in the value of sheep and wool can affect the numbers of quarantine properties at any one time. When prices rise, as they have done in recent years, producers tend to elect summer eradication instead of destocking, thereby reducing the rate of eradication from quarantined properties.

Abattoir surveillance provides a more stable reflection of the number of new cases of VFR. Providing that the inspection effort remains similar and the source of sheep for the abattoirs is also similar, it provides a measure of changes in the number of new cases. The trend over the last five years has been downward with only 0.5 per cent of lines being found positive for VFR in 2002/2003 (Table 1).

Table 1. The per cent of lines inspected that were identified as new cases of VFR

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of lines inspected</th>
<th>New VFR cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998/1999</td>
<td>660</td>
<td>4.5%</td>
</tr>
<tr>
<td>1999/2000</td>
<td>625</td>
<td>3.8%</td>
</tr>
<tr>
<td>2000/2001</td>
<td>1788</td>
<td>1.8%</td>
</tr>
<tr>
<td>2001/2002</td>
<td>1845</td>
<td>1.1%</td>
</tr>
<tr>
<td>2002/2003</td>
<td>1706</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

Summary and conclusion

Abattoir surveillance is a valuable tool in the WA FEP. The method has identified 116 new cases of VFR, it is highly cost effective to conduct and it provides a measure of progress towards eradication. It is likely that in the longer term, abattoir surveillance will become a key part of the monitoring that will be required after eradication of VFR has been achieved in WA.

Reference

TOPIC 28

DISCUSSION ON COMBINED ABATTOIR AND LABORATORY TESTING

Bob Mitchell referred to the following published paper in this discussion session:

THEME D

INDUSTRY INVOLVEMENT IN FOOTROT POLICY AND FUNDING CHALLENGES IN EACH STATE

(TOPICS 29-35)
TOPIC 29

INDUSTRY INVOLVEMENT IN NEW SOUTH WALES
FOOTROT POLICY AND FUNDING CHALLENGES

James Maslin
Chairman, NSW Footrot Steering Committee
‘Caragabal West’, Caragabal, New South Wales

In NSW we have a system of Rural Lands Protection Boards delivering animal health services at a district level. There are 48 Boards, each has eight directors who are landholders elected by fellow landholder. Each Board has a vet and a number of rangers paid by rates collected by each Board from its landholders with no external funding.

In 1988, at the request of industry, the Rural Lands Protection Boards and NSW Agriculture with help from relevant universities and industry formulated a Footrot Strategic Plan. This Plan is overseen by an industry based Footrot Steering Committee which is responsible for setting the direction of footrot control programs and monitoring progress. The Steering Committee has representatives from Rural Lands protection Boards (x2), NSW Farmers Association (x2), Stock and Veterinary Association and NSW Agriculture (Executive Officer role).

The NSW Footrot Steering Committee meets biannually (usually in March and October) to oversight the implementation of the NSWE Footrot Strategic Plan. The Committee considers such matters as policy issues, declaration of Control and Protected Areas, progress in eradication programs in Rural Lands Protection Boards, industry support and recommendations for advisory and regulatory programs. The Committee is supported by a Technical and Advisory Sub-Committee which includes a broad base of technical ‘hands-on’ representatives actively working with footrot (e.g. livestock contractors, district veterinarians, footrot ranges, senior field veterinary officers, private veterinarians and researchers). Support is also provided by a Diagnostic Sub-Committee for specific diagnostic policy issues.

Footrot policy is discussed at the Technical and Advisory Sub-Committee with a recommendation made to the Footrot Steering Committee on development of policy in specific areas. Steering Committee considers policy but actual wording is developed by NSW Agriculture (usually by representatives on the T&A Sub-Committee) in collaboration with Rural Lands Protection Boards. As from 2001, when a Memorandum of Understanding between Boards and NSW Agriculture was introduced, the proposed policy is now discussed at Animal Health Committee (joint Committee including producer and veterinary representatives from Boards and veterinary managers from NSW Agriculture). If endorsed, policy is then jointly signed-off by State Council and NSW Agriculture and issued as a ‘Written Instrument’ to be implemented through all Rural Lands Protection Boards. District veterinarians and Footrot rangers employed by Boards are responsible for implementing policy. There are obviously many opportunities for input (and changes) throughout this rather involved process. Industry can comment at T&A Sub-Committee level, at Steering Committee level and again at Animal Health Committee level. Producer representatives sit on both the Steering Committee and Animal Health Committee.

The NSW Footrot Program has been largely funded by industry through the Rural lands Protection Board system. As stated earlier, this unique system provides for delivery of an animal health service paid for by all livestock producers via a rate based on carrying capacity. The Boards District Veterinarians and para-veterinary staff (Footrot rangers)
implement the advisory and regulatory components of the Footrot Strategic Plan. The cost of work and materials associated with eradication program is funded by individual flock owners. Accredited Livestock Contractors provide a source of skilled labour to undertake eradication but again any costs involved are paid by the producer. NSW Agriculture provides a coordinating role and a (subsidised) laboratory testing service for diagnostic support. Industry funded research projects have also contributed to the success of the NSW Footrot Strategic Plan.

The NSW Footrot Steering Committee has now set the target of December 2005 for all Boards to reach Protected Area status. If successful, this will mean footrot prevalence will be reduced to below 1 per cent in all Boards throughout the State. It is difficult to obtain accurate figures relating to the cost of footrot but it is estimated the annual economic losses due to footrot in New South Wales have been reduced from $45 million to below $2 million. The challenge for the future will be maintaining momentum with eradication for the good of the whole industry (especially with low expression strains) and at the same time keeping awareness up to ensure the disease does not reappear.
TOPICS 30 and 31

No papers were provided for these topics.
TOPIC 32

FOOTROT IN TASMANIA

Jim Cooper
Tasmanian Farmers and Graziers Association, King Island, Tasmania

Tasmanian Farmers and Graziers Association (TFGA) is the peak body representing 5000 livestock producers in Tasmania.

There are around 3.4 million sheep in Tasmania.

95.7 per cent of Tasmania’s flock are located in the Northern and Southern Midlands and Central Highlands municipalities, with lower concentrations on Flinders and King Islands, Glamorgan-Spring Bay, West Tamar, Launceston, George Town, Kingborough and Meander Valley municipalities. Sheep numbers in Tasmania have been declining over the last decade from over five million in 1988. This has been due to falling wool prices and ongoing drought in many wool-producing areas of the State. Over the last 18 months however, modest flock rebuilding in Tasmania has started.

Specific disease control programs and advisory services, previously supported by State budgets, such as ovine lice, footrot and hydatids, have been declining since the early 1990s. Tasmania does not routinely quarantine for footrot, although there is legislation available to do so if required. Footrot is now ‘de-regulated’ with no formal control measures being undertaken or enforced.

Attitudes to footrot have changed over time with people no longer being ostracised for having footrot in their flock. Local buyers of sheep purchase on a ‘caveat emptor’ basis. Being a small State however a property’s past footrot history will be significant in purchasing decisions.

Tasmania and Victoria are classified as ‘residual zones’ for footrot, therefore sheep must be accompanied by a valid Footrot Vendor Declaration if they are sold to NSW.

Interestingly under major State development planning guidelines, an Agricultural Management Strategy for preventing the spread of diseases such as footrot, lice or Ovine Johne’s disease must be submitted to the planning authority for authorisation by the Food, Agriculture and Fisheries Division of DPIWE.

TFGA has had no formal input into footrot policy for many years.
TOPIC 33

FOOTROT MANAGEMENT IN QUEENSLAND

Will Banks
AgForce Sheep and Wool Policy Director
AgForce Queensland, Brisbane, Queensland

Queensland is fortunate not to have a footrot problem. In the past there have been two isolated cases of footrot near the New South Wales border. Both flocks were quickly quarantined and the outbreaks controlled.

The Queensland environment is not conducive to harbouring the footrot disease. The footrot bacterium has difficulty surviving on dry, exposed ground for more than one day. The major sheep production areas of Queensland have dry arid and semi-arid climates, making it difficult for the bacterium to survive. The regularity of drought is another factor that protects the Queensland flocks. The general lack of humidity in the sheep producing areas also helps prevent footrot.

Another factor that has protected Queensland from footrot infections are the traditional sheep trading patterns. Queensland’s only major commercial sheep trading partner is NSW. Few sheep are brought into Queensland from NSW’s footrot prone areas. If sheep come into Queensland from NSW it is with the exception of stud stock, where hopefully there is not a footrot problem anyway.

Queensland is lucky in that the State animal health systems generally have the support of the industries. There is the waybill system that monitors all stock movements. There are border checks for all stock entering Queensland, and health certificates accompany travelling stock.

AgForce support Queensland’s Department of Primary Industries approach to footrot management. If there is ever a footrot concern in Queensland, AgForce will work with the governments involved to resolve the problem as quickly as possible.
TOPICS 34 and 35

No papers were provided for these topics.
THEME E

A NATIONAL APPROACH TO FOOTROT, OPPORTUNITIES FOR HARMONISATION, AND ADVICE TO AWI ON APPROPRIATE INVESTMENT IN FOOTROT RESEARCH, DEVELOPMENT AND INNOVATION

(TOPICS 36-37)
TOPIC 36

CONSIDERATION OF A POSSIBLE NATIONAL APPROACH TO FOOTROT - SUMMARY OF DISCUSSIONS

Three outcomes were achieved within this theme of the workshop. Bevan Bessen facilitated a discussion session and provided a report. The following text was extracted from the ‘Outcomes Report’ by Bessen Consulting Services. Outcomes three and four are shown below and Outcome five follows in a subsequent section of these proceedings.

OUTCOME THREE: Review of current State footrot programs

See Topics 29-35 covered in preceding pages.

OUTCOME FOUR: Articulation of industry commitments and identification of criteria for eradication

Industry commitment

At the conclusion of the presentations on current State footrot programs, participants worked in small groups to consider the following focus question:

“What is the level of industry commitment to ongoing control/eradication, and what are the key obstacles?”

The responses were:

Victoria

- Equivocal commitment for control; because the original Footrot Control Act:
  - strongly decreased ‘hot’ virulent footrot;
  - ran into problems with eradicating less virulent strains.
- Negative for eradication, because of:
  - a change of attitude of producers, who now challenge State-run programs.

To overcome this situation, producers would need:

- Convincing and overwhelming evidence of industry and private benefit, including intangibles such as psychological worry.
- A plan that is achievable: a 20-50 year ‘road-map’ that integrates the Victorian program with a national approach.
- ‘Constitutional reform’ (Southern Australia to be split into South Eastern Australia; Western Australia and Northern Australian regions).
Tasmania
- No interest in a regulated program.
- Lack of resources.
- Lack of technical solutions.
- Producer support low and government interest low.
- If technical solutions can be found:
  - producer support will increase;
  - can then consider resources and funding.
- Must be industry driven.

South Australia
- Support for control but the obstacle is sufficient knowledge for an eradication program:
  - Test versus clinical expression (decide what to get rid of and then have a test to identify it).
  - More surveillance regarding disease distribution (abattoir).
- Resources:
  - Revisit a levy.
  - Cost benefit analysis; and
  - Open ended??

Western Australia
- Commitment:
  - Industry ‘in general’ perceived to be committed to eradication:
    - Survey needed?
- Obstacles:
  - Confidence that footrot can be eradicated.
  - Confidence in the virulence boundary (the test):
    - Need for national agreement?

Queensland
- Keep footrot out:
  - Movement controls on border.
- Surveillance needed in abattoirs?
- Rely on environment to keep footrot out.
- No need for program.

New South Wales industry commitment
- Risk of industry complacency.
- Continued biosecurity awareness on a national basis, e.g. OJD and footrot.
- Commitment is high (though covert).
- Risk of re-stigmatising the disease with regulatory phase progression.
Rural Land Protection Board involvement in the successful delivery of the program.

NSW Agriculture underpinning role in strategic division (Steering Committee).

Early success is validating eradication principles for local areas.

**New South Wales industry commitment (cont)**

Climatic variation:
- Low expression in some areas.
- Short window in other areas.

Clinically benign/laboratory virulent strains are potentially a problem.

False sense of security from a long period of drought (includes restocking).

Complacency.

Economic fluctuations of the wool industry.

**Overall**

Workshop participants agreed that the footrot approach was diverse across Australia and that any agreed approach needed to accept and build on that diversity.

**CRITERIA FOR ERADICATION**

Participants were asked to focus on one of the central questions evolving from the workshop, i.e.:

“What elements or criteria should be used to define what to eradicate/not eradicate, in footrot?”

The group responses were:

**Group One:**

What a responsible producer would be prepared to sell or not sell to other producers in the industry (or prepared to buy or not buy in), influenced by:

- stage of the program (State/Region);
- economic effect (maximum potential);
- community perception;
- diagnostic test result;
- eradicability;
- environment/host/organism interaction.

What a responsible Veterinarian would sign as a certificate to verify sheep are free of footrot (not to be eradicated).

**Group Two:**

Impact:
- Welfare.
- Productivity.
- Virulence potential.
Eradicability:
- Degree of difficulty.
- Cost.

Process:
1. Identify 'boundary' strains.
2. Pen trials for expression potential.
3. Field trials for transferability.
4. Fingerprinting of strains.

Group Three:
- Capable: Will it cause a problem anywhere?
  - Economic loss – BCA;
  - Clinical expression ← quantify
  - Exclude negative Gelatin Gel, cattle isolates.
- Mixed infections?

Approach:
- Examine well defined isolates from various regions to develop ‘test cut-off’.
- Use well-characterised clinical data under ideal expression (Armidale; University of Sydney; CHP 94; new cases).

Group Four:
- Aim: The target (simply) is to eradicate production-limiting lameness in sheep.
  - Therefore, eradicate organism(s) causing on-going intervention to manage.
  - Decision making on individual farms is possible now.
  - Sheep movements and existing biosecurity create industry problems.
  - Therefore a simple, cheap and reliable test is needed, applicable to and calibrated for sheep breed; strain; sex; condition; pasture; soil, etc.
  - A battery of tests will give increasing specificity.
Group Five:

Presence of lesions:
- Local definition of importance.

Differential diagnosis:
- Is this a \textit{D. nodosus}-related disease?
- Is this a \textit{D. nodosus} strain that should be eradicated?

How:
- Presence of lesions is clear cut.
- Detection of \textit{D. nodosus}, through:
  - MAb;
  - PCR.
- New test(s) that define the line:
  - Research needed.
  - Field kit?

Group Six:

Impact:
- Financial impact (benefit/cost analysis) and welfare (clinical expression of virulence).

Eradicability:
- Pro's and cons and financial cost.

Non-cattle.

Individual property is easy; sheep movements create problems.

Process for boundary strains:
- Define clinically quantitative ideal conditions.
- ? pen trials.
- Field trails (mixed infections?).
- Fingerprinting.
- Battery of tests.

Overall

The most common criteria are those associated with:
- impact;
- eradicability.
TOPIC 37

SUMMARY OF WORKSHOP OUTCOMES, KEY ISSUES AND AGREED ACTION LIST

At the beginning of this section, Professor Richard Whittington, Chair of Farm Animal Health, Faculty of Veterinary Science, University of Sydney, presented the following perspective derived from the previous discussions:

Opportunities for harmonisation

Slide 1

NATIONAL HARMONISATION

(and why we are probably already more harmonised than we think)

Slide 2

STEPS IN FOOTROT CONTROL

• Recognise (or diagnose)

• Respond (take some kind of action)

• Decide what we are happy to be left with at the end (e.g. < 1% prevalence VFR)
Slide 3

**RESPONSE THEORY**

Coordinated action = $K$ (prevalence + producer support)

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<th>Producer support</th>
<th>Action taken</th>
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<tbody>
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<td>high</td>
<td>+++</td>
</tr>
<tr>
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<td>+++</td>
</tr>
<tr>
<td>VIC</td>
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<tr>
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<td>-</td>
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</table>

Slide 4

**RECOGNITION THEORY**

Current diagnostic approaches are linked to the kind of response taken, and to habit

Diagnosis = $k$ (response + habit)

It might be better to view the apparently inconsistent national approach in epidemiological terms, and document and/or modify it according to epidemiological principles.

Slide 5

**‘THE NATIONAL PROGRAM’**

- Define the aim: control or eradication?
- First task for both aims is to reduce prevalence
- Desirable test characteristics change as

  NSW, VIC - ‘moderate’ prevalence - specificity is important (minimise complaints, resources spread over many farms) *(early stage of disease control)*

  WA - ‘low’ prevalence - sensitivity is important (few potential complaints, resources adequate, get the last few cases) *(late stage of disease control)*
Slide 6

NATIONAL HARMONISATION OF VFR FOOTROT DIAGNOSIS

Clinical case = trigger

- NSW

Culture, protease thermostability

Tests in series increase specificity

Unstable - not VFR

Stable = trigger

The BC test

NSW NE RLPB

Negative - not VFR

Positive - VFR

Slide 7

Clinical case = trigger

Clinical definition

- NSW significant per cent score 4
- VIC > 1% score 4
- WA any lesion

Proposal - the trigger need not be the same nationally and can be determined by regional (State/RLPB) prevalence, and by what we are happy to be left with at the end

National agreement useful

- clinical definitions
- regional prevalence at which laboratory tests are used

Slide 8

SENSITIVITY AND SPECIFICITY COMPARISON

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<td>BC test</td>
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<td>70</td>
</tr>
<tr>
<td>JR test</td>
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<td>60</td>
</tr>
</tbody>
</table>

Sensitivity impact

Specificity

Clinical

Gel gel

BC test

JR test
Slide 9

**IDENTIFICATION OF RESEARCH NEEDS FOR DIAGNOSIS**

- Clinical case = trigger
- Culture, protease thermostability
- Stable = trigger
- The BC test
  - Positive - VFR

**Comments**

Participants offered the following feedback on Professor Whittington’s presentation:

- 'Clinical test' could be multiple clinical tests.
- Increasing specificity is a key concept.
- All States and jurisdictions need to identify their goal:
  - benefit/cost analysis.
- As prevalence declines, specificity needs to increase.
- Consistent approach is needed in regard to providing advice.

**SUMMARY**

*The workshop concluded that a national footrot control/eradication program was not appropriate at this stage. The prevalence of virulent footrot varies considerably between states as does the support from the respective sheep industry organisations.*
OUTCOME FIVE: Advice to AWI on appropriate investment of producer levies in footrot research, development and innovation

Participants worked in small groups on the following focus question:

'What are the pieces of a broader picture that we can get agreement on?'

Ideas covering research, laboratory and industry were generated, then grouped into clusters or themes by the whole workshop.

The key areas of opportunity emerged as:

- Vaccine research.
- Molecular pathogenesis research.
- Better diagnostic tests.
- Definition of control/eradication targets.
- Research collaboration and linkages.
- Producer support.
- Economic analyses.
- Regional strategies.
- Funding requirements.
- Increased communication.
- Government support.

In more detail, these opportunities are:

Vaccine research:
- Need more research on:
  - application of genomics;
  - specific fimbrial vaccines.
- Specific vaccination should be evaluated (medium priority); both mono and bivalent.

Molecular pathogenesis research:
- Need to know how *D. nodosus* causes disease.
- Role of specific virulence factors in pathogenesis.
- Understanding molecular pathogenesis is a top priority.

Better diagnostic tests:
- Need a suite of tests to define ‘borderline’ strains.
- Sharpen the current tests.
- Application of genomics.
- We need a better diagnostic test that includes where to draw the line.
- Validation of the Brian Cheetham test is a top priority.
- The serial application of current and new tests is appropriate.
- New tests are needed.
- Using new technology to improve the efficiency of diagnostic tests is a medium priority (PCR, MAb).
Definition of control/eradication targets:
- Defining the virulence boundaries for eradication/control is a top priority.
- Eradicability of mild strains needs to be established (medium priority).
- Control programs do not target Gelatin Gel unstable or cattle.
- We should concentrate our efforts on eradicable strains.

Research collaboration and linkages:
- Need to facilitate research collaboration across the country.
- A collaborative approach to footrot research and development will be beneficial.
- National coordination (linkage) of research and development activities will be useful (? AWI and MLA and ARC).
- A central database of footrot knowledge should be established (medium priority).
- Footrot research should be standardised through the national collection (high priority) (e.g. same range of strains).

Producer support:
- Programs need to have industry support.
- Industry support is paramount for any program (other than advisory program?).
- Must have producer and industry support for the research effort.
- Any program must have strong and active producer support.

Economic analyses:
- Economic analysis of the cost of the disease to farmers, region, State and industry.
- Potential production impact of a range of boundary strains needs to be quantified through Benefit/Cost Analysis (high priority).
- Appropriate Regional Programs need some estimate of the prevalence of virulent footrot (this varies by region), to allow a Benefit/Cost Analysis.

Regional strategies:
- Different States and regions will progress at different rates.
- Regional targets to meet regional needs, but an understanding of different approaches.
- Agreed to set regional definitions of virulent footrot.
- Regional differences.
- A regional (versus State-based) approach will be useful (through difficult because of the regulatory background).
- Agree with the theoretical framework presented by Richard Whittington.

Funding requirements:
- Financial support is essential.
- Some or all of the program must be funded by industry.

Increased communication:
- From the field to research and back to the field.
- Conferences and workshops.

Government support:
- Required to progress programs.
As an overall comment, it was agreed that nobody wants virulent footrot and that industry supports some level of control.

The key is ‘vision and hope’.

**Comments**

Following the grouping of themes, participants made the following additional comments as part of the advice to AWI:

- Issue that young researchers are not coming through the system, especially with industry linkages and experience.
- Producer education must be a priority.
- Co-ownership of communication and joint extension.
- Collaborative opportunities with all other research bodies.
- National Program endorsement from Primary Industries Ministerial Council.
- AHA Program on footrot (?).
- Covers whole gamut from laboratory to producers.
- Australian Sheep Industry CRC to be included into the research collaboration and linkages.
CLOSING COMMENTS

Next steps

In response to the outcomes of the workshop, Dr Scott Williams emphasised that a strategy for proceeding with projects is vital, so that a clear rationale for putting proposals to the AWI Board can be demonstrated.

He committed to taking the outcomes from the National Workshop as an identification of key areas and a rationale to guide thinking, in the development of an AWI Strategy.

Dr Williams was supportive of the process of a national meeting as a way to bring perspectives together, identify synergies and make significant advances in collaboration.

It was agreed that a summary of the workshop would be circulated to all participants by 30 September 2003, with the full proceedings to follow.
REFLECTIONS

At the conclusion of the workshop, participants provided the following comments:
- Good communication, common strategies.
- Love it when a plan comes together.
- Informative, encouraging.
- Definition – first steps.
- New tests are promising.
- Perspective.
- Scientific update.
- New beginning for footrot, with producer interest.
- Directions identified.
- Heartening.
- Interaction, commonality.
- Unnecessary complexity.
- Positive, good science.
- Lot of good work.
- More enthusiasm for the task.
- Other perspective.
- Advancements made.
- Results of research being applied.
- Networking, footrot community.
- Useful research future.
- Common purpose.
- Optimism.
- Stakeholder involvement very good.
- Successful workshop.