Persistence of Forage Legumes
Persistence of Forage Legumes

Proceedings of a trilateral workshop held in Honolulu, Hawaii, 18-22 July 1988. The trilateral workshop was held under the auspices and support of the Australian/United States of America Agreement on Scientific and Technical Cooperation and the New Zealand/United States of America Science and Technology Agreement.

Editors

G. C. Marten
A. G. Matches
R. F Barnes
R. W. Brougham
R. J. Clements
G. W. Sheath

American Society of Agronomy, Inc.
Crop Science Society of America, Inc.
Soil Science Society of America, Inc.

Madison, Wisconsin, USA

1989
# Table of Contents

ACKNOWLEDGMENT .............................................................. ix

APPRECIATION EXTENDED.................................................... ix

EXECUTIVE SUMMARY.......................................................... xi

RECOMMENDATIONS FOR COLLABORATIVE RESEARCH PROJECTS OR EXCHANGES AMONG SCIENTISTS FROM AUSTRALIA, NEW ZEALAND, AND THE UNITED STATES OF AMERICA .................................................. xiii

PREFACE ............................................................................. xvi

LIST OF PARTICIPANTS......................................................... xviii

LIST OF CONTRIBUTORS NOT IN ATTENDANCE.......................... xxiii

OVERVIEW OF PROBLEMS WITH LEGUMES

Sown Pastures and Legume Persistence: An Australian Overview  
D. Gramshaw, J.W. Read, W.J. Collins, and E.D. Carter .................. 1

Overview of Legume Persistence in New Zealand  
G.W. Sheath and R.J.M. Hay .................................................. 23

A Survey of Legume Production and Persistence in the United States  
A.G. Matches ......................................................................... 37

Legume Persistence Problems in Hawaii: An Overview  
P.P. Rotar ............................................................................. 45

General Discussion .................................................................. 67

DEVELOPMENT AND GROWTH CHARACTERISTICS OF LEGUMES

The Adaptation, Regeneration, and Persistence of Annual Legumes in Temperate Pasture  
K.F.M. Reed, M.J. Mathison, and E.J. Crawford .......................... 69

Development and Growth Characteristics of Temperate Perennial Legumes  
M.B. Forde, M.J.M. Hay, and J.L. Brock ................................. 91

Selection for Root Type in Red Clover  
R.R. Smith ........................................................................... 111

Tropical Forage Legume Development, Diversity, and Methodology for Determining Persistence  
A.E. Kretschmer, Jr. .............................................................. 117
| Demography of Pasture Legumes                  | R.M. Jones and E.D. Carter          | 139 |
| Rooting Characteristics of Legumes            | A.G. Matches                         | 159 |
| General Discussion                            |                                       | 173 |
| MAJOR EDAPHIC AND CLIMATIC STRESSES           |                                       |     |
| Climatic and Edaphic Constraints to the Persistence of Legumes in Pastures | Z. Hochman and K.R. Helyar          | 177 |
| Environmental Selection of Legumes            | D. Scott, J.H. Hoglund, J.R. Crush, and J.M. Keoghan | 205 |
| Major Edaphic and Climatic Stresses in the United States | D.R. Buxton                         | 217 |
| Rhizobial Ecology in Tropical Pasture Systems | P. Woomer and B.B. Bohlool           | 233 |
| General Discussion                            |                                       | 247 |
| CULTURAL PRACTICES AND PLANT COMPETITION      |                                       |     |
| Cultural Practices Influencing Legume Establishment and Persistence in Australia | D. Gramshaw and M.A. Gilbert         | 249 |
| Aspects that Limit the Survival of Legume Seedlings | W.L. Lowther, J.H. Hoglund, and M.J. Macfarlane | 265 |
| Legume Establishment and Harvest Management in the U.S.A. | C.C. Sheaffer                      | 277 |
| Growth and Competition as Factors in the Persistence of Legumes in Pastures | M.J. Fisher and P.K. Thornton       | 293 |
| Competition from Associated Species on White and Red Clover in Grazed Swards | R.J.M. Hay and W.F. Hunt            | 311 |
| Effect of Competition on Legume Persistence   | C.C. Sheaffer                        | 327 |
| General Discussion                            |                                       | 335 |
PLANT-ANIMAL INTERFACE

The Plant-Animal Interface and Legume Persistence—
An Australian Perspective
M.L. Curll and R.M. Jones.......................... 339

Plant-Animal Factors Influencing Legume Persistence
G.W. Sheath and J. Hodgson.......................... 361

Legume Persistence Under Grazing in Stressful
Environments of the United States
C.S. Hoveland........................................ 375

A Case Study of White Clover/Ryegrass Introductions
into Kukuyu Grass on a Commercial Cattle Ranch in Hawaii
B.J. Smith........................................... 387

General Discussion.................................. 395

MAJOR PESTS AND DISEASES

Diseases of Pasture Legumes in Australia
J.A.G. Irwin.......................................... 399

Arthropod Pests and the Persistence of Pasture Legumes in
Australia
P.G. Allen............................................. 419

Initiatives in Pest and Disease Control in New Zealand
Towards Improving Legume Production and Persistence
R.N. Watson, R.A. Skipp, and B.I.P. Barratt........ 441

Diseases and Forage Stand Persistence in the
United States
K.T. Leath............................................. 465

Insects that Reduce Persistence and Productivity of
Forage Legumes in the USA
R.C. Berberet and A.K. Dowdy....................... 481

General Discussion.................................. 501

GENETICS AND BREEDING FOR PERSISTENCE

Developing Persistent Pasture Legume Cultivars for
Australia
R.J. Clements........................................ 505

Breeding for Legume Persistence in New Zealand
J.R. Caradus and W.M. Williams.......................... 523

Breeding and Genetics of Legume Persistence
R.R. Smith and A.E. Kretschmer, Jr. .................. 541

General Discussion.................................. 553

vii
AREAS OF COLLABORATIVE WORK

Collaborative Research Among Scientists in Australia, New Zealand, and the United States of America
   R.F Barnes.................................................. 555

SUMMARY OF THE TRILATERAL WORKSHOP ON PERSISTENCE OF FORAGE LEGUMES
   G.C. Marten.................................................. 569
ACKNOWLEDGMENT

The following institutions provided funds and/or helped organize the trilateral workshop:

Australian Department of Industry, Technology, and Commerce, Canberra, ACT, Australia (Australia/USA Agreement on Scientific and Technical Cooperation)
CSIRO Division of Tropical Crops and Pastures, Brisbane, Queensland, Australia
Department of Scientific and Industrial Research, Wellington, New Zealand
New Zealand Ministry of Agriculture and Fisheries, Wellington, New Zealand
New Zealand/United States of America Science and Technology Council
Hellaby Trust, New Zealand
Grassland Memorial Trust, New Zealand
C. Alma Baker Trust, New Zealand
Trimble Trust, New Zealand
National Science Foundation, Washington, DC, USA
U.S. Department of Agriculture, Agricultural Research Service, Washington, DC, USA
Department of Agronomy, Horticulture, and Entomology, Texas Tech University, Lubbock, TX, USA
Department of Agronomy and Soil Science, University of Hawaii, Honolulu, HI, USA
American Society of Agronomy, Inc., Madison, WI, USA
Crop Science Society of America, Inc., Madison, WI, USA
Soil Science Society of America, Inc., Madison, WI, USA

APPRECIATION EXTENDED

The participants extended their sincere appreciation to the Department of Agronomy and Soil Science at the University of Hawaii (especially to Samir El-Swaify, Peter Rotar, and Burton Smith) for the excellence of their hosting arrangements and the spectacular tour of the diverse grazing lands on the "Big Island" of Hawaii that concluded the workshop.
EXECUTIVE SUMMARY

Forage legumes are unique among crop plants. They contribute essential soil N, by fixing it from the air, for their own growth and associated or succeeding grasses and other crops. They also supply high-quality herbage for grazing or conserved feeding or ruminant livestock that helps ensure an economical and healthful supply of dairy products, meat, and animal fiber nationally and internationally. Further, forage legumes provide a more continuous supply of feed throughout the growing year than is possible with grasses alone. In addition, forage legumes aid in prevention of soil erosion by provision of year-round ground cover, and lessen contamination of groundwater, especially by nitrates. Finally, forage legumes enhance the beauty of the environment and promote healthy populations of numerous wild birds and mammals.

Support of research in the persistence of forage legumes is not only prudent, but essential for truly sustainable agriculture. If we increase persistence of forage legumes, we will be in a position to more effectively manage our agricultural production systems and reduce the risks associated with the ever-changing economic and environmental stresses. Support for increased collaborative interdisciplinary research among and within our countries is essential to ensure improvement of legume persistence that will aid our economic and social well-being.

Whereas no commodity group or organization is likely to promote fiscal support of this biological treasure, mostly because its economic and social value is usually hidden within systems that lead to marketed animal products, we will handicap future generations if we do not engender much greater research activity in forage legume persistence immediately.

Top priority research objectives for legume persistence identified by Australian, New Zealand, and USA scientists during the Trilateral Workshop included the following:

1. Forage legume germplasm development (including evaluation of genetic stocks and breeding of improved cultivars).
2. Disease, insect, and other pest biology, resistance, and control in forage legume species.
3. Legume plant population dynamics (demography).
4. Soil nutrient stress in legumes such as acidification, Al toxicity, and P deficiency.
5. Basic adaptive mechanisms by forage legumes to stressful environments.
6. Dynamics of the plant-animal interface during grazing of forage legumes by ruminants.

Information exchange must accompany these research endeavors; financial support will also be required to foster such exchange. We must look beyond the immediate grain futures market and recognize the potentially dominant role of the forage legume. Enhancement of the persistence of forage legumes will contribute substantially to international stability of agriculture.
The participants in the Workshop were surveyed to determine their priorities for future collaborative research in forage legume persistence. The six general areas outlined in the Executive Summary received the most support.

Participants also supported the development of a report on forage legume cultivars, similar to the "Forage Grass Varieties of the United States," which includes cultivar name, where developed, agronomic characteristics, and genetic base. Dr. Peter Rotar of the University of Hawaii at Manoa may be able to compile such a report if financial support and personnel assistance can be obtained. The Australian Register of Herbage Plant Cultivars could serve as a model.

Specific researchable problems were identified by participants. Whereas most of the researchable problems and information needs fell within the six general problem areas, a few others were identified. Areas listed by scientists as having potential for international collaboration are outlined below.

<table>
<thead>
<tr>
<th>Country</th>
<th>Specific Researchable Problems and/or Exchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem Area 1 - Forage Legume Germplasm Development</strong></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>Trilateral collection of white clover (<em>Trifolium repens</em> L.) germplasm in the Mediterranean region in autumn, 1989 and subsequent evaluation for persistence.</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Exchange of white clover germplasm; joint collection of white clover germplasm from Yugoslavia; development of screening options; coordinated evaluation of germplasm across environmental gradients.</td>
</tr>
<tr>
<td>USA</td>
<td>Coordinated collection of forage legume germplasm; evaluation of red clover (<em>T. pratense</em> L.) and alfalfa (<em>Medicago sativa</em> L.) germplasm for foliar and other diseases; evaluation of palatability variation among genotypes within legume species that have low palatability.</td>
</tr>
</tbody>
</table>
Problem Area 2 - **Legume Plant Population Dynamics (Demography)**

Australia and New Zealand: Short-term personnel exchanges and continuing information exchange.

USA: Coordinated determination of pest effects on stand longevity; persistence of legumes in conserved crop-pasture systems.

Problem Area 3 - **Soil Nutrient Stress in Legumes**

Australia and USA: Development of legume models and expert systems on soil acidification and lime requirements; short-term personnel exchanges.

New Zealand: Acidification and Al toxicity tolerance; establishment of birdsfoot trefoil (*Lotus corniculatus* L.) in acid, low-fertility soils; legume inoculation in difficult soils; adaptation of perennial lupine and annual legumes in acid, low-fertility soils.

Problem Area 4 - **Basic Adaptative Mechanisms by Forage Legumes to Stressful Environments**

Australia: Information exchange and short-term personnel exchanges to study root mechanisms of legumes generally and to study stress adaptive mechanisms and the genetics of adaptations specifically in tropical legumes.

New Zealand: Root dynamics of white and red clovers under grazing.

USA: Influence of root characteristics on water stress of legumes; effects of drought on growth, morphology, disease resistance, and physiology of red clover, alfalfa, and other legumes; influence of plant morphology on persistence; influence of enzyme kinetics on legume plant tolerance to environmental stress (especially heat and drought).

Problem Area 5 - **Disease, Insect, and Other Pest Biology, Resistance, and Control in Legumes**

Australia: Collaboration at all levels in legume insect and disease studies; specific research with USA on siratro (*Macroptilium atropurpureum*) rust strain differentiation.
New Zealand

Impact of Sitona on alfalfa nodulation; quantitative assessment of virus effects on white clover and its genetic improvement for virus resistance.

USA

Legume root insect-pathogen interactions, especially related to Sitona, root organisms and nodulation; influence of Verticillium wilt of alfalfa on persistence; biocontrol of forage legume diseases by use of bacterial antagonists.

Problem Area 6-

Dynamics of the Plant-Animal Interface During Grazing

Australia

Information exchange generally; joint experimentation with tropical legumes and coordinated total effort (workshop needed to determine priorities).

New Zealand

Plant-animal impact on selective grazing behavior and plant competition.

USA

Assessment of intake variation among and within grazed legume species.

Other Problems

Australia

Modelling relative to plant competition in tropical legume pasture systems; personnel exchanges on regional/national legume surveys, including use of satellite imagery for vegetation mapping.

New Zealand

Impact of grass endophytes on legume persistence.

USA

Seed coating and vegetative propagation systems for forage legumes.

Those wishing to initiate or become involved in collaborative efforts in any of the above exchanges or research problems are urged to contact participants of this workshop who appear to have similar areas of interest. Also, the Proceedings editors may serve as initial contacts. They will attempt to identify appropriate scientists in the three countries who might be interested in collaborative research or exchanges.
Legumes are unique among forages in that they generally have two major advantages compared to grasses: (i) only legumes can fix significant amounts of atmospheric N, thereby obviating the need for fossil-fuel-energy consuming synthetic N fertilizers; and (ii) legumes have greater nutrient intake potential by ruminants, thereby allowing more efficient animal production. More than 60% of the feed that ruminant livestock, horses, swine, and poultry consume in the USA is derived from forages. Forages supply more than 80% of the nutrients consumed in the nation's leading agricultural industry, beef cattle production. The principal forage legume in the USA is alfalfa (*Medicago sativa* L.) (13 million ha), but substantial areas have also been sown to red clover (*Trifolium pratense* L.) (6 million ha), white clover (*T. repens* L.) (5 million ha), and other miscellaneous legumes. In New Zealand, 9 million ha of white clover-based pastures provide the main grazing resource for livestock industries. There are 23 million ha of improved pastures in southern Australia, principally based on subterranean clover (*T. subterraneum* spp. *subterraneum*) and white clover, and 4.5 million ha of sown pastures in northern Australia, of which 1 million ha includes tropical legumes such as stylo (*Stylosanthes* spp.) and siratro (*Macroptilium atropurpureum*).

If problems in legume establishment and persistence could be overcome, then the hundreds of millions of hectares of grazing and forage cropland in the three countries could be better used to increase efficiency of animal production, as well as conserve soil, water, and wildlife resources. Legume forages, when rotated with other crops such as corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), and sorghum (*Sorghum bicolor* (L.) Moench), also serve as economical sources of N for grain crop production; therefore, enhancement of legume persistence could improve the efficiency of grain production too.

In 1984, a trilateral workshop on Forage Legumes for Energy-Efficient Animal Production was held in New Zealand. Scientists at that workshop identified the solution to poor persistence of forage legumes as a key priority for further research. Thus, this workshop in Hawaii was organized to provide an opportunity to discuss the problem in depth and to enable direct examination of both temperate and tropical forages within a single geographic location.
This trilateral workshop, with the goal of defining and narrowing the gaps in knowledge in legume persistence, included 33 papers presented and discussed by 33 scientists from Australia, New Zealand, and the USA. The workshop consisted of invited papers and extensive discussions in eight areas: (i) overview of problems with legumes, (ii) development and growth characteristics of legumes, (iii) major edaphic and climatic stresses, (iv) cultural practices and plant competition, (v) plant-animal interface, (vi) major pests and diseases, (vii) genetics and breeding for persistence, and (viii) areas of collaborative work.

The workshop objectives were: (i) to document problems of poor forage legume persistence in each country and their economic consequences, (ii) to review what is known of constraints to forage legume persistence in each country, (iii) to exchange information on concepts, methods, approaches, and recent advances regarding forage legume persistence, (iv) to compile, interpret, and document pertinent data on persistence of forage legumes, (v) to develop a consensus on important gaps in biological information needed to allow modelling of forage legume persistence, and (vi) to enable key scientists of Australia, New Zealand, and the USA conducting research on forage legume persistence to meet and to promote exchange of information and future research collaboration.

This publication should prove helpful as further research is planned. Grateful appreciation is extended to the agencies, institutions, and professional scientific and educational societies that provided funds or assisted in the organization of the workshop and publication of the Proceedings. The editorial committee also expresses its appreciation to the authors and workshop participants from Australia, New Zealand, and the USA.

Editorial Committee

G. C. Marten
U.S. Department of Agriculture, Agricultural Research Service at the Univ. of Minnesota, St. Paul, MN, USA

A. G. Matches
Department of Agronomy, Horticulture, and Entomology, Texas Tech Univ., Lubbock, TX, USA

R. F Barnes
American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, WI, USA

R. W. Brougham
DSIR, Grasslands Division, Palmerston North, New Zealand

R. J. Clements
CSIRO, Division of Tropical Crops and Pastures, St. Lucia, Queensland, Australia

G. W. Sheath
Ministry of Agriculture and Fisheries, Whatawhata Research Centre, Hamilton, New Zealand
LIST OF PARTICIPANTS

Peter G. Allen
Entomologist
South Australian Dep. of Agriculture
Northfield Research Laboratories
GPO Box 1671
Adelaide, SA 5001, Australia

Robert F Barnes
Agronomist
ASA-CSSA-SSSA
677 S. Segoe Rd.
Madison, WI 53711, USA

Richard C. Berberet
Entomologist
Dep. of Entomology
Oklahoma State University
Stillwater, OK 74078-0464, USA

B. Ben Bohlool
Microbiologist
Dep. of Agronomy and Soil Science
University of Hawaii
1000 Holomua Ave.
Paia, Maui, HI 96779, USA

Raymond W. Brougham
Agronomist/Ecologist
P. O. Box 8094
Palmerston North, New Zealand

Dwayne R. Buxton
Plant Physiologist
USDA-ARS, Dep. of Agronomy
Iowa State University
Ames, IA 50011, USA

John R. Caradus
Pasture Plant Breeder
Grasslands Division
DSIR
Palmerston North, New Zealand

Robert J. Clements
Pasture Agronomist/Plant Breeder
CSIRO Div. of Tropical Crops & Pastures
306 Camden Rd.
St. Lucia, Queensland 4067, Australia
Michael L. Curll
Pasture Agronomist
NSW Dep. of Agriculture
Agric. Research and Advisory Stn.
Glen Innes, NSW 2370, Australia

Samir El-Swaify
Soil Scientist
Dep. of Agronomy and Soil Science
Sherman Laboratory
University of Hawaii
1910 East-West Road
Honolulu, HI 96822, USA

Myles J. Fisher
Ecophysiologist
CIAT (Centro Int. de Agric. Tropical)
Apartado Aereo 6713
Cali, Colombia, South America

Margot B. Forde
Botanist
Grasslands Division
DSIR
Palmerston North, New Zealand

David Gramshaw
Pasture Agronomist/Ecologist
Queensland Dep. of Primary Industries
GPO Box 46
Brisbane, Queensland 4001, Australia

Michael J. M. Hay
Plant Nutritionist
Grasslands Division
DSIR
Palmerston North, New Zealand

R. John M. Hay
Pasture Agronomist
Grasslands Division
DSIR
Palmerston North, New Zealand

John Hodgson
Pasture Agronomist
Agronomy Dep.
Massey University
Palmerston North, New Zealand

Zvi Hochman
Agronomist
NSW Dep. of Agriculture
North Coast Agric. Institute
Wollongbar, NSW 2480, Australia
Carl S. Hoveland
Agronomist
Agronomy Dep.
University of Georgia
Athens, GA 30602, USA

John A. G. Irwin
Plant Pathologist
Botany Dep.
University of Queensland
St. Lucia, Queensland 4067, Australia

Richard M. Jones
Pasture Agronomist
CSIRO Div. of Tropical Crops and Pastures
306 Camody Rd.
St. Lucia, Queensland 4067, Australia

Albert E. Kretschmer, Jr.
Agronomist
University of Florida
IFAS Agric. Res. and Education Center
P. O. Box 248
Fort Pierce, FL 34954, USA

Kenneth T. Leath
Plant Pathologist
USDA-ARS and Professor,
Plant Pathology Dep.
Pennsylvania State University
University Park, PA 16802, USA

William L. Lowther
Rhizobiologist/Agronomist
Ministry of Agriculture & Fisheries
Invermay Agriculture Centre
Mosgiel, New Zealand

Gordon C. Marten
Agronomist
USDA-ARS
411 Borlaug Hall
University of Minnesota
1991 Upper Buford Circle
St. Paul, MN 55108, USA

Arthur G. (Jerry) Matches
Thornton Professor
Dep. of Agronomy, Horticulture, and Entomology
Texas Tech University
P. O. Box 4169
Lubbock, TX 79409, USA
Kevin F. M. Reed
Pasture Agronomist
Victorian Dep. of Agriculture and Rural Affairs
Pastoral Research Institute
P. O. Box 180
Hamilton, Victoria 3300, Australia

Peter B. Rotar
Agronomist
Dep. of Agronomy and Soil Science
University of Hawaii at Manoa
1910 East-West Road
Honolulu, HI 96822, USA

David Scott
Pasture Agronomist
Grasslands Division
DSIR
Lincoln, New Zealand

Craig C. Sheaffer
Agronomist
Dep. of Agronomy and Plant Genetics
University of Minnesota
St. Paul, MN 55108, USA

Gavin W. Sheath
Pasture Agronomist
Ministry of Agriculture and Fisheries
Whatawhata Research Centre
Hamilton, New Zealand

Burton J. (Burt) Smith
Extension Specialist in Pastures and Livestock Management
University of Hawaii
P. O. Box 237
Kamuela, HI 96743, USA

Richard R. Smith
Geneticist, USDA-ARS
Agronomy Dep.
U.S. Dairy Forage Research Ctr.
University of Wisconsin
1925 Linden Drive West
Madison, WI 53706, USA

Richard N. Watson
Entomologist/Nematologist
Ministry of Agriculture and Fisheries
Ruakura Agriculture Centre
Hamilton, New Zealand
Paul Woomer  
Microbiologist  
Dep. of Agronomy and Soil Science  
University of Hawaii  
1000 Holomua Avenue  
Paia, Maui, HI 96779, USA

Guests at the Conference

Mr. Andres Alvarez  
Graduate Student  
Dep. of Agronomy and Soil Science  
University of Hawaii  
Honolulu, HI, USA

Dr. Nguyen Hue  
Soil Scientist  
Dep. of Agronomy and Soil Science  
University of Hawaii  
Honolulu, HI, USA

Dr. George Love  
Range Ecologist  
USDA-SCS  
Honolulu, HI, USA

Ms. Karen Oglesby  
Graduate Student  
Dep. of Agronomy and Soil Science  
University of Hawaii  
Honolulu, HI, USA

Dr. Russell Yost  
Soil Scientist  
Dep. of Agronomy and Soil Science  
University of Hawaii  
Honolulu, HI, USA
LIST OF CONTRIBUTORS NOT IN ATTENDANCE

B. I. P. Barratt
Ministry of Agriculture and Fisheries
Invermay Research Centre
Mosgiel, Otago
New Zealand

J. L. Brock
Grasslands Division
DSIR
Palmerston North
New Zealand

E. D. Carter
Waite Agricultural Research Inst.
Univ. of Adelaide
Glen Osmond 5064, S.A.
Australia

W. J. Collins
Dep. of Agriculture
South Perth 6151, W.A.
Australia

E. J. Crawford
Dep. of Agric.
Box 1671
Adelaide, S.A. 5001
Australia

J. R. Crush
Grasslands Division
DSIR
Palmerston North
New Zealand

A. K. Dowdy
Dep. of Entomology
Oklahoma State University
Stillwater, OK 74078-0464
USA

M. A. Gilbert
Dep. of Primary Industries
Mareeba 4880, Queensland
Australia

K. R. Helyar
Agricultural Research Centre
Wollongbar, N.S.W. 2480
Australia

J. H. Hoglund
Grasslands Division
DSIR
Lincoln
New Zealand

W. F. Hunt
Grasslands Division
DSIR
Palmerston North
New Zealand

J. M. Keoghan
Ministry of Agriculture & Fisheries
Invermay Research Centre
Mosgiel, Otago
New Zealand

M. J. Mathison
Dep. of Agriculture
Box 361
Mt. Barker, S.A. 5251
Australia

M. J. Macfarlane
Ministry of Agriculture & Fisheries
Whatawhata Research Centre
Hamilton, New Zealand

J. W. Read
Dep. of Agriculture
Sydney 2000, N.S.W.
Australia

R. A. Skipp
Plant Diseases Division
DSIR
Palmerston North
New Zealand
P. K. Thornton  
Division of Animal Resource Mgt.  
The Edinburgh School of Agriculture  
West Mains Road  
Edinburgh, EH9 3JG  
United Kingdom

W. M. Williams  
Grasslands Division  
DSIR  
Palmerston North  
New Zealand