Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
The Influence of Pastoral Fallow on Hill Country Pastures, Emphasising White Clover Growth Behaviour

A thesis presented
in partial fulfilment of the requirements
for the degree of Doctor of Philosophy in Plant Science
at Massey University, New Zealand

Zhongnan Nie
1997
DECLARATION

The studies presented in this thesis were completed by the author whilst a postgraduate student in the Department of Plant Science, Massey University, Palmerston North, New Zealand. This is all my own work and the views presented are mine alone. Any assistance received is acknowledged in the thesis. All references cited are included in the bibliography.

I certify that the substance of the thesis has not been already submitted for any degree and is not being currently submitted for any other degree. I certify that to the best of my knowledge any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

Zhongnan Nie
PhD candidate

Dr. I. Valentine
Chief supervisor

Professor J. Hodgson
Co-supervisor

Dr. A. D. Mackay
Co-supervisor

Dr. D. J. Barker
Co-supervisor

June 1997
ABSTRACT

Appropriate pre-sowing methods for oversowing new plant germplasm and the presence of productive legume are of key importance to development of New Zealand hill country. A pastoral fallow, which involves not defoliating pasture for a period generally from spring to autumn, has profound influence on plant and soil, and creates a potentially favourable environment for introducing improved germplasm. A series of field and glasshouse experiments examined the response of pasture structure, soil properties and natural reseeding to pastoral fallow, and the post-fallowing effects on white clover (*Trifolium repens* L.) and pasture growth in moist North Island hill country, New Zealand.

Pastoral fallowing effectively reduced the plant population density and altered the structure of a hill sward. A seven-month (October - May) pastoral fallow dramatically decreased the densities of grass tillers by 72%, white clover growing points by 87% and other species by 87%. The decline in tiller density by pastoral fallow was enhanced on a shady, south facing aspect. Root growth and distribution was altered by pastoral fallowing and there was significantly less root biomass at 0 - 50 mm depth of soil in the fallowed than the grazed sward. Decreased plant density during pastoral fallowing was attributed to above-ground biomass accumulation which altered sward structure, leading to inter-plant competition and mortality by self-thinning and completion of the life circle of some matured plants.

Pastoral fallowing significantly improved soil physical properties. Compared with the grazed treatment, pastoral fallow increased soil air permeability at 500 mm tension by 38%, saturated hydraulic conductivity by 26%, unsaturated hydraulic conductivity at 20 mm tension by 56% and soil moisture by 10 - 15%, and reduced soil bulk density by 11% at the end of an October - May pastoral fallow. Pastoral fallow had little effect on the concentration of most
nutrients in soil both at the end of fallowing and two to three years after fallowing.

A spring - autumn pastoral fallow increased the viable grass, legume and weed seed population by 51-160%, compared with the grazed control. The variation in viable seed population during the fallow followed a predictable pattern, which could be used to manipulate natural reseeding in practice. Regression analysis revealed that the patterns of cumulative seedling appearance followed a modified negative exponential function. Partial differentiation of this function derived a germination rate curve on which a two-pool (rapidly germinable pool and base pool) model was developed to quantitatively describe the seed dynamics of soil viable seed reserves.

Short-duration (partial) pastoral fallow had a marked effect on plant population density and natural reseeding. Pastoral fallows starting from December, January and February or March with nitrogen addition and ending in June considerably reduced plant population density. Most partial pastoral falls also considerably reduced viable seed population of all plant species, except for December to June fallow which had a higher viable grass seed population than the grazed sward.

Pastoral fallowing increased dispersion of white clover stolons by internode elongation. At the conclusion of a pastoral fallow, the clover stolons initiated branching, and grasses initiated tillering. Their growth and competition resulted in a greater grass growth rate in the first two years after fallowing, and a greater white clover yield and content with an increase in clover patch density and size 3 - 4 years post-fallowing, compared with the grazed pastures.

**Key words:** hill pasture, pastoral fallow, plant population density, soil physical properties, stolon, sward structure, viable seed population, white clover.
ACKNOWLEDGEMENTS

I am particularly grateful to Prof. J. Hodgson and Prof. A. C. P. Chu, Department of Plant Science, Massey University, for providing me with the opportunity to undertake a PhD study. Without their help, my study at Massey University, New Zealand would not have been possible. I thank Prof. J. Hodgson for his enthusiasm, encouragement, guidance and support as my co-supervisor throughout this study, and Prof. A. C. P. Chu for his instruction in the early stage of this study.

I would like to express my deepest gratitude to my supervisors, Dr I. Valentine (chief), Department of Plant Science, Massey University, and Dr. A. D. Mackay and Dr. D. J. Barker, AgResearch Grasslands, for their enthusiasm, patience, encouragement and close supervision throughout the course of this study. Their invaluable guidance, advice and constructive criticism have made this study fruitful. I have been most joyfully benefited by a combination of their profound knowledge in pasture ecology, agronomy and soil science.

I would extend my sincere thanks to the following people who provided technical assistance or help in various ways for the project: Y. Gray, C. Van Meer and M. Greig, Herbage Dissection Laboratory, AgResearch; N. Dymock, P. Budding and all staff at AgResearch Hill Country Research Station, 'Ballantrae'; T. Lynch and M. Osborne, Pasture Teaching Complex, Massey University; R. Johnstone, Plant Growth Unit, Massey University; K. Hamilton, F. Brown, R. Dissanayake, M. Alexander, Pastoral Science Group, Department of Plant Science, Massey University.

My special thanks to Dr. C. Matthew for his valuable help and comments on statistical analysis and other topics, and to Dr. I. Gordon for his excellent presentation of the advanced biometrics course.
Thanks to Dr. P. Kemp and Mr. P. N. P. Matthews, Department of Plant Science, Massey University and Dr. D. E. Hume, Mr. K. Betteridge, Dr. D. F. Chapman, Dr. M. G. Lambert and Dr. M. J. M. Hay, AgResearch Grasslands, for their friendly manner and help in different ways.

I appreciate the enjoyable times that I shared with all my fellow graduate students at Pastoral Science Group, Department of Plant Science, Massey University, and all my Chinese friends at Palmerston North. Their friendship and help cannot be forgotten.

The financial assistance of Massey University Doctoral Scholarship and FRST contract C10633 are highly appreciated.

Lastly, a special thank you to my wife, Anli Zuo for her love, patience, support and help both at home and the Herbage Dissection Laboratory, and to my son, Bruce Y. Nie for bringing our family cheer and happiness.
TABLE OF CONTENTS

Abstract........................................................................................................................................i
Acknowledgements......................................................................................................................iii
Table of Contents ..........................................................................................................................v
List of Tables ..................................................................................................................................xi
List of Figures ..............................................................................................................................xv
List of Plates ...................................................................................................................................xviii
Preface ..........................................................................................................................................xix

CHAPTER 1 GENERAL INTRODUCTION AND OBJECTIVES .............................................1

CHAPTER 2 LITERATURE REVIEW ..................................................................................8

2.1 INTRODUCTION .................................................................................................................9
2.2 HILL COUNTRY PASTURE IMPROVEMENT .....................................................................10
  2.2.1 History of hill country pasture improvement ...............................................................10
  2.2.2 Limitations to hill pasture production .........................................................................12
    2.2.2.1 Moisture, temperature and their alteration by aspect and slope .......................12
    2.2.2.2 Soil fertility ...........................................................................................................13
  2.2.3 Pasture/grazing management .......................................................................................14
  2.2.4 Oversowing hill pasture ...............................................................................................15
    2.2.3.1 Seedbed preparation methods .............................................................................16
    2.2.3.2 The potential of pastoral fallowing to prepare seedbed ......................................18
  2.2.5 Other methods of hill country pasture improvement .................................................19
2.3 THE PERFORMANCE OF WHITE CLOVER IN HILL PASTURES ......................21
  2.3.1 The role of white clover in hill country .......................................................................21
  2.3.2 Propagation and persistence .......................................................................................22
    2.3.2.1 Seedling regeneration .........................................................................................22
    2.3.2.2 Vegetative spread ...............................................................................................25
CHAPTER 3 CHANGES IN PLANT POPULATION DENSITY, COMPOSITION AND SWARD STRUCTURE OF A HILL PASTURE DURING A PASTORAL FALLOW

3.1 INTRODUCTION .................................................................................. 44
3.2 MATERIALS AND METHODS ................................................................. 46
  3.2.1 Site ................................................................................................. 46
  3.2.2 Design and treatments ................................................................. 46
  3.2.3 Measurements ............................................................................... 48
  3.2.4 Statistical analysis ......................................................................... 48
3.3 RESULTS .............................................................................................. 49
  3.3.1 Climate .......................................................................................... 49
  3.3.2 Plant population density ............................................................... 50
  3.3.3 Thinning lines ................................................................................ 53
  3.3.4 Sward structure ............................................................................. 53
  3.3.5 Comparison of the effects of partial and full pastoral falls on final plant population densities .......................................................... 56
3.4 DISCUSSION ....................................................................................... 58
  3.4.1 Treatment effects and mechanisms of tiller population change ...... 58
  3.4.2 Self-thinning response ................................................................... 60
  3.4.3 Implications for resowing improved forage germplasm .................. 61
3.5 REFERENCES ......................................................................................... 64

CHAPTER 4 INFLUENCE OF PASTORAL FALLOW ON PLANT ROOT GROWTH AND SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS IN A HILL PASTURE

4.1 INTRODUCTION .................................................................................. 69
4.2 MATERIALS AND METHODS ................................................................. 71
4.2.1 Site .................................................................................. 71
4.2.2 Design and treatments .......................................................... 71
4.2.3 Measurements ..................................................................... 72
  4.2.3.1 Root biomass ............................................................... 72
  4.2.3.2 Soil moisture ............................................................... 72
  4.2.3.3 Soil hydraulic conductivity, air permeability and bulk density .... 73
  4.2.3.4 Soil nutrient analysis .................................................... 73
4.2.4 Statistical analysis ................................................................. 74
4.3 RESULTS .................................................................................. 74
  4.3.1 Root biomass and distribution ........................................... 74
  4.3.2 Soil moisture .................................................................. 74
  4.3.3 Air permeability, bulk density and hydraulic conductivity ........... 77
  4.3.4 Soil nutrients .................................................................. 77
4.4 DISCUSSION ........................................................................... 83
  4.4.1 Root biomass ................................................................... 83
  4.4.2 Soil physical properties .................................................... 84
  4.4.3 Soil chemical properties ................................................... 86
4.5 REFERENCES ........................................................................... 87

CHAPTER 5 INFLUENCE OF PASTORAL FALLOW ON NATURAL RESEEDING IN A HILL PASTURE ................................. 92

5.1 INTRODUCTION ..................................................................... 94
5.2 MATERIALS AND METHODS .................................................... 96
  5.2.1 Site and treatments .......................................................... 96
  5.2.2 Measurements ................................................................. 97
    5.2.2.1 Experiment 1 ............................................................. 97
    5.2.2.2 Experiment 2 ............................................................. 97
  5.2.3 Statistical analysis ............................................................. 98
5.3 RESULTS .................................................................................. 98
  5.3.1 Rainfall and temperature .................................................... 98
5.3.2 Experiment 1 .................................................................................................................. 99
5.3.2.1 Viable seed population .......................................................................................... 99
5.3.2.2 Pattern of cumulative seedling population ......................................................... 99
5.3.3 Experiment 2 .................................................................................................................. 102
5.3.3.1 Effects of fallowing, fertilizer and aspect ............................................................ 102
5.3.3.2 Effects of full and partial fallow ......................................................................... 102
5.3.3.3 Variation of viable seed population during pastoral fallowing ....................... 105
5.4 DISCUSSION ................................................................................................................... 105
5.4.1 Methodology for testing viable seed reserves in soil ........................................... 105
5.4.2 Germination rate curve and soil viable seed reserve ............................................ 107
5.4.3 Effects of pastoral fallow ......................................................................................... 110
5.4.4 Effects of fertilizer and aspect .............................................................................. 113
5.4.5 Practical implications ............................................................................................... 113
5.5 REFERENCES .................................................................................................................. 115

CHAPTER 6 INFLUENCE OF THE TIMING AND DURATION OF PASTORAL FALLING AND NITROGEN FERTILISER ON PASTURE AND WHITE CLOVER (TRIFOLIUM REPENS L.) GROWTH IN HILL COUNTRY ......................................................................................................................... 119

6.1 INTRODUCTION .............................................................................................................. 121
6.2 MATERIALS AND METHODS ...................................................................................... 122
6.2.1 Site .............................................................................................................................. 122
6.2.2 Treatments .................................................................................................................. 123
6.2.3 Measurements ........................................................................................................... 124
6.2.4 Statistical analysis ..................................................................................................... 125
6.3 RESULTS ....................................................................................................................... 125
6.3.1 Rainfall and temperature ......................................................................................... 125
6.3.2 Plant population density ......................................................................................... 126
6.3.3 Nitrogen effects ......................................................................................................... 128
6.3.4 Sward structure ........................................................................................................ 131
6.3.5 The stolon characteristics of white clover ............................................................. 131
CHAPTER 7 SHORT- AND LONG-TERM EFFECTS OF PASTORAL FALLOWING ON WHITE CLOVER (TRIFOLIUM REPENS L.) AND PASTURE GROWTH .................................................. 148

7.1 INTRODUCTION .................................................. 149
7.2 LITERATURE REVIEW ............................................. 149
7.3 MATERIALS AND METHODS ...................................... 150
   7.3.1 Trial site and design ........................................... 150
      7.3.1.1 Experiment 1 ............................................ 151
      7.3.1.2 Experiment 2 ............................................ 151
   7.3.2 Measurements .................................................. 152
      7.3.2.1 Experiment 1 ............................................ 152
      7.3.2.2 Experiment 2 ............................................ 152
   7.3.3 Statistical analysis ........................................... 153
7.4 RESULTS ....................................................... 153
   7.4.1 Experiment 1 .................................................. 153
      7.4.1.1 The morphological characteristics of white clover .... 153
      7.4.1.2 Pasture growth rate .................................... 154
   7.4.2 Experiment 2 .................................................. 154
      7.4.2.1 Herbage mass, botanical composition and pasture density .. 154
      7.4.2.2 Stolon characters ........................................ 157
      7.4.2.3 Distribution pattern ..................................... 157
7.5 DISCUSSION.................................................................................................................. 160
  7.5.1 Short-term post-fallowing effects........................................................................... 160
  7.5.2 Long-term post-fallowing effects.......................................................................... 163
7.6 CONCLUSION............................................................................................................... 165
7.7 REFERENCES .............................................................................................................. 165

CHAPTER 8 GENERAL DISCUSSION AND CONCLUSION ................................................. 169

8.1 INTRODUCTION ............................................................................................................. 170
8.2 RESPONSE OF PASTURE PLANTS AND SOIL TO PASTORAL FALLOW................................................................. 170
  8.2.1 Above and below ground plant response .............................................................. 172
  8.2.2 Soil physical and chemical properties ................................................................. 174
  8.2.3 Natural reseeding and partial pastoral fallow ...................................................... 175
    8.2.3.1 Natural reseeding ........................................................................................ 175
    8.2.3.2 Partial pastoral fallow ............................................................................... 177
8.3 SHORT- AND LONG-TERM EFFECTS OF PASTORAL FALLOW .......... 178
  8.3.1 White clover stolon growth during pastoral fallow .............................................. 178
  8.3.2 White clover and grass growth post pastoral fallow .......................................... 178
8.4 CONCLUSION .............................................................................................................. 180
8.5 REFERENCES .............................................................................................................. 182
LIST OF TABLES

Chapter 2

Table 2.1 Effect of paraquat on grass and clover survival in dense closely-grazed sward (From Cullen, 1969). .......................................................... 17

Table 2.2 Seedling appearance and survival (total area = 64 m²) of white clover in summer moist hill country (From Chapman, 1987). ................. 24

Chapter 3

Table 3.1 Mean plant density (19 October 1993 - 31 May 1994) of grass (tillers/m²), white clover (growing points/m²) and weeds (plants/m²) and moss cover (0, 1 (< 50%), 2 (> 50%), 3 (100%)) under different treatments of pastoral fallow, fertiliser (Fert + and Fert -) and aspect and some significant interactions. .......................................................... 51

Table 3.2 Total initial plant density (IPD, plant units/m²), plant density of grass (tillers/m²), white clover (growing points/m²) and weed (plants/m²) and total dry matter (DM) accumulation (kg/ha) under full and partial pastoral fallowing treatments. .......................................................... 57

Chapter 4

Table 4.1 Effects of pastoral fallow, fertiliser and aspect on gravimetric (0-50 mm depth) and volumetric (0-150 mm depth, TDR tested) soil moisture at the late stage (27-28 April 1994) of a spring - autumn fallow. ....................... 76
Table 4.2 Air permeability ($10^{-12} \text{ m}^2$) and bulk density (Mg/m$^3$) of fallowed and grazed swards at the conclusion (31 May 1994) of a spring - autumn fallow. ..................................................78

Table 4.3 Soil nutrients (ppm) of fallowed and grazed treatments at the conclusion (31 May 1994) of a spring - Autumn fallow (OC and OS represent organic carbon and organic sulphur, respectively). ................80

Table 4.4 Ammonium nitrogen (N-NH$_4^+$), nitrate nitrogen (N-NO$_3^-$) and mineral N (N as NH$_4^+$ + N as NO$_3^-$) content of soil at a range of soil depths (mm) under fallowed and grazed treatments (31 May 1994). ......................81

Table 4.5 Soil nutrients (ppm) of fertilised (Fert+), non-fertilised (Fert-), 89/90 fallowed (PF89) and 90/91 fallowed (PF90) treatments tested on 19 October 1993 (PR and OS represent phosphorus retention and organic sulphur, respectively). ..................................................82

Chapter 5

Table 5.1 Viable seed population (seedlings/m$^2$) of grasses, legumes, weeds and the total in 1991/92 fallowed sward (F91/92), 1990/91 fallowed sward (F90/91) and the grazed sward (sampled on 26 May 1992)............100

Table 5.2 General effects of pastoral fallow, fertilizer application and aspect on the viable seed population (seedlings/m$^2$) of grasses, legumes, weeds and the total sampled at the completion (31 May 1994) of an October 1993 - May 1994 fallow with seven months of germination. ....................103

Table 5.3 Viable seed population (seedlings/m$^2$) of grasses, legumes, weeds and the total under early fallow, late fallow and full fallow with (Fallow + F) and without (Fallow - F) added fertilizer at the end of each fallow during Experiment 2 (October 1993 - May 1994). .................................................104
Table 5.4 Total viable seed reserve (VSR, seeds/m²) calculated for 224 days of incubation and the size (seeds/m²) of the rapidly germinable pool (RGP) and the base pool (BP) for grasses, legumes and weeds under fallowed and grazed treatments; F-G is the viable seed population (seeds/m²) of the fallowed subtracting that of the grazed and % VSR_{F-G} is the percentage to VSR in row F-G .......................................................... 111

Chapter 6

Table 6.1 The interaction of N addition and late-commenced (February and March) falls on grass tiller density (TD) at six weeks after pastoral fallowing was imposed, and the effects of N on the specific stolon weight (SSW) of white clover and viable seed population (VSP) of weeds and rush........................................................................................................ 129

Table 6.2 Viable seed population (seeds/m²) of grasses, legumes, weeds, rush and the total at the conclusion of fallowing on 30 June 1995. ........ 135

Table 6.3 Red:far-red (R:FR) ratio at the canopy surface and 10 mm above ground-level and mean photosynthetically active radiation (PAR) monitored while surface and 10 mm above ground-level R:FR ratio were measured at the late stage (May - June 1995) of pastoral fallowing. ...... 136

Chapter 7

Table 7.1 Effects of fallowing and the time post-fallowing on the growth rate (kg DM/ha/month) of grass, white clover and weed in the periods of 15 December 1994 - 18 May 1995 (Year 1) and 28 September 1995 - 5 February 1996 (Year 2). .......................................................... 156
Table 7.2 Effects of post fallowing duration on pasture yield (g/m²) from 15 December 1994 to 18 May 1995 (means of three harvests) and grass tiller and white clover growing point density on 5 December 1994..........................158

Table 7.3 Scale of pattern, average diameter of gap and white clover patch and mean ratio of gap:white clover patch diameter (G:C ratio)................................162
LIST OF FIGURES

Chapter 3

Figure 3.1 Plant population density of grass, white clover and weed under pastoral fallow (△) and grazing (○) regimes (vertical bars show LSD_{0.05}; ns represents not significant). .................................................................52

Figure 3.2 Scatter plots and self-thinning lines calculated by Principal Components Analysis: (a) mean plant unit size plotted against total density of all plant species; (b) mean tiller size of grasses plotted against grass tiller density. ......................................................................................54

Figure 3.3 Change of sward phytomass of reproductive tillers (R.Tiller), vegetative tillers (V.Tiller), dead matter (D.Matter), legumes and weeds under (a) pastoral fallowing, and (b) grazing (vertical bars show s.e.) .....55

Figure 3.4 Quantitative description of net tiller survival and mortality due to competition and reproduction during an October - May pastoral fallow (unit of tiller density: tillers/m²) .................................................................59

Chapter 4

Figure 4.1 Root biomass of a range of soil depths under fallowing and grazing (bars indicate LSD_{0.05}; ** represents P < 0.05) ...............................................................75

Figure 4.2 Saturated and unsaturated hydraulic conductivity at tensions of 100, 40 and 20 mm in grazed and fallowed soils (bars indicate LSD_{0.05}; * represents P < 0.05). ........................................................................................................79
Chapter 5

Figure 5.1 Cumulative (a) grass, (b) legume and (c) weed seedling populations and their curve patterns with incubation time under treatments fallowed September 1991 - May 1992 (o), fallowed September 1990 - April 1991 (Δ) and grazed (●) (vertical bars show s.e.m.; † and ns represent P < 0.001, P < 0.05, P < 0.1 and not significant, respectively). ................................................................. 101

Figure 5.2 Change of viable seed population of grasses, legumes and weeds under (a) pastoral fallowing and (b) grazing (vertical bars show s.e.). ....106

Figure 5.3 Germination rate curve (the partial derivative (dy/dt) of the seedling cumulative model, y=a(1-be−ct)+dt) and the two pools (rapidly germinable pool and the base pool) of the soil seed reserves. .............................................. 109

Chapter 6

Figure 6.1 Mean plant population density of (a) grass tillers, (b) white clover growing points, (c) weeds under various fallowing treatments at the initial, 6 weeks and final stage (June and September 1995) of fallowing (vertical bars show s.e.; * and ** represent P < 0.05 and P < 0.01, respectively). 127

Figure 6.2 Change of sward biomass of reproductive tillers, vegetative tillers, legume and dead matter under treatments with various fallowing durations and initial dates (initial measurements were made one month after fallowing started from each treatment; vertical bars show s.e.).......130

Figure 6.3 Change of (a) stolon density and, (b) internode length of white clover under treatments with various fallowing durations and initial dates (vertical bars show s.e.; * and ** represent P < 0.05 and P < 0.01, respectively). ................................................................. 132
Figure 6.4 Relationship between: (a) Plant size and plant density - self-thinning line (slope = -3/2) and scatter plots of plant unit size against total plant density of all fallowing treatments at the end of each fallow; (b) Red:far red ratio and white clover internode length for both fallowed and grazed treatments.................................................................138

Chapter 7

Figure 7.1 Response of (a) white clover stolon length, (b) stolon weight and (c) internode length to fallowed and non-fallowed (grazed) treatment in the first and second year post-fallowing (* and † represent interaction significance P < 0.05 and P < 0.1, respectively)........................................155

Figure 7.2 Total stolon and average internode length of white clover with various fallow history (Vertical bars show LSD_{0.05}).................................................................159

Figure 7.3 Distribution pattern of white clover of various treatments (TTLQV variouce plot for one transect with the x-axis of local maxima as the scale of pattern for each treatment. For F0 the variance at block size 150 was 2).........................................................................................................161

Chapter 8

Figure 8.1 Responses of plant, soil and natural reseeding to full and partial pastoral fallows which may favour (4) or harm (8) oversowing and natural regeneration in practice........................................................................171

Figure 8.2 Change of white clover growth behaviour and clover/grass competition during and post pastoral falling-------------------------------179
LIST OF PLATES

Plate 3.1 An overview of the experiment site showing fallowed and grazed plots.....................................................................................................................................47

Plate 3.2 A close view of the open sward when plant materials have been grazed off by cattle........................................................................................................................................63

Plate 6.1 A close view of white clover stolon elongation in fallowed sward .... 133
PREFACE

Pastoral fallow - what is it? Why do you do it? How does it affect plant and soil in a hill pasture? When and how long do you do it? What are its short- and long-term effects on pasture species composition and yield? This thesis provides answers to these questions.

This thesis is based on a series of papers that have been prepared for publication, preceded by Introduction and Objectives (Chapter 1) and General Literature Review (Chapter 2), and succeeded by General Discussion and Conclusion (Chapter 8). A series of experiments were undertaken to quantify the effects of pastoral fallow on pasture plant, soil, natural reseeding and white clover growth behaviour in a naturalised hill pasture at the AgResearch Hill Country Research Station, ‘Ballantrae’ near Palmerston North, New Zealand.

Chapters 3 and 4 are based on a field experiment where a fallowing treatment was imposed from October 1993 to May 1994. Chapter 3 describes changes in plant population density and sward structure of a mixed-species hill pasture during the experiment, and the application of self-thinning rule to the fallowed treatments. Chapter 4 compares plant root growth and soil physical and chemical properties between fallowed and grazed swards. To describe the long-term effects of pastoral fallow on soil chemical characteristics, soil samples were taken and analysed from plots with previous fallowing history (Experiment 2 in Chapter 4).

Since the seed production by pasture plants and resultant drop in plant/tiller density by fallowing were considered as an opportunity to reseed, identification and numbers of seedlings germinating from turf plugs kept in a glasshouse were recorded to examine the effect of pastoral fallow on the potential to naturally reseed. Chapter 5 gives quantitative descriptions on 1)
the patterns of seed germination for various plant species after fallowed and grazed treatments (Experiment 1 in the chapter), and 2) variation of natural reseeding during the October 1993 to May 1994 pastoral fallow (Experiment 2 in the chapter).

Chapter 6 describes the impact of timing and duration of pastoral fallow and nitrogen fertiliser on plant density, sward structure, natural reseeding and white clover growth in a field experiment from December 1994 to September 1995. Seed germination from soil plugs held over seven-months in a glasshouse was recorded to estimate the capacity of natural reseeding in various treatments following the field experiment.

Chapter 7 describes the short- and long-term effects of pastoral fallow on herbage production and plant population density with emphasis on white clover growth and distribution. The results of the experiment examining the short-term effect of pastoral fallow, based on the experiment described in Chapter 3, are presented as Experiment 1 in this chapter. The long-term effect of pastoral fallow was investigated on plots with a series of fallowing history (Experiment 2 in the Chapter).

Since the individual papers are self-contained with their reference listing, separate reference listing is given for Chapters 1, 2 and 3 as well. The context and/or structure of individual papers have been modified to fit into chapters, which are integrated into the thesis.