INTERNAL PARASITISM AND GROWTH OF FARMED DEER FED DIFFERENT FORAGE SPECIES

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DECLARATION

The studies presented in this thesis were completed by the author while a post-graduate student in the Institute of Food, Nutrition and Human Health, College of Sciences, 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.

I certify that the substance of this 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.

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ABSTRACT

A series of grazing and indoor experiments were conducted to investigate interactions between internal parasitism and different forage species affecting farmed deer growth, carcass production, voluntary feed intake (VFI) and nutrient digestion. These studies have provided information into aspects of internal parasitism in farmed red (*Cervus elaphus*) and hybrid (0.75 red:0.25 elk) deer. These studies have also investigated the potential of forage crops with a different plant morphology to perennial ryegrass/white clover (PRG/WC), such as chicory (*Cichorium intybus*), and those containing condensed tannins (CT) such as sulla (*Hedysarum coronarium*) and birdsfoot trefoil (*Lotus corniculatus*), as natural aids in the control of internal parasites of farmed deer. Use of such forage crops could enhance sustainable management systems for deer production with minimal anthelmintic input. This is consistent with the New Zealand Deer Industry's strategy for clean, green, natural products produced using minimal chemical inputs.

During 1994, a grazing trial was conducted to evaluate the use of sulla (cv Necton), a new forage legume for deer production. Growth and carcass production from weaning to one year of age on sulla was compared with that on chicory (cv Grasslands Puna) and PRG (*Lolium perenne*, cv Nui)/WC (*Trifolium repens* cv Huia) pasture, with all deer receiving three-weekly oral anthelmintic treatment. VFI of deer grazing sulla was greater than for deer grazing chicory in autumn, with pasture being intermediate. Autumn LWG, final liveweight and carcass weight of deer grazing sulla was greater than for deer grazing either pasture or chicory. The proportion of deer reaching 50-65kg carcass weight by one year of age was 100% for sulla and 89% for pasture and chicory. The increased growth and carcass weight of young deer grazing sulla was due to its higher feeding value, particularly during autumn, including increased utilisation of digested nutrients associated with the high CT concentration of sulla (5.1-8.4%).

Concurrently, another grazing trial showed that grazing deer on chicory reduced the development of internal parasitism and hence increased deer growth and carcass production, compared with grazing PRG/WC pasture. Deer on the two forages were either treated with anthelmintic three-weekly to control internal parasites, or anthelmintic was withheld until pre-determined trigger-treatment criteria to minimise the welfare risk to the animal were reached. Chicory and PRG/WC pasture were grazed at the same herbage allowance per animal, but the forages differed in morphology and sward structure, with the broad-leaved chicory sward being taller and more open. Both forages were maintained in the vegetative state, were of high *in-vitro* digestibility and contained

only traces of CT (<0.3%). Untreated deer grazing pasture rapidly developed clinical lungworm infections during the autumn period and required anthelmintic treatment. In contrast, the untreated chicory group required no anthelmintic treatment during the autumn period when grazing chicory, but required treatment 26 days after transfer to pasture during winter. VFI and LWG of untreated deer grazing pasture in autumn was reduced, contributing to lower carcass weights, but anthelmintic treatment had no effect upon the productivity of deer grazing chicory. This experiment also demonstrated limitations of current tools for diagnoses of sub-clinical and clinical internal parasite infections in farmed deer, particularly during the early stages of infection and indicated that further research is needed to investigate the epidemiology, pathogenicity and diagnosis of internal parasite infections. Further research is also needed to partition the effects of plant morphology and plant chemical composition on development of internal parasitism in deer grazing different forage species.

Subsequently, a model for sub-clinical parasite infection in deer was established, in a controlled environment, using individually housed deer fed lucerne hay, upon which further evaluation of forage species could be based, allowing individual animal measurement of factors such as VFI, digestion, growth and aspects of parasitology. The initial model investigated the effect of three sub-clinical dose rates of deer-origin lung (*Dictyocaulus viviparus*) and gastrointestinal (GI) parasite larvae by trickle-infection, relative to an uninfected control group, on deer VFI, liveweight, faecal egg counts (FEC), faecal larval counts (FLC), haematology, serum biochemistry, apparent digestibility, nitrogen (N) retention and digesta N flow at the abomasum and terminal ileum and worm counts at euthanasia. Sub-clinical parasitism reduced liveweight, VFI and serum albumin concentration, elevated serum pepsinogen, gastrin and globulin concentrations and elevated peripheral eosinophil counts, and caused slight haemoconcentration, despite low nematode counts. Reductions in liveweight, N-retention and flow of N at the terminal ileum were shown to be largely due to the reduction in VFI, with no effect of parasite infection on apparent digestibility. This experiment also showed that such studies could be conducted using anthelmintic-treated deer from natural rearing systems as well as artificially-reared deer, thus reducing cost.

Finally, the model was used to investigate the effect of feeding forage legumes containing different concentrations of CT on apparent establishment of lung and GI nematodes, VFI, liveweight, FEC, FLC, haematology and serum biochemistry. Fresh, vegetative lucerne (*Medicago sativa*; 0.1% CT), birdsfoot trefoil (1.9% CT) and sulla (3.5% CT) were compared. This experiment showed a significant negative linear

relationship between dietary CT concentration and apparent establishment of abomasal nematodes, particularly *T.axei*. Deer fed sulla had reduced FLC, higher liveweight gain, carcass weight, dressing-out percentage, serum total protein and albumin concentration and lower serum gastrin concentration, compared with lucerne-fed deer. There were no significant differences in mean VFI between treatment groups during the period of infection, suggesting that the increased liveweight gain of deer fed CT-containing forages was due to an increased efficiency of utilisation of digested nutrients, probably caused by action of CT counteracting protein losses normally associated with parasite infections. It is proposed that the reduced establishment of abomasal nematodes and reduced faecal lungworm larval count in deer fed sulla containing a high concentration of CT may be due to a direct effect of free CT inactivating nematodes in the GI tract.

This study is the first to report and quantify significant reductions in VFI, liveweight gain, N-retention and carcass production in young, farmed deer sub-clinically infected with internal parasites, with most of the reductions being attributable to reduced VFI. Indices for diagnosis of internal parasitism in farmed deer have also been evaluated. Feeding forages containing CT has been shown to reduce apparent establishment of GI nematodes, FLC and increase liveweight gain of parasitised deer. Grazing chicory, a crop of differing plant morphology and sward structure to PRG/WC pasture has also been shown to reduce the development of internal parasitism in farmed deer. The grazing and indoor studies together highlight the potential use of forage crops to increase growth of farmed deer while minimising anthelmintic input. The studies presented in this thesis have great potential significance to the New Zealand Deer Industry. The working model of internal parasitism for deer developed here can now be used to develop further knowledge of deer parasitism and alternative methods of parasite control that are more ecologically sustainable than regular chemical treatment.

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TABLE OF CONTENTS

ABSTRACT i
ACKNOWLEDGEMENTS iv
LIST OF FIGURES vi
LIST OF TABLES viii
LIST OF PLATES xi
LIST OF ABBREVIATIONS xii

CHAPTER 1: Review of Literature 1
1.1. THE NEW ZEALAND DEER INDUSTRY: ORIGINS AND HISTORY 1
1.1.1. Introduction of Deer to New Zealand 1
1.1.2. The History of the New Zealand Deer Industry 1
1.2. THE NEW ZEALAND FARMED DEER INDUSTRY 2
1.2.1. The New Zealand Farmed Deer Population 2
1.2.2. The New Zealand Farmed Venison Industry 3
1.2.2.1. New Zealand Farmed Venison vs other Ruminant Meats 3
1.2.2.2. Venison Production 4
1.2.2.3. Venison Marketing 5
1.2.3. Velvet Production 6
1.2.4. On-Farm Quality Assurance 6
1.3. SEASONALITY IN TEMPERATE DEER SPECIES 7
1.3.1. Seasonality in Voluntary Food Intake 7
1.3.2. Seasonality in Digestion 8
1.3.3. Seasonality in Growth 8
1.4. FEED REQUIREMENTS OF TEMPERATE DEER SPECIES AND RELATIONSHIP TO SEASONAL FEED SUPPLY 9
1.4.1. Annual Feed Requirements of Temperate Deer 9
1.4.2. The Seasonality of Pasture Growth in New Zealand 11
1.4.3. Matching Deer Feed Requirements with Feed Supply in New Zealand 11
1.5. THE USE OF SPECIAL PURPOSE FORAGES FOR VENISON PRODUCTION 12
1.5.1. Forage Crops Evaluated for Venison Production in New Zealand 12
1.5.1.1. Summer Forage Crops 12
1.5.1.2. Winter Forage Crops 14
1.5.2. Potential Forage Crops 15

1.6. PRINCIPLES OF FORAGE FEEDING VALUE 15
1.6.1. Definition of Feeding Value 15
1.6.2. Forage Intake by Grazing Animals 16
1.6.2.1. Nutritional and Non-Nutritional Components 16
1.6.2.2. Grazing Management 18
1.6.3. Nutritive Value of Forages 19
1.6.3.1. Forage Chemical and Physical Composition 19
1.6.3.2. Digestibility and Site of Digestion 21
1.6.3.3. Efficiency of Utilisation of Digested Nutrients 24
1.6.4. Differences Between Forages in Feeding Value 25
1.6.5. Measuring Voluntary Food Intake in the Grazing Animal 25
1.6.5.1. Animal Techniques 25
1.6.5.1.1. Chromium Oxide 25
1.6.5.1.2. Alkanes 26
1.6.5.2. Sward Technique 27
1.7. EFFECT OF CONDENSED TANNINS IN TEMPERATE FORAGES ON FEEDING VALUE 29
1.7.1. Introduction to Condensed Tannins 29
1.7.2. Condensed Tannins and Protein and Carbohydrate Digestion 31
1.7.2.1. Protein Digestion 31
1.7.2.2. Carbohydrate Digestion 32
1.7.3. Condensed Tannins and Animal Production 32
1.7.4. The Effect of Condensed Tannins in the Diets of Deer. 33
1.8. INTERNAL PARASITISM OF TEMPERATE DEER SPECIES 36
1.8.1. Lungworm (*Dictyocaulus viviparus*) 36
1.8.1.1. Epidemiology of Lungworm Infections 36
1.8.1.2. Clinical Signs and Pathogenicity of Lungworm Infections 39
1.8.1.3. Diagnosis of Lungworm Infections 39
1.8.2. Gastrointestinal Parasite Infections 39
1.8.2.1. Epidemiology of GI Nematode Infections 40
1.8.2.2. Clinical Signs and Pathogenicity of GI Nematode Infections 42
1.8.2.3. Diagnosis of GI Nematode Infections 44
1.8.3. Susceptibility of Farmed Deer to Internal Parasitism 44
1.8.4. Control of Internal Parasites in Farmed Deer 45
1.8.4.1. Anthelmintic Efficacy and Use 46

1.8.4.2. Grazing Strategies 48
1.9. THE USE OF FORAGE CROPS TO CONTROL INTERNAL PARASITES OF RUMINANTS 49
1.9.1. Plant Morphology and "Safe Crops". 49
1.9.2. Condensed Tannins and Internal Parasites. 50
1.10. CONCLUSION AND REQUIREMENTS FOR FURTHER RESEARCH 52

CHAPTER 2: Growth and carcass production of young farmed deer grazing sulla (*Hedysarum coronarium*), chicory (*Cichorium intybus*) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture 55
2.1. ABSTRACT 56
2.2. INTRODUCTION 56
2.3. MATERIALS AND METHODS 57
2.3.1. Trial Design 57
2.3.2. Forages 58
2.3.3. Animals 58
2.3.4. Grazing Management 59
2.3.5. Forage Sampling and Measurements 59
2.3.6. Voluntary Feed Intake 59
2.3.7. Slaughter 60
2.3.8. Laboratory Analysis 60
2.3.9. Calculations and Data Analysis 60
2.4. RESULTS 61
2.4.1. Herbage Mass and Botanical Composition 61
2.4.2. Nutritive Value of Forages 65
2.4.3. Voluntary Feed Intake 67
2.4.4. Liveweight and Liveweight Gain 67
2.4.5. Carcass Production 69
2.4.6. Velvet Antler Production 69
2.5. DISCUSSION 71

CHAPTER 3: Effects of reducing anthelmintic input upon growth and faecal egg and larval counts in young farmed deer grazing chicory (*Cichorium intybus*) and perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture 75
3.1. ABSTRACT 75

3.2. INTRODUCTION 76
3.3. MATERIALS AND METHODS 78
3.3.1. Experimental Design 78
3.3.2. Forages 78
3.3.3. Animals 79
3.3.4. Grazing Management 79
3.3.5. Forage Sampling and Measurements 81
3.3.6. Voluntary Feed Intake 81
3.3.7. Slaughter Procedure 81
3.3.8. Laboratory Analysis 81
3.3.9. Calculations and Data Analysis 82
3.4. RESULTS 82
3.4.1. Herbage Mass and Botanical Composition 82
3.4.2. Nutritive Value and Chemical Composition of the Diet Selected 84
3.4.3. Liveweight Gain and Anthelmintic Treatment 84
3.4.4. Voluntary Feed Intake 88
3.4.5. Carcass Production 88
3.4.6. Velvet Antler Production 90
3.4.7. Serum Pepsinogen 90
3.4.8. Faecal Egg and Larval Counts 91
3.5. DISCUSSION 94

CHAPTER 4: Development of a model for study of lungworm (*Dictyocaulus* sp.) and gastrointestinal nematode infection in red deer (*Cervus elaphus*). 98
4.1. ABSTRACT 98
4.2. INTRODUCTION 99
4.3. MATERIALS AND METHODS 100
4.3.1. Experimental Design 101
4.3.2. Animals and Housing 101
4.3.3. Infective Larvae 102
4.3.4. Voluntary Feed Intake 104
4.3.5. Blood Sampling, Serum Biochemistry and Haematology 104
4.3.6. Euthanasia and Organ Processing 105
4.3.7. Parasitology 105
4.3.7.1. Faeces 105

4.3.7.2. Lungs 106
4.3.7.3. Abomasum 106
4.3.7.4. Small and Large Intestines 107
4.3.8. Dietary Chemical Analyses 107
4.3.9. Statistical Analyses 107
4.4. RESULTS 108
4.4.1. Diet 108
4.4.2. Investigation of Infection Rate 108
4.4.2.1. Voluntary feed intake and liveweight 108
4.4.2.2. Faecal egg and larval counts 111
4.4.2.3. Serum biochemistry 114
4.4.2.4. Haematology 118
4.4.2.5. Nematode counts 122
4.4.3. Rearing Method Comparison 127
4.5. DISCUSSION 137

CHAPTER 5: Apparent digestibility and nitrogen retention of weaner deer fed lucerne chaff and infected with lungworm (*Dictyocaulus* sp.) and gastrointestinal nematodes. 147
5.1. ABSTRACT 148
5.2. INTRODUCTION 148
5.3. MATERIALS AND METHODS 149
5.3.3. Experimental Design 149
5.3.2. Animals and Housing 150
5.3.3. Apparent Digestibility and Nitrogen Balance 150
5.3.4. Digesta Flow 151
5.3.5. Dietary Chemical Analyses 152
5.3.6. Statistical Analyses 152
5.4. RESULTS 152
5.5. DISCUSSION 156

CHAPTER 6: Effect of forage legumes containing different concentrations of condensed tannins on establishment of internal parasites in young red deer. 158
6.1. ABSTRACT 158
6.2. INTRODUCTION 159
6.3. MATERIALS AND METHODS 160

6.3.1. Experimental Design 160
6.3.2. Animals and Housing 161
6.3.3. Forages 162
6.3.4. Culture and Administration of Infective Larvae 163
6.3.5. Blood Sampling, Serum Biochemistry and Haematology 163
6.3.6. Slaughter 164
6.3.7. Parasitology 164
6.3.8. Dietary Chemical Analyses 165
6.3.9. Statistical Analyses 166
6.4. RESULTS 167
6.4.1. Diet 167
6.4.2. Voluntary Feed Intake and Liveweight 169
6.4.3. Carcass Data 172
6.4.4. Faecal Egg and Larval Counts 172
6.4.5. Serum Biochemistry 175
6.4.6. Haematology 175
6.4.7. Nematode Counts at Slaughter 181
6.5. DISCUSSION 182

CHAPTER 7: General Discussion 190
7.1. INTRODUCTION 190
7.2. INTERNAL PARASITISM IN DEER 190
7.2.1. Quantifying Sub-clinical Effects of Internal Parasitism in Deer 191
7.2.2. The Effects of Internal Parasitism on Growth and Carcass Production 191
7.2.3. Diagnosis of Sub-Clinical Parasitism in Deer 192
7.3. FORAGES FOR CONTROL OF INTERNAL PARASITES IN DEER 196
7.3.1. Effect of Plant Morphology and Sward Structure on Internal Parasites 197
7.3.2. Plant Chemical Composition 198
7.4. CONCLUSIONS 201

LIST OF REFERENCES 203
APPENDICES 236

LIST OF FIGURES

Figure 1.1. The New Zealand deer herd ($x10^3$) over the last decade. 2.

Figure 1.2. Mean monthly dry matter intake (DMI) of hinds and stags fed indoors for one year. 7.

Figure 1.3. Mean monthly live weight of hinds and stags fed indoors for one year. 9.

Figure 1.4. Life cycle of *Dictyocaulus viviparus* in red deer. 38.

Figure 1.5. Typical life cycle of trichostrongylid gastrointestinal parasites in red deer. 42.

Figure 3.1. Three-weekly mean (+SE) daily liveweight gain (LWG) of deer grazing PRG/WC pasture (P) or chicory (C) and treated with anthelmintic 3-weekly (T) or trigger-treated (TT). 85.

Figure 3.2. Mean (+SE) faecal egg counts of deer grazing PRG/WC pasture (P) or chicory (C) and treated with anthelmintic 3-weekly (T) or trigger-treated (TT). 92.

Figure 3.3. Mean (+SE) faecal larval counts of deer grazing PRG/WC pasture (P) or chicory (C) and treated with anthelmintic 3-weekly (T) or trigger-treated (TT). 93.

Figure 4.1. Mean (+SE) voluntary feed intake. 109.

Figure 4.2. Mean (+SE) liveweight. 110.

Figure 4.3. Mean (+SE) faecal egg counts. 112.

Figure 4.4. Geometric mean (+SE) faecal lungworm larval count. 113.

Figure 4.5. Mean (+SE) serum total protein, albumin and globulin concentration 115.

Figure 4.6. Mean (+SE) serum pepsinogen concentration. 116.

Figure 4.7. Mean (+SE) serum gastrin concentration. 117.

Figure 4.8. Mean (+SE) total leucocyte (WBC) and erythrocyte (RBC) counts. 119.

Figure 4.9. Mean (+SE) lymphocyte, neutrophil and monocyte counts. 120.

Figure 4.10. Mean (+SE) peripheral eosinophil counts. 121.

Figure 4.11. Mean (+SE) faecal egg counts of artificially (AR) and naturally (NR) reared deer. 129.

Figure 4.12. Geometric mean (+SE) faecal lungworm larval counts of artificially (AR) and naturally (NR) reared deer. 130.

Figure 4.13. Mean (+SE) serum total protein, albumin and globulin concentration of artificially (AR) and naturally (NR) reared deer. 132.

Figure 4.14. Mean (+SE) serum pepsinogen concentration of artificially (AR) and naturally (NR) reared deer. 133.

Figure 4.15. Mean (+SE) serum gastrin concentration of artificially (AR) and naturally (NR) reared deer. 134.

Figure 4.16. Mean (+SE) total leucocyte (WBC) and erythrocyte (RBC) counts of artificially (AR) and naturally (NR) reared deer. 135.

Figure 4.17. Mean (+SE) lymphocyte, neutrophil and monocyte counts of artificially (AR) and naturally (NR) reared deer. 136.

Figure 4.18. Mean daily VFI vs daily liveweight gain for each group following start of infection. 138.

Figure 4.19. Group mean pre-euthanasia serum pepsinogen concentration vs group mean GI counts. 141.

Figure 4.20. Pre-euthanasia individual serum pepsinogen concentration vs GI nematode count. 142.

Figure 4.21. Pre-euthanasia peripheral eoinophil count vs GI nematode count. 143.

Figure 4.22. Pre-euthanasia peripheral eosinophil count vs lungworm count. 144.

Figure 4.23. Pre-euthanasia individual serum gastrin concentration vs GI nematode count. 145.

Figure 5.1. Nitrogen intake vs nitrogen retention. 154.

Figure 6.1. Mean (+SE) voluntary feed intake of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 170.

Figure 6.2. Mean (+SE) liveweight of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 171.

Figure 6.3. Mean (+SE) faecal egg counts of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 173.

Figure 6.4. Mean (+SE) faecal lungworm larval counts of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 174.

Figure 6.5. Mean (+SE) serum total protein, albumin and globulin concentration of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 176.

Figure 6.6. Mean (+SE) serum pepsinogen concentration of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 177.

Figure 6.7. Mean (+SE) serum gastrin concentration of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 178.

Figure 6.8. Mean (+SE) peripheral eosinophil counts of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 179.

Figure 6.9. Mean (+SE) blood haemoglobin concentration of deer fed lucerne (L), birdsfoot trefoil (B) or sulla (S). 180.

Figure 6.10. Group mean number of abomasal worms at slaughter as a function of forage condensed tannin concentration. 183.

Figure 6.11. Group mean number of abomasal *T.axei* at slaughter as a function of forage condensed tannin concentration. 183.

Figure 6.12. Group mean pre-slaughter faecal larval count as a function of forage condensed tannin concentration. 184.

Figure 6.13. Lungworm recovered at slaughter vs pre-slaughter faecal larval count. 188.

Figure 6.14. GI nematodes recovered at slaughter vs pre-slaughter faecal egg count. 188.

Figure 7.1. Gastrointestinal nematode count at slaughter vs lungworm count at slaughter for Chapters 4 & 6 combined. 195.

LIST OF TABLES

Table 1.1. New Zealand farmed deer slaughter statistics. 3.

Table 1.2. The composition of uncooked lean meat. 4.

Table 1.3. Seasonal ME requirement and target liveweight of red deer. 10.

Table 1.4. Daily liveweight gain (g/day) for young red deer stags grazing perennial ryegrass/white clover pasture (PRG/WC), red clover (R), chicory (C) or birdsfoot trefoil (B) in summer, autumn and spring and PRG/WC in winter. 13.

Table 1.5. Effect of species, plant component and maturity on the chemical composition of pasture (% dry matter). 21.

Table 1.6. Concentrations (g/kgDM) of extractable (ECT), protein-bound (PCT), fibre-bound (FCT) and total condensed tannins (TCT) in a range of whole plants. 30.

Table 1.7. Helminth parasites identified from temperate deer species worldwide. 37.

Table 1.8. Percentage of weaner deer shedding faecal parasite eggs and lungworm larvae, and mean and range of geometric means (larvae/g) of positive faecal larval counts 1992-1994. 43.

Table 1.9. Mean number of annual anthelmintic treatments by farm and age/sex group. 48.

Table 2.1. Seasonal pre- and post-grazing herbage mass (kgDM/ha ±SE) of perennial ryegrass/white clover pasture, chicory or sulla grazed deer. 62.

Table 2.2. Seasonal botanical composition (%DM ±SE) of perennial ryegrass/white clover pasture, chicory or sulla on offer. 64.

Table 2.3. Chemical composition (mean ±SE) of forage on offer and diet selected by deer grazing either perennial ryegrass/white clover pasture, chicory or sulla. 66.

Table 2.4. Condensed tannin concentration (%DM ±range) of diet selected by deer grazing either perennial ryegrass/white clover pasture, chicory or sulla. 67.

Table 2.5. Voluntary feed intake (gOM/d), liveweight (kg) and liveweight gain (g/d) of deer grazed on perennial ryegrass/white clover pasture, chicory or sulla. 68.

Table 2.6. Carcass production of red and hybrid stags grazed on perennial ryegrass /white clover pasture, chicory or sulla. 70.

Table 2.7. Velvet antler production from red and hybrid yearling stags grazing either perennial ryegrass/white clover pasture, chicory or sulla. 71.

Table 3.1. Seasonal pre- and post-grazing herbage mass (kgDM/ha ±SE) of perennial ryegrass/white clover pasture or chicory. 83.

Table 3.2. Seasonal chemical composition (%DM ±SE) of diet selected by deer grazing either perennial ryegrass/white clover pasture or chicory. 84.

Table 3.3. Seasonal voluntary feed intake (gOM/d), liveweight (kg) and liveweight gain (g/d) of deer grazed on perennial ryegrass/white clover pasture or chicory and treated with anthelmintic 3-weekly or trigger-treated. 87.

Table 3.4. Carcass measurements of stags and hinds, treated (T) or trigger-treated (TT) with anthelmintic and grazed on perennial ryegrass/white clover pasture or chicory. 89.

Table 3.5. Serum pepsinogen concentration (mU tyrosine/l ±SE) from deer grazing either perennial ryegrass/white clover pasture or chicory and treated with anthelmintic 3-weekly (T) or trigger-treated (TT). 90.

Table 4.1. Experimental design. 101.

Table 4.2. Sequence of experimental events. 101.

Table 4.3. Mean (± SE) number of lung and gastrointestinal nematodes recovered from deer experimentally infected at three different levels of infection with nematode larvae and control deer. 123.

Table 4.4. Species of nematodes identified from deer artificially infected with nematode larvae, expressed as a proportion (%) of the total number of identifiable nematodes counted. 126.

Table 4.5. Liveweight, VFI and numbers of lung and gastrointestinal nematodes (mean ± SE) recovered from artificially and naturally reared deer infected with nematode larvae. 127.

Table 5.1. Experimental design. 149.

Table 5.2. Chemical composition (%DM ±SE) of chaffed lucerne hay fed. 153.

Table 5.3. Apparent digestibility (%) of DM, OM, gross energy, ADF, NDF, cellulose, hemicellulose and lignin in deer fed lucerne chaff and infected with zero (C), low (LT), medium (MT) and high (HT) levels of nematode larvae. 153.

Table 5.4. Apparent N digestibility, N-retention and flow of N measured at the abomasum and terminal ileum, in g/d and expressed as a percentage of N intake, in deer fed lucerne chaff and infected with zero (C), low (LT), medium (MT) and high (HT) levels of nematode larvae. 155.

Table 6.1. Experimental design. 160.

Table 6.2. Sequence of experimental events. 161.

Table 6.3. Dry matter (%) and chemical composition (%DM ±SE) of fresh forage fed to weaner red deer housed indoors and fed chicory (adjustment period), lucerne, birdsfoot trefoil or sulla. 168.

Table 6.4. Group mean (± SE) VFI and LWG of deer fed lucerne, birdsfoot trefoil or sulla during infection with internal parasites (weeks 1-7), carcass weight (CW; with and without initial liveweight as a covariate) and carcass dressing out percentage (DR%) at slaughter. 172.

Table 6.5. Lung and gastrointestinal nematodes (mean ±SE) recovered from weaner red deer fed lucerne, birdsfoot trefoil or sulla. 182.

Table 7.1. Growth (g/d) of red (R) and hybrid (H) stags to one year of age grazing perennial ryegrass/white clover pasture, red clover, chicory and sulla, and feeding value of forages relative to perennial ryegrass/white clover pasture. 197.

LIST OF PLATES

Plate 2.1. Perennial ryegrass/white clover pasture grazed in early spring. 62.

Plate 2.2. Chicory grazed in early spring. 63.

Plate 2.3. Sulla grazed in early spring. 63.

Plate 3.1. Method of paddock bissection using a five-strand electric fence. This shows winter grazing with TT groups on the left and T groups on the right. 80.

Plate 4.1. Artificial rearing of deer calves using ewe milk replacer. 111.

Plate 4.2. Spicules of *Spiculopteragia assymetrica* from the abomasum. 118.

Plate 4.3. Spicules of *Skrjabinagia kolchida* from the abomasum. 124.

Plate 4.4. Spicules of *Ostertagia leptospicularis* (a morph of *S.kolchida)* from the abomasum. 124.

Plate 4.5. Spicules of *Ostertagia circumcincta* from the abomasum. 125.

Plate 4.6. Spicules of *Cooperia punctata* from the small intestine 125.

LIST OF ABBREVIATIONS AND CODES

$	New Zealand dollars	*et al.,*	and others
%	percentage	Exp.	experiment
°C	degrees Celsius	Eqn.	equation
/ (/g)	per (per gram)	FEC	faecal egg count /g faeces
AA	amino acids	FCT	fibre-bound CT
ADF	acid detergent fibre	Fig.	figure
ANOVA	analysis of variance	FLC	faecal lungworm larval count /g faeces
BCT	bound CT	FO	faecal output
B	birdsfoot trefoil	FrCT	free CT
BW	body weight	FV	feeding value
C.	*Cooperia*	g	gram
C	chicory	GE	gross energy
Cm	centimetre	GI	gastro-intestinal
CP	crude protein	GIB	Game Industry Board
Cr	chromium	GR	soft tissue depth over 12th rib at a point 16cm from carcass midline
CT	condensed tannin	GT	grazing time
CW	carcass weight	h	head (animal)
D.	*Dictyocaulus*	*H.*	*Haemonchus*
D	digestibility	hr (s)	hour (s)
d	day	Ha	hectare
DLWG	daily liveweight gain	Hb	haemoglobin (g/l)
DM	dry matter	HI	high
DMI	dry matter intake	HT	hydrolysable tannins
DSP	deer slaughter premises	IB	intake per bite
EAA	essential amino acids	iu (IU)	international units
ECT	extractable CT	K_f	efficiency of utilization of ME for fattening
epg	eggs per gram faeces	K_g	efficiency of utilization of ME for growth

K_l	efficiency of utilization of ME for lactation	NS	not statistically significant at $p<0.05$
K_m	efficiency of utilization of ME for maintenance	NV	nutritive value
kg	kilograms	NZ	New Zealand
KJ	kilojoule	*O.*	*Ostertagia*
L	litres	*Oe.*	*Oesophagostomum*
L_3	third stage larvae (infective stage)	OM	organic matter
lpg	larvae per gram faeces	OMD	organic matter digestibility
Ltd	Limited	OMI	organic matter intake
L	lucerne (*Medicago sativa*)	P	probability statistic
LW	liveweight	pers. comm.	personal communication
LWG	liveweight gain	PCT	protein-bound CT
m	metres	PCV	packed cell volume (l/l)
ME	metabolizable energy	PEG	polyethylene glycol
MED (med)	medium	PRG	perennial ryegrass
ME_g	ME for growth	R	red clover
MEI	ME intake	RB	rate of biting
ME_m	ME for maintenance	RBC	red blood cell count (10^{12}/l)
mg	milligram	RFC	readily fermentable carbohydrate
MJ	megajoule	rpm	revolutions per minute
ml	millilitres	SAA	sulphur AA
mm	millimetres	SE	standard error
MRT	rumen mean retention time	SI	small intestine
mU	milli-international enzyme unit	t	tonne
MW	molecular weight	*T.*	*Trichostrongylus*
N	nitrogen	TCT	total CT
NAN	non-ammonia nitrogen	STP	serum total protein (g/l)
nd	not determined	µg	microgram
NDF	neutral detergent fibre	UK	United Kingdom

µl	microlitre	VFI	voluntary feed intake
USA	United States of America	WBC	white blood cell count (10^9/l)
VFA	volatile fatty acids	WC	white clover