

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.

3
15383

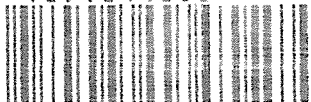
**VENISON PRODUCTION FROM WEANER RED DEER STAGS
GRAZING MOATA ANNUAL RYEGRASS OR
PERENNIAL RYEGRASS PASTURES**

A thesis presented in partial fulfilment
of the requirements for the Degree of
Doctor of Philosophy in Animal Science
at Massey University, Palmerston North,
New Zealand

ABU MOHAMMED ATAJA

1990

1091044060



DEDICATION

This thesis is dedicated to my late mother, Zainab Acharu Ataja, and also to my elder sister, Hawawo Ataja, who passed away on September 14, 1990.

ABSTRACT

Four grazing experiments were conducted with red deer stags, three with weaner stags (start 6 months old; end 12 months old) and one with yearling stags (start 15 months old; end 21 months old). In New Zealand (NZ) the calving season for red deer is during late spring/early summer (November/December) and the calves are normally weaned in late February/early March. The price schedule for venison is highest during August to November, in response to Northern Hemisphere export market demand and is greater for carcasses of 50 kg or above. However, there is no well defined system for meat production from deer. The objective of these studies was to evaluate different systems of growing red deer stags to a slaughter liveweight (LW) of 92 kg (> 50 kg carcass weight (CW)) by one year of age or less, by the end of November. Thus an attempt was made to define a system of meat production from deer that was most profitable to NZ venison producers.

Experiment 1

The effects of two pasture dry matter (DM) allowances (medium and high; 4.5 and 6.3 kg DM/animal/day), the introduction of annual Italian ryegrass ('Grasslands Moata') direct drilled into existing perennial ryegrass/white clover pasture (PRG) at 15 kg seed/ha and active immunisation against melatonin (commencing at 6 months of age) upon voluntary food intake (VFI) and liveweight gain (LWG) of weaner red deer stags were studied during winter and spring. The Moata paddocks were direct drilled and band-sprayed with herbicide. The pastures were grazed under a rotational grazing system, with VFI estimated from pasture cuts before and after grazing.

1. During winter, Moata comprised 19% and 17% of total DM in the medium and high allowances, respectively. During spring these increased to 27% in the Moata medium allowance and 36% in the Moata high allowance.
2. During winter, the diet of animals grazing PRG pasture had predicted digestibility of OM (OMD) and ME values of 0.82 and 11.8 MJ/kg DM, respectively. These increased slightly to 0.84 and 12.0 MJ/kg DM, respectively, during spring. The diet of the Moata group had predicted OMD and ME of 0.84 and 12.0 MJ/kg DM, respectively during both winter and spring.

3. LWG and VFI during winter were approximately 100 g/day and 1.7 kg DM/day, respectively, and were not affected by either herbage allowance or the introduction of Moata. LWG increased in spring, and was higher ($P < 0.10$) for animals grazing Moata high herbage allowance (222 g/day) than those grazing pasture high (186 g/day) or Moata medium herbage allowance (176 g/day). The VFI increased in spring to about 2.2 kg DM/day and was not affected by either herbage allowance or the introduction of Moata.
4. Twenty-five percent of animals grazing the Moata high allowance and 17% of those grazing the Moata medium allowance attained the target slaughter LW (92 kg; 50 kg CW) by the end of November, but no animals grazing the pasture allowances attained the target LW by this date.
5. Fifty-six percent of stags immunised against melatonin developed detectable levels of antibody titre. Antibody titres against melatonin were slow to develop, being absent during winter and slowly increasing during spring to attain a mean level of $1:1571 \pm 583$ by early November. Immunisation against melatonin had no effect on the plasma concentrations of LH, testosterone and prolactin, or upon LWG.

Experiment 2

The effects of two different sward surface heights (5 and 10 cm), using set stocking grazing system; the introduction of Moata (direct drilled into PRG pasture at 20 kg seed/ha, band-sprayed with herbicide) and active immunisation against melatonin (commencing at weaning; 3 months of age) upon LWG and diet selection of weaner red deer stags were studied during winter and spring. Diet selection was determined using complete rumen emptying of rumen fistulated stags.

1. During winter, Moata comprised 46% and 33% of total DM in the 5 cm and 10 cm swards, respectively. During spring these declined to 22% in the Moata 5 cm sward and 19% in the Moata 10 cm sward. The amount of perennial ryegrass and other species in the diet was greater than that in the herbage on offer ($P < 0.001$), however, the diet contained less white clover and Moata than herbage on offer.

2. During winter, the two herbage types on offer (PRG and Moata) had similar OMD of 0.82 and ME of 11.2 MJ/kg DM. During spring these values were also similar for both herbage types, though slightly lower at 0.78 and 10.7 MJ/kg DM for the OMD and ME, respectively. In June and November the OMD and ME for the herbage ingested by both PRG and Moata groups were similar.
3. During winter, herbage accumulation rates in both Moata swards were similar (19 kg DM/ha/day) and higher than either in PRG 5 cm (11 kg DM/ha/day) or PRG 10 cm sward (16 kg DM/ha/day). Consequently, the Moata swards had higher average carrying capacity (14.3 animals/ha/day) than the PRG swards (11.5 animals/ha/day). During spring herbage accumulation rates increased in all swards, with that in Moata swards being similar (41 kg DM/ha/day) but slightly lower than that either in PRG 5 cm (44 kg DM/ha/day) or PRG 10 cm sward (50 kg DM/ha/day). Consequently, the Moata swards had slightly lower average carrying capacity (12.4 animals/ha/day) than the PRG swards (13.4 animals/ha/day).
4. During winter, LWG was greater in weaner stags grazing the 10 cm swards (142 g/day) than those grazing the 5 cm swards (77 g/day; $P < 0.001$), with the introduction of Moata having no effect. During spring, there was an interaction ($P < 0.001$) between sward height and the presence of Moata, with LWG being high on 10 cm swards (222 g/day) and not affected by introduction of Moata. LWG was lower in animals grazing pasture 5 cm sward (147 g/day) and was increased by the presence of Moata ($P < 0.001$), with LWG of the Moata 5 cm group being similar to that of the 10 cm groups (211 g/day). Forty-two-50% of animals grazing the 10 cm swards and 21% of those grazing the Moata 5 cm sward reached the target LW (92 kg) by the end of November, whilst no animal grazing the pasture 5 cm swards attained the target LW.
5. Seventy-three percent of stags actively immunised against melatonin developed detectable levels of antibody titre and this attained highest values ($1:613 \pm 256$) in November. Immunisation against melatonin had no effect on the plasma concentrations of LH and testosterone, however, plasma prolactin concentration was consistently higher in immunised than non-immunised animals with the difference being significant ($P < 0.10$) in October. Active immunisation against melatonin had no effect on either LWG during winter and spring or carcass composition.

Experiment 3

Two immunisation experiments were conducted.

- A. The effects of active immunisation against luteinising hormone releasing hormone (LHRH) upon LWG was examined with 10 yearling red deer stags (5 immunised + 5 non-immunised; 90-96 kg LW) during autumn. Yearling stags normally undergo a growth stasis during autumn which includes the rut. Thus, active immunisation against LHRH was examined as a potential means of increasing growth over this period.
1. Eighty percent of stags actively immunised against LHRH developed detectable levels of antibody titre (1:173 - 1:925). Immunisation against LHRH reduced plasma LH concentrations.
 2. Yearling stags immunised against LHRH grew faster than the control stags (13 v -54 g/day; $P < 0.05$) during the rut season. However, immunisation had no effect upon carcass weight and slightly lowered carcass dressing-out percentage.
- B. The effects of active immunisation against melatonin upon LWG was examined with 15 yearling red deer stags (8 immunised + 7 non-immunised; 90-96 kg LW) during autumn and winter.
1. Seventy-five percent of stags immunised against melatonin developed detectable levels of antibody titre (1:210 - 1:3,167). Plasma concentrations of LH and testosterone were not affected by active immunisation against melatonin. However, plasma prolactin concentration was consistently, but non-significantly, higher in immunised than non-immunised animals.
 2. Active immunisation against melatonin had no effect upon either liveweight loss during the rut (-45 v -35 g/day) or the low rate of LWG (46 v 63 g/day) during winter. However, stags immunised against melatonin had lower rump fat width ($P < 0.05$) than the non-immunised stags.

Experiment 4

Studies on the effect of the introduction of Moata (direct drilled into PRG at 24 kg seed/ha, blanket-sprayed with herbicide) and active immunisation against melatonin (commencing at birth) upon VFI, rumen VFA and ammonia concentration, diet selection and LWG of weaner red deer stags were carried out during winter and spring. Rumen fluid was taken from rumen fistulated stags (RF) and extrusa was collected from oesophageal fistulated stags (OF). VFI was estimated using chromium capsules.

1. Moata annual ryegrass (MAR) comprised an average of 82% of total DM in the direct drilled swards during winter. However, this declined to 65% during spring. Extrusa from OF animals grazing both swards contained less dead matter (Dm; 1.9% and 0.8%) during winter and spring, respectively, than the amounts present in the herbage on offer in winter (6.1%) and spring (13.6%).
2. The OMD of herbage on offer was higher for Moata than PRG during winter (0.86 v 0.80) and spring (0.80 v 0.79), but was similar for herbage ingested (extrusa) by the animals during winter and spring (0.89). ME concentration for both types of herbage on offer and also for extrusa were similar during winter and spring (11.4 and 12.5 MJ/kg DM, respectively).
3. During winter, both Moata and PRG swards supported a similar number of animals/ha/day (8.8 v 8.7). The number of animals/ha/day increased for both sward types during spring, with Moata swards having lower carrying capacity than the PRG swards (16.6 v 23.0).
4. During winter, animals grazing the Moata swards had greater VFI (1615 v 1185 g DM/day; $P < 0.001$) and LWG (165 v 140 g/day; $P < 0.05$) than those grazing the PRG swards. During spring, both the Moata and the PRG groups had similar VFI (1718 v 1762 g DM/day; $P > 0.10$), calculated from individual rectal faecal samples, and similar LWG (235 v 226 g DM/day; $P < 0.10$). Analysis of group faecal samples showed greater VFI, with the Moata group being similar to the PRG group (2570 v 2318 g DM/day; $P > 0.10$). Sixty percent of animals grazing Moata swards and 40% of those grazing PRG swards attained the slaughter LW of 92 kg by 12 months of age. The Moata group had greater carcass dressing-out percent than the PRG group (53.8 v 52.6; $P < 0.05$).

5. There was no significant difference ($P > 0.10$) in the concentration of total VFA in the rumen fluid of animals grazing Moata swards (94.7 m mol/l) and those grazing PRG (89.2 m mol/l). Acetate/propionate ratio for both groups were similar (3.56 v 3.70). However, ammonia concentration was lower in the Moata group (133.8 mg N/l) than the PRG group (188.0 mg N/l).

6. Seventy-five percent of stags immunised against melatonin developed detectable levels of antibody titre. Commencing active immunisation against melatonin at birth resulted in the development of high mean antibody titres ($1:15,215 \pm 5,551$) for animals immunised using Freund's adjuvant and ($1:1,941 \pm 423$) for those immunised using DEAE-dextran adjuvant. Active immunisation against melatonin had no effect on the plasma concentrations of LH and testosterone. Plasma prolactin levels were consistently higher in the immunised animals than the non-immunised animals. The DEAE-dextran group had greater plasma prolactin levels than the control group in mid May and early November ($P < 0.05$; 0.10 , respectively). Active immunisation against melatonin had no effect on carcass composition. However, the Freund's immunised group had heavier testes than the control group ($P < 0.10$).

Conclusions

Grazing deer on pasture at 5 cm sward surface height as is normally practised with sheep reduced their growth rate, hence no stags grazing PRG 5 cm swards attained slaughter LW of 92 kg by 12 months of age. However, grazing weaner stags on ryegrass, especially Moata at 10 cm sward surface height (high DM allowance) can provide a means of finishing a high proportion of weaner stags in their first year. To further enhance the success rate of early venison production programmes, there is a need for further studies in the development of alternative pasture types for summer and autumn grazing for deer, e.g. red clover, chicory and lucerne. Increased weaning liveweights from grazing these pastures would result in heavier stags as starting material for the early venison production programmes in winter.

Peak antibody titre against melatonin is slow to raise in the deer. With commencing active immunisation against melatonin at birth, antibody titre peaked about 11 months later. Therefore, the timing of immunisation programmes and the choice of appropriate adjuvants to generate early optimum immune responses and sustained antibody titres over a long period of time, needs further study.

ACKNOWLEDGEMENTS

I am grateful to the New Zealand Government for awarding me a three-year scholarship, and to the Department of Animal Science, Massey University and the DSIR (Palmerston North) for the research facilities made available to me.

My sincere thanks and appreciation to my Chief Supervisor, Professor T.N. Barry, for his patience, guidance and encouragement throughout the duration of my studies. I also wish to thank my other supervisors, Dr P.R. Wilson, Dr R.W. Purchas and Professor J. Hodgson, for their contribution towards the success of my programme, and Dr Hugo Varela-Alvarez for advice on the statistical analysis of data.

I am greatly indebted to Mr Phil Whitehead and Mr Charlie Howell and family. Charlie taught me a great deal about deer handling and was always ready to help. I am also grateful to Mr Ernie Ranson and Gallagher Electronics Limited, for the donation of fencing equipment.

I wish to acknowledge the warm hands of friendship extended to my family and I by Mrs Anne Odogwu and family, Professor Ken and Janet Milne, Simon and Nikki Moloney and the Victoria League for Commonwealth Friendship in New Zealand. You all made our stay in New Zealand more enjoyable.

My fervent thanks to Dr J. Hay, Dr F. Domingue, Dr M. Ishida (Japanese Visiting Scholar), J. Niezen, A. Abdullah and W. Parker for their assistance.

Many thanks to my elder brother, Chief Achemu Ataja, for his support and encouragement. Also to Ageni Yusuf, John Adejoh, Sam Jones and my other brothers and sisters for believing in me.

I am grateful to R. Watson and D. Hamilton of the Nutrition Laboratory, for their technical assistance. I want to thank Dr R.W. Hoskinson of the CSIRO's Division of Animal Production, Sydney, Australia for the determination of anti-melatonin and anti-LHRH antibody titres, Dr G. Asher, for running the RIA of LH and testosterone, the New Zealand Society of Animal Production for financial assistance and all technical personnel of the Department of Animal Science who contributed to the success of my studies.

I sincerely wish to thank Kathy Hamilton for typing and organising this thesis.

Finally, my love, thanks and appreciation to my dear wife, Abigail Ataja, and to our two daughters, Nana and Lami. "You have come a long way babies". Thank you for everything.

CONTENTS

	PAGE
DEDICATION	ii
ABSTRACT	iii
ACKNOWLEDGEMENTS	ix
CONTENTS	xi
LIST OF TABLES	xviii
LIST OF FIGURES	xxiv
LIST OF ABBREVIATIONS	xxviii
CHAPTER 1	1
A REVIEW OF THE LITERATURE	
1.1 INTRODUCTION	2
1.2 PHYSIOLOGICAL CONTROL OF SEASONAL VOLUNTARY FOOD INTAKE (VFI) AND LIVEWEIGHT GAIN IN DEER	2
1.2.1 Seasonal patterns of VFI and growth in deer	2
1.2.2 Seasonal patterns of hormonal secretion in deer	4
1.2.2.1 Luteinizing hormone (LH)	4
1.2.2.2 Testosterone	5
1.2.2.3 Prolactin	6
1.2.2.4 Growth hormones (GH) and Insulin-like Growth Factor-1 (IGF-1)	8
1.3 HORMONAL MANIPULATION OF GROWTH, REPRODUCTION AND VFI IN DEER	9
1.3.1 Melatonin administration	9
1.3.2 Active immunisation against melatonin	10
1.3.3 Active immunisation against LHRH	11
1.4 PRINCIPLES OF NUTRITIVE VALUE OF FORAGES	12
1.4.1 Seasonal patterns of pasture production and quality	14
1.4.2 Deer grazing on pasture	16
1.4.3 Agronomic characteristics of Moata annual ryegrass	16
1.4.4 Feed requirements of the deer	17
1.4.5 Diet selection by grazing sheep, goats and cattle	19

1.5	MEAT PRODUCTION FROM DEER IN NEW ZEALAND	20
1.5.1	The New Zealand deer population	20
1.5.2	Venison production from male deer	21
1.5.3	Efficiency of meat production from deer	23
1.5.4	Export market requirements	24
1.5.5	Seasonal fluctuations in price schedule of venison	26
CHAPTER 2		28
INITIAL STUDIES ON THE EFFECTS OF PASTURE DM ALLOWANCE, THE INTRODUCTION OF ANNUAL RYEGRASS AND IMMUNIZATION AGAINST MELATONIN UPON EARLY VENISON PRODUCTION		
2.1	INTRODUCTION	29
2.1.1	Objective	29
2.2	MATERIALS AND METHODS	31
2.2.1	Experimental design	31
2.2.2	Animals	31
2.2.3	Pasture	32
2.2.4	Vaccination procedures and blood sampling	33
2.2.5	Slaughter and carcass data	34
2.2.6	Laboratory methods	35
2.2.7	Statistical analyses and calculation of data	37
2.3	RESULTS	39
2.3.1	Botanical composition of pastures	39
2.3.2	Chemical composition of pastures	39
2.3.3	Leaf Strength	39
2.3.4	Seasonal liveweight	42
2.3.5	Liveweight gain	42
2.3.6	Carcass composition	45
2.3.7	Melatonin antibody titre	45
2.3.8	Plasma hormone concentrations	45
2.4	DISCUSSION	48
2.4.1	Seasonal Liveweight and VFI	49

2.4.2	Liveweight gain	49
2.4.3	Nutritive value of Moata annual ryegrass and perennial ryegrass	50
2.4.4	Melatonin antibody titre	51
2.4.5	Plasma hormones	51
2.4.6	Carcass cuts	52
2.5	CONCLUSIONS	52
 CHAPTER 3		56
STUDIES ON THE EFFECTS OF DIFFERENT SWARDS HEIGHTS, THE INTRODUCTION OF ANNUAL RYEGRASS AND IMMUNIZATION AGAINST MELATONIN UPON EARLY VENISON PRODUCTION		
3.1	INTRODUCTION	57
3.2	MATERIALS AND METHODS	58
3.2.1	Experimental design	58
3.2.2	Animal temperament	58
3.2.3	Animal allocation	59
3.2.4	Rumen fistulated stags	59
3.2.5	Pasture management	60
3.2.6	Pasture production and composition	61
3.2.7	Vaccination procedures and blood sampling	62
3.2.8	Slaughter and carcass data	63
3.2.9	Laboratory methods	63
3.2.10	Statistical analyses and calculation of data	64
3.3	RESULTS	65
3.3.1	Seasonal pattern of sward components	65
3.3.2	Botanical composition of herbage and rumen ingesta	72
3.3.3	Chemical composition of pastures	72
3.3.4	Seasonal distribution of herbage yields and carrying capacity	77
3.3.5	Seasonal liveweight	80
3.3.6	Liveweight gain	80
3.3.7	Melatonin antibody titre	82
3.3.8	Plasma hormone concentrations	84
3.3.9	Carcass data	86

3.4	DISCUSSION	86
3.4.1	Seasonal pattern of sward components	87
3.4.2	Seasonal distribution of herbage yields and carrying capacity	88
3.4.3	Diet selection by grazing stags	88
3.4.4	Nutritive value of Moata annual ryegrass and perennial ryegrass	89
3.4.5	Seasonal pattern of growth	90
3.4.6	Liveweight gain	90
3.4.7	Anti-melatonin titre and its effect on winter and spring LWG	91
3.4.8	Plasma hormone concentrations	92
3.4.9	Carcass data	92
3.5	CONCLUSIONS	93
CHAPTER 4		96
THE EFFECT OF ACTIVE IMMUNISATION AGAINST MELATONIN OR LHRH UPON THE GROWTH OF YEARLING RED DEER STAGS DURING AUTUMN AND WINTER, AND UPON PLASMA HORMONE PROFILES		
4.1	INTRODUCTION	97
4.2	MATERIALS AND METHODS	98
4.2.1	Animals and vaccination procedures	98
4.2.1.1	Anti-LHRH trial	98
4.2.1.2	Anti-Melatonin trial	98
4.2.2	Grazing management	98
4.2.3	Weighing and blood sampling procedures	99
4.2.4	Slaughter and carcass data	99
4.2.5	Laboratory analyses	99
4.2.5.1	Antibody titre determination	99
4.2.5.2	Hormone assays	100
4.2.6	Statistical analyses and calculation of data	101
4.3	RESULTS	102
4.3.1	Anti-LHRH trial	102
4.3.1.1	Anti-LHRH antibody titres	102
4.3.1.2	Plasma hormone concentrations	102
4.3.1.3	Liveweight patterns	102
4.3.1.4	LWG	102

4.3.1.5	Carcass data	108
4.3.2	Anti-Melatonin trial	109
4.3.2.1	Anti-melatonin antibody titres	109
4.3.2.2	Plasma hormone concentrations	109
4.3.2.3	Liveweight patterns	109
4.3.2.4	LWG	116
4.3.2.5	Carcass data	116
4.4	DISCUSSION	117
4.4.1	Anti-LHRH trial	117
4.4.1.1	Anti-LHRH antibody titres	117
4.4.1.2	The timing of the LHRH primary vaccination	117
4.4.1.3	Plasma hormone concentrations	117
4.4.1.4	Liveweight patterns and LWG	118
4.4.1.5	Carcass data	118
4.4.2	Anti-Melatonin trial	119
4.4.2.1	Anti-melatonin antibody titres	119
4.4.2.2	Plasma hormone concentrations	120
4.4.2.3	Liveweight patterns and LWG	120
4.4.2.4	Carcass data	121
4.5	CONCLUSIONS AND FUTURE RESEARCH	121
CHAPTER 5		123
STUDIES ON THE EFFECTS OF HIGH FEED ALLOWANCE, THE INTRODUCTION OF MOATA ANNUAL RYEGRASS AND IMMUNISATION AGAINST MELATONIN UPON VFI, DIET SELECTION AND GROWTH RATE OF GRAZING RED DEER STAGS		
5.1	INTRODUCTION	124
5.2	MATERIALS AND METHODS	125
5.2.1	Experimental design	125
5.2.2	Animal temperament	125
5.2.3	Animal allocation	126
5.2.4	Oesophageal fistulated (OF) stags	126
5.2.5	Rumen fistulated stags	127
5.2.6	Pasture management	127
5.2.7	Vaccination procedures and blood sampling	128

5.2.8	Slaughter and carcass data	129
5.2.9	Laboratory methods	130
5.2.10	Statistical analyses and calculation of data	130
5.3	RESULTS	131
5.3.1	Feed on offer	131
5.3.2	Seasonal patterns of sward components	132
5.3.3	Botanical composition of swards	138
5.3.4	Botanical composition of feed and extrusa	138
5.3.5	Nutritive values of feed and extrusa	139
5.3.6	Carrying capacity (animals/ha)	140
5.3.7	Growth patterns and LWG	142
5.3.8	Rumen VFA and NH ₃ concentrations	144
5.3.9	Plasma anti-melatonin antibody titre	145
5.3.10	Plasma hormone concentrations	145
5.3.11	Effect of vaccination on weaning weight and LWG	145
5.3.12	Carcass data	151
5.4	DISCUSSION	152
5.4.1	Seasonal patterns of sward components and carrying capacity	153
5.4.2	Diet selection by grazing deer	153
5.4.3	Nutritive value of Moata and PRG	153
5.4.4	VFI of deer under grazing conditions	154
5.4.5	Seasonal growth patterns and LWG	154
5.4.6	Rumen VFA and NH ₃ concentrations	155
5.4.7	Anti-melatonin titre and its effect on LWG	156
5.4.8	Plasma hormone concentrations	157
5.4.9	Carcass data	157
5.5	CONCLUSIONS	157
CHAPTER 6		161
GENERAL DISCUSSION		
6.1	Deer temperament	162
6.2	LWG of deer grazing PRG/WC pasture	162
6.3	Proportion of stags attaining slaughter weight by 12 months	164
6.4	Effect of introduction of Moata annual ryegrass	165
6.5	Carrying capacity of Moata swards to achieve maximum growth	166

6.6	Feeding deer calves during summer and autumn	167
6.7	Estimation of VFI of grazing red deer using intraruminal chromium controlled release devices	169
6.8	Feed selection	170
6.9	Immunisation against LHRH	172
6.10	Anti-melatonin antibody titre	175
6.11	Effect of immunisation on carcass components	177
APPENDIX I		179
APPENDIX II		182
APPENDIX III		183
REFERENCES		184

LIST OF TABLES

		PAGE
Table 1.1	Comparative feeding value in terms of sheep liveweight gain of some pasture species grown in New Zealand. All values relative to white clover, 'Grasslands Huia'. (Source: Waghorn and Barry 1987)	13
Table 1.2	Approximate seasonal nutritive value (M/D) for ryegrass/white clover dominant pastures. (Source: Ulyatt <u>et al</u> 1980)	15
Table 1.3	Seasonal metabolisable energy requirements and target liveweights for red deer (Source: Fennessy and Milligan 1987)	18
Table 1.4	Mean proportion (DM) of sward components and digestibility of OM in oesophageal extrusa from goats, sheep and calves grazing similar ryegrass/white clover swards. (Source: Hughes <u>et al</u> 1984)	20
Table 1.5	Deer population summary. (Source: GIB 1990)	21
Table 1.6	Deer product exports for year ended December 1989. (Source: GIB 1990)	23
Table 1.7a	Carcass weight (CW) and fatness in lambs, bulls and stags. (Source: Drew 1985)	24
Table 1.7b	Comparative efficiency of feed conversion of ruminants. (Source: Yerex and Spiers 1990)	24
Table 1.8	Venison exports to top ten markets. (Source: GIB 1990)	25

Table 2.1	Definitions of the carcass linear measurements	35
Table 2.2	Botanical composition (% DM) of the swards	40
Table 2.3	Organic matter digestibility (OMD), total nitrogen concentration, calculated concentrations of metabolisable energy (M/D values) and estimated metabolisable energy intakes (MEI) of grazing stags during winter and spring	41
Table 2.4	Leaf tensile strength comparison between perennial ryegrass and Moata annual ryegrass	42
Table 2.5	Liveweight gain (g/day), VFI (g/day) and percentage of stags attaining slaughter weight (92 kg), of grazing stags during winter and spring	44
Table 2.6	Carcass characteristics of deer carcasses (n = 45)	44
Table 2.7	Plasma concentrations of LH and testosterone (ng/ml) in red deer stags during October and November 1987	48
Table 2.8	Comparison of the estimated ME intakes of growing red deer stags	49
Table 3.1a	Botanical composition (% DM) of the swards during winter (May-August) 1988	71
Table 3.1b	Botanical composition (% DM) of the swards during spring (September-November) 1988	71
Table 3.2	Botanical composition of herbage (% DM) and rumen ingesta (% contact) of grazing stags during June and November 1988	73

Table 3.3a	Organic matter digestibility (OMD), total nitrogen concentration and calculated concentrations of metabolisable energy (M/D values) of herbage and rumen ingesta of grazing stags during winter (June-August) 1988	76
Table 3.3b	Organic matter digestibility (OMD), total nitrogen concentration and calculated concentrations of metabolisable energy (M/D values) of herbage and rumen ingesta of grazing stags during spring (September-December) 1988	77
Table 3.4	Average seasonal herbage yields (kg DM/day) and carrying capacity (animals/ha)	80
Table 3.5	Liveweight gain (g/day) of grazing stags during winter and spring of 1988, and percentage of stags attaining slaughter liveweight of 92 kg	82
Table 3.6	Plasma concentrations of LH and testosterone (ng/ml) in red deer stags during October and November 1988	84
Table 3.7	Carcass data of red deer stags slaughtered in 1988, liveweight gain (g/day) during winter and spring and percentage of stags attaining slaughter liveweight of 92 kg	86
Table 4.1	Liveweight gain (g/day) of yearling red deer stags during the rut season (March 22-May 25, 1989) and carcass data	108
Table 4.2	Liveweight gain (g/day) of anti-melatonin treated and control yearling red deer stags during the rut and during winter (1989) and carcass data	116
Table 5.1	Level of feed on offer (kg DM/ha) during winter (June-August) and spring (September-November) 1989	132

Table 5.2	Botanical composition (% DM) of the swards during winter and spring 1989	138
Table 5.3	Botanical composition of feed (% DM) and oesophageal extrusa (% contact) of grazing stags during winter and spring 1989	139
Table 5.4a	Organic matter digestibility (OMD), organic matter (OM), total nitrogen concentration (N) and calculated concentrations of metabolisable energy (M/D values) of feed on offer and oesophageal extrusa of grazing stags during winter (June-August) 1989	140
Table 5.4b	Organic matter digestibility (OMD), organic matter (OM), total nitrogen concentration (N) and calculated concentrations of metabolisable energy (M/D values) of feed on offer and oesophageal extrusa of grazing stags during spring (September-November) 1989	141
Table 5.5	Carrying capacity (animals/ha/day) during winter and spring 1989	141
Table 5.6	Liveweight gain (g/d), voluntary feed intake (g DM/d) and percentage of stags attaining slaughter weight (92 kg) by November 30, 1989	142
Table 5.7	Total VFA (m mole/l), the molar proportions of acetate, propionate, butyrate, and valerate and ammonia concentrations in the rumen fluid of red deer stags grazing pasture or Moata swards, during spring	144
Table 5.8	Plasma concentrations of LH and testosterone in red deer stags during October and November 1989	150
Table 5.9	Effect of vaccination on stag weaning weight	150

Table 5.10	Liveweight gain (g/day) of yearling red deer stags during winter and spring (1989) and carcass data	151
Table 5.11	VFI (g/day) of grazing red deer stags during winter and spring of 1987 and 1989	155
Table 6.1	Liveweight gain (g/day) of weaner red deer stags over winter and spring	163
Table 6.2	Percent of red deer stags grazing perennial ryegrass/white clover pasture at high DM allowance that attained slaughter weight by 12 months of age (November 30)	165
Table 6.3	Liveweight gain (g/day) and percentage of stags attaining slaughter LW (92 kg) at 12 months of age for red deer stags grazing Moata annual ryegrass swards 1987-89	166
Table 6.4	Direct drilling methods of Moata swards and the carrying capacity (animals/ha/day) on high Moata and PRG allowances during 1987, 1988 and 1989	167
Table 6.5	The LWG (g/day), feed on offer and weaning weight of red deer calves grazing perennial ryegrass/white clover or pure red clover swards during summer (December 1989 - February 1990; 61 days) at Massey University deer research unit	168
Table 6.6	The LWG, feed on offer and final LW of weaner red deer stags grazing perennial ryegrass/white clover or red clover swards during autumn at Massey University deer research unit	169
Table 6.7	Seasonal ME requirement and VFI of young (3-15 months) red deer stags (Source: Fennessy and Milligan 1987; Ulyatt <i>et al</i> 1980)	171

Table 6.8	Mean proportion of sward components of feed on offer (% DM) and oesophageal extrusa (% contact) and digestibility of OM for grazing red deer stags over winter and spring (1989)	172
Table 6.9	Mean proportion (DM) of sward components and digestibility of OM in oesophageal extrusa from goats, sheep and calves grazing similar ryegrass white clover swards (Source: Hughes <i>et al</i> 1984)	172
Table 6.10	Age of stags at primary vaccination against melatonin hormone and anti-melatonin antibody titres raised	176
Appendix		
Table 1	Level of feed on offer (kg DM/ha) during winter (June-August) and September-November) 1988	181

LIST OF FIGURES

		PAGE
Figure 1.1	Seasonal variations in venison schedule (Dollar/Kg), prime 50-70 Kg carcass during 1988 and 1989	27
Figure 2.1	Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high and medium DM allowance	43
Figure 2.2	Pattern of anti-melatonin antibody titre development in the red deer	46
Figure 2.3	Plasma prolactin concentrations of weaner red deer stags immunised with melatonin antigen and vehicle only and the non-immunized (control) group	47
Figure 3.1a	The proportion of Moata annual ryegrass on offer in the grazed pastures	66
Figure 3.1b	The proportion of perennial ryegrass on offer in the grazed pastures	67
Figure 3.1c	The proportion of dead matter in the grazed pastures	68
Figure 3.1d	The proportion of other species in the grazed pastures	69
Figure 3.1e	The proportion of white clover on offer in the grazed pastures	70
Figure 3.2a	Seasonal variations in total N concentration of feed on offer	74
Figure 3.2b	Seasonal variations in OM digestibility of feed on offer	75
Figure 3.3a	Seasonal distribution of pasture yield (Kg DM/day) at Massey University deer research unit during the 1988 season	78

Figure 3.3b	Seasonal distribution of pasture yield (Kg DM/day) at Massey University deer research unit during the 1988 season	79
Figure 3.4	Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high (10 cm) and medium (5 cm) DM allowance	81
Figure 3.5	Pattern of anti-melatonin antibody titre development in the red deer	83
Figure 3.6	Plasma prolactin concentrations of weaner red deer stags immunized with melatonin antigen and the non-immunized (control) group	85
Figure 4.1	Pattern of anti-LHRH antibody titre development in the red deer	103
Figure 4.2a	Plasma concentrations of LH in immunized (n = 4) and non-immunized (n = 5) weaner red deer stags against LHRH	104
Figure 4.2b	Plasma concentrations of testosterone in immunized (n = 4) and non-immunized (n = 5) weaner red deer stags against LHRH	105
Figure 4.3a	Seasonal liveweight pattern of vaccinated (n = 5) and non-vaccinated (n = 5) yearling red deer stags against LHRH	106
Figure 4.3b	Seasonal liveweight pattern of immunized (n = 4) and non-immunized (n = 5) yearling red deer stags against LHRH	107
Figure 4.4	Pattern of anti-melatonin antibody titre development in the red deer stags	110
Figure 4.5a	Plasma concentrations of LH in immunised (n = 6) and non-immunized (n = 7) yearling red deer stags against melatonin	111

Figure 4.5b	Plasma concentrations of testosterone in immunized (n=6) and non-immunized (n=7) yearling red deer stags against melatonin	112
Figure 4.5c	Plasma concentrations of prolactin in immunized (n=6) and non-immunized (n=7) yearling red deer stags against melatonin	113
Figure 4.6a	Seasonal liveweight pattern of vaccinated (n=8) and non-vaccinated (n=7) yearling red deer stags against melatonin	114
Figure 4.6b	Seasonal liveweight pattern of immunized (n=6) and non-immunized (n=7) yearling red deer stags against melatonin	115
Figure 5.1a	The proportion of moata annual ryegrass on offer in the grazed pastures	133
Figure 5.1b	The proportion of perennial ryegrass on offer in the grazed pastures	134
Figure 5.1c	The proportion of dead matter in the grazed pastures	135
Figure 5.1d	The proportion of other species in the grazed pastures	136
Figure 5.1e	The proportion of white clover on offer in the grazed pastures	137
Figure 5.2	Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high DM allowance	143
Figure 5.3	Patterns of anti-melatonin antibody titre development in red deer stags	146
Figure 5.4	Plasma prolactin concentrations of weaner red deer stags immunized and non-immunized (control) against melatonin	147

Figure 5.5	Seasonal liveweight patterns of weaner red deer stags vaccinated with melatonin antigen	148
Figure 5.6	Seasonal liveweight patterns of weaner red deer stags immunized against melatonin (Responders to anti-melatonin vaccinations only)	149
Figure 6.1	Seasonal liveweight patterns of yearling red deer stags vaccinated with LHRH antigen	174
Appendix		
Figure 1	Curves for parallelism test between cervine plasma and ovine reference standard for the validation of prolactin assay for use with red deer plasma	180
Appendix		
Figure 2	Mean sward surface heights grazed by weaner red deer stags during the 1988 season	181

LIST OF ABBREVIATIONS

ARH-291	Anti-melatonin vaccine (5-methoxy-tryptamine hemisuccinamide: Human serum albumin conjugate)
CW	Carcass weight
c.v.	coefficient of variation
CRD	Controlled release device
Cr	Chromium
Cr ₂ O ₃	Chromium sesquioxide
C.S.I.R.O.	Commonwealth Scientific and Industrial Research Organisation
cv	Cultivar
d	day
DEAE-dextran	Diethylaminoethyl dextran
DLWG (LWG)	Daily liveweight gain
Dm	Dead matter
DM	Dry matter
DMI	Dry matter intake
DOMD	Digestible organic matter digestibility
DSP	Deer slaughter premises

E	Expected plasma prolactin concentration
FCA	Freund's complete adjuvant
FIA	Freund's incomplete adjuvant
FO	Faecal output
G	Guage
GH	Growth hormone
GHRH	Growth hormone releasing hormone
GIB	New Zealand Game Industry Board
GLM	General linear models procedure
GR	Tissue depth over the 12th rib, 16 cm from the mid line
ha	Hectare
HCl	Hydrochloric acid
HSA	Human Serum Albumin
IGF-1	Insulin-like growth factor-1
i.m.	Intramuscular
IR	Internal recovery rate
i.v.	Intravenous
$\text{kg}^{0.75} (\text{LW}^{0.75})$	Metabolic liveweight

L	litre
LH	Luteinizing hormone
LHRH	Luteinizing hormone releasing hormone
LSM	Least squares means
LW	Liveweight
LWG	Daily liveweight gain
MAR	Moata annual ryegrass
M/D	Nutritive value
ME	Metabolisable energy
MEI	Metabolisable energy intake
MJ	Megajoule
MR	Maintenance requirements
N	Nitrogen
Na	Sodium
NaCl	Sodium chloride
NH ₃	Ammonia
NHPP	National Hormone and Pituitary Programme
NIADDK	National Institute of Arthritis, Diabetes, Digestive and Kidney Diseases

CHAPTER 1

A REVIEW OF THE LITERATURE

1.1 INTRODUCTION

This chapter will review grazing, nutritional and hormonal literature concerning deer, with particular emphasis on the red deer (Cervus elaphus). Use will be made of sheep data for comparative purposes, as extensive research has been carried out over the past thirty years with this species. Whilst deer have been farmed for the past two decades, sheep have been domesticated, fed and genetically selected by man for about 6000 years. Reference will also be made to cattle and to lesser known deer species such as North American wapiti and reindeer.

Research on farmed deer started in New Zealand in 1968 at Lincoln University, Canterbury and in 1973 at the Invermay Agricultural Research Centre (Drew 1976). The very early research was to study the feasibility of intensive husbandry of red deer. A reasonable amount of research has been done with farmed deer in New Zealand and elsewhere since then, notably in nutrition (Blaxter et al 1974; Fennessy et al 1981; Kay and Staines 1981; Domingue 1989) and reproduction (Lincoln 1971; Fletcher 1974; Asher and Adam 1985). Most of the nutritional work has been done indoors, where energy requirement estimates have been made and relationships with outdoor conditions have been derived for red deer (Fennessy et al 1981). There is little or no information in the literature on deer nutrition under grazing conditions. This aspect needs to be researched thoroughly, and systems developed for the efficient production of venison from grazing deer.

1.2 PHYSIOLOGICAL CONTROL OF SEASONAL VOLUNTARY FOOD INTAKE (VFI) AND LIVELWEIGHT GAIN IN DEER

1.2.1 **Seasonal patterns of VFI and growth in deer**

Red deer exhibit very marked seasonal patterns of VFI and liveweight change, with both VFI and liveweight gain being high over spring-summer and low in winter (Blaxter et al 1974, 1988; Pollock 1975; Fennessy 1981; Kay and Staines 1981; Suttie and Kay 1985; Suttie et al 1989). Intermediate growth rates occur over the calves' first autumn (Moore et al 1988). The seasonal cycles of body condition and VFI are most evident in entire stags, and are less pronounced in non-pregnant hinds, castrate stags and young stags (Blaxter et al 1974; Kay 1979; Suttie and Simpson 1985). Similar cycles of dry matter intake (DMI) and liveweight

gain have been reported in other temperate and boreal species: the reindeer, Rangifer tarandus (Ryg and Jacobsen 1982), the moose, Alces alces (Gasaway and Coady 1974), the North American wapiti, Cervus elaphus canadensis (Watkins and Hudson 1984), and the roe, Capreolus capreolus (Drozd et al 1975). The VFI cycle was first reported in mule deer, Odocoileus hemionus (Wood et al 1962) and white-tailed deer, Odocoileus virginianus (Cowan and Long 1962). Whilst this seasonal pattern is less marked in amplitude in domesticated sheep (Simpson et al 1984; Domingue 1989), it is very evident in wild sheep such as the Soay breed (Lincoln and Davidson 1977; Kay 1985).

The seasonal change in daylength acts as the main environmental cue which controls the annual cycle of VFI and also the levels of circulating testosterone (McMillin et al 1984; Mirachi et al 1975), the cycle of antler growth (Brown et al 1978; Goss 1983b) and the timing of the breeding season (Marshall 1937; Pollock 1975; Lincoln 1985). Deer, like sheep, have endogenous seasonal rhythms induced by photoperiod. The pineal hormone, melatonin, acts as the time-keeper that entrains the seasonal rhythms to the photoperiod. Reports on related deer species have shown that the response to daylength is dependent on a functionally active pineal gland (Plotka et al 1981; Bubenik 1983; Lincoln 1983, 1985). Results published from studies with sheep have shown that it is the daily pattern of melatonin secretion from the pineal gland that acts as the endocrine signal that relays the effects of photoperiod on reproduction and other seasonal characteristics (Rollag et al 1978; Lincoln and Almeida 1981; Bittman et al 1983). Any interruption of this process will lead to changes in circadian and circannual rhythmicity (Ralph et al 1975; Thorpe and Herbert 1976).

The deer have timed their seasonal activities with high nutrient demands to occur in the summer, when high quality food is available in abundance. Activities such as increased VFI and body weight, antler growth, parturition and lactation and the early phase of calf growth all occur during early spring and summer. Melatonin (Lincoln 1983) and other related hormones that control these seasonal activities all show seasonal cycles in their pattern of release and plasma concentration (Lincoln and Kay 1979; Barrell et al 1985; Loudon et al 1989). The appetite cycle may be regarded as a response to the sum of the nutrient demands arising from the other seasonal cycles, rather than a primary response to changing daylength. Increased appetite is thus a consequence rather than a cause of growth and fattening (Barry et al 1990).

1.2.2 Seasonal patterns of hormonal secretion in deer

1.2.2.1 Luteinizing hormone (LH)

Seasonal changes in the secretion of the LH have been investigated in roe deer (Schams and Barth 1982), white-tailed deer (McMillin *et al* 1974; Mirarchi *et al* 1978), red deer (Lincoln and Kay 1979; Suttie *et al* 1984), fallow deer (Asher *et al* 1989) and sheep (Barrell and Lapwood 1979).

LH secretion in the sheep (Katongole *et al* 1974; Schanbacher and Ford 1976) and the red deer (Lincoln and Kay 1979; Suttie *et al* 1984) is episodic. In the red deer transitory peaks in the blood levels of LH occur every few hours, and the overall pattern changes during the year. The episodic peaks in levels of LH are most apparent during spring/summer, when the testes are enlarging prior to the rut. At this time, discrete, high-amplitude LH peaks occur in the hormone profiles. Closer to the rutting season in autumn, the frequency of the episodic peaks in the blood level of LH increases while the amplitude decreases, and it becomes progressively more difficult to see the individual LH pulses (Lincoln 1985). The seasonal change in the episodic pattern of LH secretion apparently dictates the changes in activity of the testes, and the occurrence of pulses of LH of increasing frequency provides the stimulus during summer and autumn to prepare for the mating season.

In intact stags plasma LH concentrations are maximal during mid/late summer during the phase of testicular redevelopment prior to the rut season (Lincoln and Kay 1979; Fennessy *et al* 1985; Asher *et al* 1989a), and are minimal during the winter following the rut. While the circulating levels of LH in the intact stag changed with season, there was no clear cycle in the castrated animals (Lincoln 1979). Mean concentrations and pulse frequency of LH in castrated deer were higher than for intact animals at all times of the year (Lincoln and Kay 1979; Asher *et al* 1989a). The synthesis and release of LH by the anterior pituitary gland is regulated by luteinising hormone releasing hormone (LHRH), secreted by the hypothalamus (Fennessy *et al* 1985; Lincoln 1985). Studies with sheep have shown that the release of LHRH is pulsatile, and there is a close relationship between the episodic peaks in the concentration of LHRH in hypothalamic-pituitary portal blood and the episodic peaks in the level of LH in the peripheral blood (Clarke and Cummins 1982; Levine *et al* 1982). There have been no equivalent studies on LHRH secretion in deer, however, the mechanisms are assumed to be similar. The way in which environmental factors influence the release of LHRH from the hypothalamus is not very well understood, although there is evidence that

the pineal gland is involved in the photoperiodic control of reproduction through its secretion of melatonin. Melatonin is thought to influence the group of compounds known as the "pulse generators" which regulate the release of LHRH. Lincoln and Short (1980) reported that testicular development of rams in response to a decreasing photoperiod is caused by an increased frequency of LHRH release from the hypothalamus and subsequent change in gonadotrophin levels.

1.2.2.2 Testosterone

In seasonal breeders like deer it is the seasonal changes in secretion of gonadotrophic hormones from the anterior pituitary gland which regulate the activity of the gonads and dictate the seasonal pattern of fertility. In the female this allows for ovulation to occur at a specific time of the year, while in the male there is a corresponding seasonal cycle in the activity of the testes (Lincoln 1985). During the mating season in September and October (N. hemisphere) both the spermatogenic (Hochereau-de Reviers and Lincoln 1978) and androgenic (Lincoln 1971) functions of the testes are at a maximum, and the testes are about 5 times larger than in the sexually quiescent period in April, May and June (Lincoln and Kay 1979). Generally the changes in testicular size are in phase with the pattern recorded for plasma testosterone levels, being maximal from September to November (N. hemisphere) coinciding with the time of peak testicular activity and the mating season (Lincoln and Kay 1979). In New Zealand, the testosterone annual pattern in the red deer consists of low values throughout winter and spring followed by an increase during late December which eventually rises to peak levels in April (Barrell *et al* 1985; Fennessy *et al* 1985). This seasonal pattern in plasma concentrations of testosterone was, however, delayed by 1 month in pinealectomised white-tailed deer (Snyder *et al* 1983). Studies of seasonal changes in plasma levels of testosterone have also been carried out in males of other species such as reindeer (Leader-Williams 1979), reindeer and caribou (Whitehead and McEwan 1973), white-tailed deer (McMillin *et al* 1974; Bubenik *et al* 1977; Brown *et al* 1978), Columbian black-tailed deer (West and Nordan 1976), roe deer (Sempéré and Boissin 1981; Sempéré and Lacroix 1982), fallow deer (Asher *et al* 1989) and rams (Barrell and Lapwood 1979).

The seasonal cycle of casting and re-growth of the antler is believed to be dictated by changes in testosterone: casting and re-growth occurring in the spring and summer when the testosterone levels are very low during the non-mating season, and maturation of the hard antler occurring in the autumn when the testosterone levels increase before the mating season (Wislocki *et al* 1947; Lincoln *et al* 1970; Lincoln 1971; Lincoln *et al* 1972; Bubenik *et al*

1975; Lincoln and Kay 1979; Suttie et al 1984). Evidence that the seasonal changes in testosterone secretion is directly linked to the changes in the various male characteristics and behaviour comes from experiments involving castration and the administration of testosterone. Studies with adult red deer stags have shown that following castration the accessory sex glands became small, the antlers remained in velvet, and there was no seasonal development of the other male secondary sexual characteristics or rutting behaviour (Lincoln 1971). However, when castrated red deer were implanted with testosterone, the velvet was cleaned from the antlers and the animals developed all aspects of rutting behaviour (Lincoln et al 1972). The effect of castration and testosterone therapy on the antler cycle has been described for white-tailed deer (Wislocki et al 1947), roe deer (Bramley 1970), and sika deer (Goss 1968).

There is evidence of rhythm between the seasonal testosterone cycles and VFI and weight loss in the red deer stags. Suttie and Kay (1985) reported that troughs of food intake on a decreasing photoperiod occurred at or slightly after peaks of testosterone. This is in agreement with other reports that adult red deer stags experience marked anorexia during the rut season (Lincoln 1971; Pollock 1975) with a resultant loss of body weight of as much as 25%; this coincides with the time of the year when the plasma testosterone concentration is at a maximum. The rut induced weight loss is superimposed on the normal seasonal cycle of VFI and body weight change. There was also a report that during late September and early October (N. hemisphere), coinciding with testosterone peaks, the intact young male reindeer lost weight, whereas the weight of the castrates was stable. However, the castrates gained less weight than the intact animals during summer, and during late summer food intake was lower in the castrates (Ryg and Jacobsen 1982).

1.2.2.3 Prolactin

The seasonal changes in blood levels of prolactin have been measured in red deer (Brown et al 1979; Suttie et al 1984; Barrell et al 1985), roe deer (Schams and Barth 1982), white-tailed deer (Mirarchi et al 1978, Bubenik et al 1985) and rams (Brown et al 1979; Simpson et al 1984). In each of these species, peak levels of prolactin occur in spring and summer. Brown et al (1979) reported peak values of prolactin concentration in the red deer stags (100 ng/ml) at maximum daylength and lowest values (5 ng/ml) during declining daylength. A similar pattern was recorded for the rams but with higher prolactin concentrations (150 and 20 ng/ml) during the respective seasons. This seasonal pattern of

prolactin levels was altered by pinealectomy in the white-tailed deer (Schulte *et al* 1981; Snyder *et al* 1983). Studies with the sheep and red deer have shown that melatonin feeding significantly depresses the serum level of prolactin (Kennaway *et al* 1982; Milne *et al* 1990).

Prolactin secretion is thought to be under inhibitory control by the hypothalamus, possibly through dopamine, unlike the stimulatory system for the gonadotrophic hormones through LHRH. Since the temporal relationships between the seasonal changes in prolactin and gonadotrophin secretion vary between species of deer, it is probable that the two control systems function independently (Lincoln 1985).

The function of the increased prolactin secretion during summer is not very clear, but it was thought that prolactin might play a role in influencing the seasonal cycle in growth of the summer coat (Allain *et al* 1981), growth of the antlers (West and Nordan 1976a,b), and changes in appetite (Suttie 1979; Ryg and Jacobsen 1982). Because of the association between high plasma concentrations of prolactin and long day length, high food intake, increased weight gain and antler growth, prolactin has been implicated as a hormone mediating the effects of photoperiod, as entrained by melatonin on VFI (Forbes *et al* 1979; Snyder *et al* 1983; Suttie and Kay 1985). Eisemann *et al* (1984) tested this hypothesis in growing lambs by combining daylength treatments with a course of either bromocryptine (a dopamine agonist and thus an inhibitor of prolactin release) or prolactin injections. They reported higher food intake for the lambs on long days rather than short days, reduced VFI in the long day animals due to the bromocryptine administration, but the prolactin administered to the lambs on short days did not cause any increase in VFI. Therefore there was no clear evidence supporting this hypothesis in sheep. Daily injections of domperidone to increase the plasma concentration of prolactin in winter (Loudon *et al* 1986), or daily injections of bromocryptine to suppress plasma prolactin concentration in summer (Curlewis *et al* 1988), have been carried out to determine whether prolactin has a mediating role in the seasonal cycle of VFI in deer. There was no clear evidence that prolactin mediates the increase in VFI during spring/summer in deer. Milne *et al* (1990) also reported no association between increased plasma prolactin concentration and changes in VFI in the red deer. However, Ryg and Jacobsen (1982) reported that injections of prolactin to yearling male reindeer during winter were associated with increases in VFI and weight gain.

Thus although seasonal variations in appetite and prolactin secretion appeared subject to the same photoperiodic control, the changes in food intake were not clearly associated with prolactin.

1.2.2.4 Growth hormones (GH) and Insulin-like Growth Factor-1 (IGF-1)

Seasonal secretion of GH has been investigated in the red deer (Barrell *et al* 1985; Suttie *et al* 1989), Norwegian red deer (Ryg and Langvatn 1982), white-tailed deer (Bubenik *et al* 1975; Bahnak *et al* 1981), moose (Ryg 1982) and reindeer (Reingberg *et al* 1978; Ryg and Jacobsen 1982). The secretion of GH was highest during the spring for these species, although Barrell *et al* (1985) recorded an elevation of GH in adult red deer stags during winter. Suttie *et al* (1989) reported that the GH secretion was both seasonal and pulsatile in red deer with the pulse frequency and amplitude being highest during spring, resulting in a high mean level of GH circulating in the plasma. Seasonal patterns of GH secretion have not been reported in domestic ruminants (Suttie *et al* 1989), but it is known that the secretion of GH is pulsatile in cattle (Anfinson *et al* 1975; Breier *et al* 1986) and sheep (Davis *et al* 1977). Plasma concentration of IGF-1 in the red deer is seasonal and peaks in the spring, one month after the peak of GH level (Suttie *et al* 1989). Growth hormone is released in a pulsatile manner from the pituitary gland under the control of growth hormone releasing hormone (GHRH; stimulatory) and somatostatin (inhibitory) from the hypothalamus (Tannenbaum and Ling 1984). GH influences tissue growth mainly through IGF-1 secretion from the liver (Daughaday *et al* 1972).

Suttie *et al* (1989) observed positive and significant correlations between GH and IGF-1 concentrations and liveweight gain and antler growth rate in the red deer stags. They suggested that the spring and summer seasonal acceleration of liveweight gain and antler development in stags could be a consequence of high winter/early spring GH pulse frequency and amplitude resulting in increased concentrations of IGF-1. On the other hand, Ryg (1982) reported that in the male moose, there was often a marked increase in GH levels in April or May (N. hemisphere), prior to the onset of rapid weight gain, but this was not consistent, and otherwise there was no correlation between GH levels and weight gain. This is in agreement with the observation made by Barrell *et al* (1985) on red deer stags.

Suttie *et al* (1985) reported that plasma levels of IGF-1 were significantly elevated during the velvet antler growing phase relative to the other phases of pedicle and first antler development and that a strong positive correlation existed between antler growth rate and circulating levels of IGF-1. Suttie *et al* (1988) demonstrated that the antler is a target organ for IGF-1, therefore showing the positive role the IGF-1 plays in the initiation of growth of antler.

1.3 HORMONAL MANIPULATION OF GROWTH, REPRODUCTION AND VFI IN DEER

1.3.1 **Melatonin administration**

Deer, like sheep, are stimulated to breed by short daylength and there is considerable evidence from studies with sheep for the role of the pineal hormone, melatonin, as the primary mediator of the effects of photoperiod on reproduction (Lincoln and Almeida 1981; Bittman *et al* 1983). Plasma levels of melatonin are elevated during the hours of darkness (Arendt *et al* 1981; Lincoln *et al* 1981) and this nocturnal rise is readily mimicked during daylight hours by exogenous melatonin administration. Daily melatonin administration has been an effective alternative treatment to shortened photoperiod for lowering serum prolactin concentration in ewes (Kennaway *et al* 1982) and for inducing reproductive function in anoestrous ewes when given orally (Kennaway *et al* 1982; Arendt *et al* 1983). In addition to advancement of oestrus in the ewe, feeding melatonin also caused an increase in ovulation rate (Kennaway *et al* 1984b). Implantation of melatonin, either subcutaneously in rams or ewes (Lincoln and Ebling 1985; English *et al* 1985) or intra-vaginally (Nowak and Rodway 1984) following a period of long days, led to early testicular growth or oestrous cycles, a reduction in plasma prolactin concentration and moulting of the body coat. Lincoln and Almeida (1981) and Lincoln and Ebling (1985) found that, if implants are left *in situ* after one breeding season, or if implantation is performed in short-days, animals become 'blind' (photorefractory) to the following session of short-days.

Similarly, oral administration of melatonin advanced antler mineralisation, rutting behaviour and pelage changes in white-tailed deer (Bubenik 1983; Bubenik and Smith, 1985). Melatonin administration in the red deer has also been investigated. Oral melatonin treatment (5 and 10 mg melatonin adsorbed onto a feed pellet given daily in the afternoon to the hinds and stag respectively) has been shown to advance the onset of oestrous in hinds and rutting in the stag by 5 weeks and 2 months respectively (Adam and Atkinson 1984). Adam *et al* (1986) also showed that oral melatonin administration was equally effective in advancing the breeding season in both lactating and non-lactating hinds, and that it had no effect on the pattern of lactation. They also reported that melatonin advanced puberty in prepuberal yearling hinds and that the early induced breeding season was normal and fertile.

Webster and Barrell (1985) reported that melatonin injection in red deer hinds caused premature moulting of summer pelage, reduced serum prolactin concentration and advanced

mating and calving dates. It has been shown that melatonin given in subcutaneous implants induced early rutting in stags (Lincoln *et al* 1984). As this might prove a potentially simpler manipulative technique than timed daily feeds for farm animals at pasture, the effects of melatonin implantation into hinds has also been investigated. Subcutaneous implants (18 mg melatonin) which continuously release melatonin are being used in New Zealand to advance the time of calving in deer. When administered at 30 day intervals for period of 60-120 days over late spring/summer, these implants advance the mean dates of mating and calving by 11-35 days (Asher *et al* 1988; Fisher *et al* 1988; Wilson *et al* 1988), without depressing liveweight in adult females. In another study, Domingue (1989) showed that VFI was depressed by 10-15% and heart rate by 22% during 180 days after initial implantation, after which both criteria declined during winter in control animals and rose in implanted deer to be greater than the controls, thus further supporting the concept that melatonin entrains seasonal rhythms.

Both daily melatonin feeding and melatonin implants are capable of advancing the breeding season of yearling red deer hinds, with both methods appearing reliable once the problem of feed acceptance is overcome (Webster *et al* 1986).

The basic principles behind advancing the calving season of farmed deer in New Zealand is to better align the high energy demands of lactation with the season of greatest feed availability and quality. This should allow for better utilisation of the pasture resource and increase dam milk yields, resulting in greater calf growth rates, increased weaning weights and earlier attainment of acceptable carcass weights. This could be an alternative approach towards achieving the goal of early venison production.

Well grown hinds may breed for the first time at about 16 months of age (yearling) but usually conceive later in the year than older hinds (Hamilton and Blaxter 1980). The resulting later calving dates have their disadvantages and these are outweighed by the advantage of a hind producing her first calf at the earliest possible age to maximise her lifetime reproductive performance. The use of exogenous melatonin to advance puberty in young hinds therefore has considerable potential.

1.3.2 Active immunisation against melatonin

The annual changes in daylength that regulate seasonal reproductive activity in seasonal breeding animals are mediated by the pineal gland hormone, melatonin. However,

the persistence of seasonality (asynchronous) after pinealectomy in the Tammar wallaby (McConnell *et al* 1985), white-tailed deer (Brown *et al* 1978; Snyder *et al* 1983) and sheep (Barrell and Lapwood 1979; Lincoln and Forbes 1984) and after superior cervical ganglionectomy in ram (Lincoln 1979) suggests that these animals inherently possess an endogenous annual rhythm, but that this is entrained to photoperiod by melatonin. One possibility for reducing the seasonal increase in free plasma melatonin concentration and perhaps reducing the autumn/winter depressions in body growth, VFI and reproductive cycles in the short-day breeders, is by active immunisation against melatonin. Active immunisation against endogenous melatonin using a modified form, melatonin conjugated to a foreign protein (antigen), along with an immunological adjuvant was aimed at stimulating production of melatonin-binding antibodies. Melatonin antibodies thus present in the body would bind and inactivate the endogenous hormone and thus prevent its biological action. This might create a state of free-running endogenous rhythm in the animals, unentrained to photoperiod through absence of free melatonin. Experiments with rats have shown that animals with free-running endogenous rhythm have greater performance (J.M. Suttie, pers. comm.). McConnell *et al* (1987) reported that active immunisation against melatonin in Tammar wallaby had no effect on the seasonal breeding cycles. Abolition of the daily pattern of melatonin secretion by active immunisation has been attempted in mature rams (Lincoln and Almeida 1981) and ewes (Arendt 1986) but they did not observe any effect on reproductive activity. Immunisation of red deer calves at birth, however, increased body weights at the end of winter (9-11 and 16-20 months) by 7-10% (Duckworth and Barrell 1989), and did not observe any effect of immunisation on calving date of the hinds, casting date and time of stripping of the antlers in the stags or on pelage changes in deer of either sex. No endocrine changes or anti-melatonin titres were reported.

1.3.3 Active immunisation against LHRH

The synthesis and release of LH and FSH by the anterior pituitary gland is regulated by luteinising hormone releasing hormone (LHRH), secreted by the hypothalamus. LHRH is synthesised by neurones in the anterior region of the hypothalamus and is released into the local portal blood system supplying the anterior pituitary gland (Lincoln 1985). Studies with ewes (Clarke *et al* 1978) and red deer stags (Lincoln *et al* 1982 and 1984) illustrated the way in which LHRH acts as the key hormone in control of seasonal breeding, and it is the increased release of LHRH in summer and autumn which provides the impetus to the reproductive system culminating in full sexual function for the rutting season. When LHRH

activity is blocked by active immunisation there is no breeding season (Lincoln 1985). Clarke *et al* (1978) reported that ewes immunised against LHRH failed to show oestrus or ovulate, and had significantly lower levels of plasma LH and higher levels of prolactin than control animals. Lincoln *et al* (1982) showed that male red deer actively immunised against LHRH cast their antlers prematurely, and that the animals with the highest titre developed new antlers that resembled those of a castrate, had reduced testes size, reduced plasma levels of testosterone and showed no rutting behaviour in the autumn. Therefore, the neutralisation of LHRH by immunisation produces temporary physiological castrates. The immunised stag that had the lowest antibody titre retained its hard antlers throughout the autumn and winter, as did the non-immunised controls.

1.4 PRINCIPLES OF NUTRITIVE VALUE OF FORAGES

The ryegrasses (*Lolium* spp.) and white clover (*Trifolium repens*) are the major improved pasture species sown in New Zealand (Ulyatt and Macrae 1974). They are normally sown as a mixed pasture (ie sward), with perennial ryegrass (*Lolium perenne*) comprising 75-85% of the sward whilst white clover comprises 15-25% (Barry and Wilson 1990). The higher proportions of clover occur in spring. The nutritional quality of these species has been assessed by many workers (Hight and Sinclair 1965; Grimes *et al* 1967; Ulyatt 1971) using liveweight gain (LWG) from sheep as a criterion of animal response. This is referred to as the feeding value, ie animal production response to the total herbage consumed.

The feeding value is higher for white clover than for perennial ryegrasses, with annual ryegrasses and other legumes being intermediate (Table 1.1). The superiority of legumes and annual ryegrasses over perennial ryegrasses may be due to difference in VFI and critical particle size theory, efficiency of nitrogen (N) utilisation, and ME utilisation. Voluntary feed intakes are much lower for sheep fed fresh perennial ryegrass than those fed fresh legumes (Ulyatt 1971; Ulyatt *et al* 1986). Perennial ryegrass has a higher content of poorly digested structural carbohydrate than white clover (30% vs 15%), and a higher ratio of structural to soluble carbohydrate (Ulyatt 1981). The rate at which long feed particles can be broken down to the critical size required to leave the rumen (< 1 mm in sheep, goats and deer; Domingue 1989; < 2 mm in cattle, Waghorn and Barry 1987) is important in regulating digestion in the rumen. Perennial ryegrass has a relatively low fermentation rate and in

addition, because of its anatomical structure, is very resistant to mechanical and microbial breakdown. The more difficult it is to reduce plant material to a small particle size, the longer it will take to move out of the rumen; the net effect being less room in the rumen for incoming feed and therefore reduced VFI.

Table 1.1 Comparative feeding value in terms of sheep liveweight gain of some pasture species grown in New Zealand. All values relative to white clover, 'Grasslands Huia'. (Source: Waghorn and Barry 1987)

	Comparative feeding value	Number of studies
White clover		
'Grasslands Huia'	100	14
Other legumes, annual ryegrasses and short-rotation ryegrass		
Lotus pedunculatus 'Grasslands Maku'	84	6
Sainfoin, 'Melrose'	84	2
Italian ryegrass 'Grasslands Paroa'	83	1
Lucerne, 'Wairau'	82	10
Short-rotation ryegrass 'Grasslands Manawa'	77	11
Red clover, 'Grasslands Hamua'	71	5
Red clover, 'Red West'	69	2
Red clover, 'Grasslands Pawera'	65	4
Perennial ryegrass and other grasses		
Timothy, common	67	5
Perennial ryegrass, 'Grasslands Ariki'	58	2
Perennial ryegrass, 'Grasslands Ruanui'	52	16
Browntop, spring	52	1
Browntop, summer	43	1

The efficiency of digestion of nutrients varies, with digestion in the rumen and caecum by microbial fermentation occurring with a loss of approximately 25% of digestible energy as methane and heat (Ulyatt 1981). In addition, the fermentation of protein in the rumen or caecum causes loss of nitrogen as ammonia, and when protein is digested in the small intestine there is little loss of nitrogen. Thus any shift of absorption from the rumen to the small intestine should result in increased efficiency of utilisation of both protein and the whole diet. Ulyatt (1981) reported that less nitrogen was lost from the rumen of sheep fed white clover than those fed perennial ryegrass. This could be explained by the fact that white clover has a lower retention time in the rumen (ie a faster rate of passage) than perennial ryegrass (Cruickshank *et al* 1985), resulting in more nutrients passing into the small intestine for digestion and less rumen fermentation taking place. The result was more efficient nitrogen utilisation by animals fed white clover compared with those fed perennial ryegrass. Another factor supporting the superior feeding value of white clover and the growth of animals feeding on it, is the efficiency of ME utilisation. Rattray and Joyce (1974) showed that efficiency of ME utilisation for maintenance (k_m) and gain (k_g) was higher for lambs fed fresh white clover than those fed fresh perennial ryegrass, and was intermediate for those fed 50:50 grass/white clover.

1.4.1 Seasonal patterns of pasture production and quality

The seasonal patterns of DM production of ryegrass/white clover pastures has been measured extensively throughout New Zealand (Radcliffe 1974, 1975). Patterns of pasture production fall into four major environmental categories; warm humid (Northland), summer dry (Canterbury, Manawatu, Hawke's Bay and Wairarapa), cold humid (Southland) and cold dry (Central Otago) (Korte *et al* 1987). Pasture production measurements done over a period of five years at Masterton on the Wairarapa plains (Radcliffe 1975) showed seasonal production (kg DM/ha/day) ranges for spring (September-November) 34.7-73.2, summer (December-February) 7.6-34.4, autumn (March-May) 14.1-32.5 and winter (June-August) 15.9-38.3. This reflects a typical seasonal pattern of pasture production in the summer-dry areas of New Zealand, with a high pasture production occurring during spring. Peak production occurs in November as a result of a rise in the soil temperature, followed by a decline in production in summer as a result of the hot and dry conditions. The least pasture production occurs during winter and summer. Korte *et al* (1987) reported differences in pasture production between pasture species during winter, reflecting their different responses to temperature. Annual ryegrasses show better winter and early spring growth

than perennial ryegrass, whilst grasses generally have greater pasture production than clovers during winter (Suckling 1960).

Seasonal changes in pasture composition, plant maturity and grazing management influence pasture quality, intake and animal performance. Table 1.2 shows the seasonal changes in nutritive value of pasture, with the value being highest (12.0 MJ ME/kg DM) for spring (short) pasture and lowest (8.0 MJ ME/kg DM) for summer (dry stalky) feed. As grass matures the highly digestible leaves become a smaller and less digestible fraction of the whole plant. The less digestible stem increases as a proportion of the plant and also declines in digestibility as it matures. Vegetative Italian ryegrass (green leaf) and white clover (pre-flowering) had digestibilities of 64% and 82% DM respectively and declined to 58% and 70% DM, respectively, as they mature. Legumes differ from grasses in the effect of maturity on their structural and chemical composition and digestibility. Most legumes maintain a higher proportion of leaf:stem with advancing maturity compared with grasses and the leaf retains a higher digestibility than grass leaf of comparable maturity, and this is especially true of white clover (Waghorn and Barry 1987).

Table 1.2 Approximate seasonal nutritive value (M/D) for ryegrass/white clover dominant pastures. (Source: Ulyatt *et al* 1980).

Season/Feed type	M/D (MJ ME/kg DM)
Autumn	10.5
Winter - short	11.2
Spring - short	12.0
- mixed	11.2
- rank	10.3
Summer - leafy	10.3
- dry stalky	8.0

Restricting the reproductive growth of grasses and development of rank pasture during late spring/early summer reduces the accumulation of low quality stem and dead material and also increases white clover growth. For every percentage unit increase in dead

matter content of the pasture or diet, digestibility falls by 1.5% units (Sheath *et al* 1987). It is therefore essential to adopt grazing management practices that ensure pastures remain in the leafy vegetative state for as long as possible, thus maximising their nutritive value.

1.4.2 Deer grazing on pasture

Ever since deer farming became legal in 1969 (Challies 1985), all captive deer in New Zealand have been farmed under pastoral conditions, largely based on more traditional sheep and cattle management, with the principal pasture being perennial ryegrass/white clover. There is very limited published information on deer grazing experiments. However, reports from Europe (Blaxter *et al* 1974; Kay and Staines 1981) indicated that wild and farmed red deer ate a wide variety of plant species. Milne *et al* (1987) reported that liveweight gains in weaner red deer calves grazing sown swards during autumn were positively related to sward surface height and herbage mass. Weaners grazing 6 cm sward (2860 ± 24.2 kg DM/ha) had significantly higher LWG than those grazing 2.54 cm sward (1600 ± 50.2 kg DM/ha).

It is now clear that the seasonal feed requirements of red deer are poorly aligned with the average seasonal pasture production pattern in most parts of New Zealand, characterised by surplus spring pasture and a feed deficit during summer and winter (Adam 1988; Asher 1989). This is basically due to deer calving (November/December) much later than the onset of spring pasture production (September). It has been suggested that alternative pasture species with improved summer growth characteristics be examined. It is also thought that earlier calving would more closely align feed requirements of deer with pasture growth. In a study on alternative pasture species for deer production, in an attempt to resolve the Ryegrass Staggers/Argentine stem Weevil dilemma associated with traditional pastures, Hunt and Hay (1989) reported that red deer preferred legumes to grasses. Red deer hinds showed a high preference for red clover, whilst fallow deer showed little preference between grasses, legume and herbs, but rejected high endophyte ryegrass, cocksfoot, sainfoin and sulla. This emphasises the need for more research into deer grazing and the need for development of specialist pastures for the deer industry.

1.4.3 Agronomic characteristics of Moata annual ryegrass

Moata annual ryegrass 'Grasslands Moata' was bred from colchicine induced tetraploids of Paroa Italian ryegrass to provide farming with a more vigorous and persistent

short-term high quality winter/spring cultivar (R.J.M. Hay, pers. comm.). It is very rapid and easy to establish and produces best under reasonably high fertility conditions. With favourable management and adequate moisture during the summer periods, Moata will persist into the year following sowing. With a very high percentage of plants producing aftermath heads, pasture renovation by natural reseeding may be obtained. Seed head emergence will occur in mid-November (late spring), and flowering will commence some 16 days later. Moata will not produce seed after spring sowing. To obtain maximum production, it is recommended that Moata be sown into a well prepared seed bed in early autumn, at a seeding rate of at least 30 kg/ha. Because of its fast establishment, it could be of benefit for direct drilling into existing pastures. Although Moata may be susceptible to attacks by Argentine stem weevil, control can be obtained by the use of pesticides (Armstrong 1981).

1.4.4 Feed requirements of the deer

There is no published information on feed or energy requirements of the deer derived under grazing conditions. Fennessy *et al* (1981) published energy requirement estimates for red deer (Table 1.3). The energy requirements were based upon relationships derived indoors between liveweight gain and metabolisable energy intake (MEI) for stags, and for groups of mixed-age stags fed outdoors in winter. The relationships for the stags indoors were derived from two groups of stags each fed high quality barley-lucerne-linseed pelleted diets (11 MJ ME/kg DM and 26 g N/kg DM) *ad libitum* in individual pens. The estimates of maintenance requirement (MR) calculated from the regression relationships of liveweight gains and intake were 0.57 and 0.85 MJ ME/kg^{0.75}/day for stags fed indoors and outdoors respectively.

The MR for stags kept outdoors were estimated to be 30, 50, 20 and 10% above those for pen-fed stags kept indoors from autumn, winter, spring and summer respectively (ie 0.74, 0.85, 0.68 and 0.63 MJ ME/kg^{0.75}/day). The ME requirement for liveweight gain was derived from the equations for the stags fed indoors and was estimated to be 37 MJ/kg LWG. The ME requirement for the suckling calf was derived from the data of Fennessy *et al* (1981) for deer calves fed milk replacers indoors and was estimated to be 65 MJ/kg LWG.

Suttie (1987) estimated the ME requirements for maintenance and growth of red deer hinds penned indoors to be 0.52 MJ/kg^{0.75}/day and 53 MJ/kg LWG respectively. Suttie

concluded that hinds require slightly less ME for maintenance than stags, but require about 1.5 times energy for liveweight gain, indicating that the current estimates of hind energy requirement based on stag data were underestimated.

Table 1.3 Target liveweights for red deer and estimated seasonal ME requirements for maintenance and growth (Source: Fennessy and Milligan 1987).

	Target live weight (kg)	Daily ME requirement (MJ ME/head/day)				Annual total ME requirement (MJ ME/head) 365d
		autumn 65d	winter 100d	spring 100d	summer 100d	
Stags						
(age-years)						
0.25-1.25	48	16.0	20.9	27.0	26.5	8300
1.25-2.25	105	24.5	28.0	31.5	30.0	10 500
2.25-3.25	140	23.5	33.0	38.0	36.2	12 200
3.25-4.25	175	19.5	33.0	38.5	38.2	12 200
4.25-5.25	190	18.5	34.5	43.5	39	12 900
> 5.25	200	19.0	26.0	42.5	38	12 900
Hinds						
(age-years)						
0.25-1.25	44	15.0	17.5	22.0	21.0	7000
1.25-2.25	83	20.5	23.5	23.5	45.0	10 500
2.25-3.25	94	22.5	24.0	24.5	47.5	11 000
> 3.25	100	23.5	22.5	24.5	47.5	10 900

Note: Metabolisable energy requirements have been calculated from the equations given below.

- (i) For growing animals, adult stags and non-lactating hinds

$$ME = S[0.57 LW^{0.75}] + 37 DLWG$$

where, ME is metabolisable energy requirement in MJ ME/day. S is the 'seasonal coefficient'; 1.30 for autumn (65 d), 1.50 for winter (100 d), 1.20 for spring (100 d) and 1.10 for summer (100 d); LW is liveweight in kg; DLWG is daily liveweight gain in kg/d.

- (ii) For lactating hinds and their calves at foot

$$ME = S[0.57 LW^{0.75} \text{hind}] + 37 DLWG \text{hind} + 65 DLWG \text{calf}$$

where, DLWG is daily liveweight gain in kg/day for the hind or calf as indicated.

There is a need to determine the feed requirements or ME requirements for red deer under grazing conditions for the four seasons, in order to confirm the assumptions made in estimating the current guide for red deer nutrition.

1.4.5 Diet selection by grazing sheep, goats and cattle

Grazing sheep have been shown to harvest green leaf in preference to green stem and dead material (Arnold 1964; Clark *et al* 1982). L'Huillier *et al* (1984) also provide evidence that the distribution of green material determined the horizon of the sward that was grazed by sheep. Cattle are less selective grazers than sheep and consume rank pasture that is rejected by sheep. The integration of sheep and cattle is of greatest benefit where pasture supply and demand is not well matched and large surpluses develop (Sheath *et al* 1987). Milne *et al* (1982) reported that sheep grazing a series of swards containing different proportions of white clover (0-55%) and perennial ryegrass generally had greater proportions of white clover in the diet than was present in the sward, and therefore concluded that sheep selected for white clover within the grazed horizon. Hughes *et al* (1984) reported that on similar swards the diet of the lamb contained a greater proportion of white clover and a smaller proportion of grass and dead material than that of the calf. The diet of the kid was intermediate between that of the lamb and the calf (Table 1.4). Clark *et al* (1982), and L'Huillier *et al* (1984) reported that sheep ate white clover in proportion to its presence in the sward and that no selection for this component was evident. In a grazing trial where sheep and goats grazed scrub pasture containing different proportions of grass, white clover and gorse, sheep ate very little gorse whilst goats preferred gorse and rejected white clover (Clark *et al* 1982).

While older goats consumed a diet similar in composition to the young goat, older sheep consumed more dead material than lambs, although the proportions concerned were small. In a mixed sward, sheep select for white clover, especially lambs, cattle are not very selective, and goats prefer grasses and scrub weeds and reject clover. There is no published information on diet selection by grazing deer. In a pasture species preference trial, Hunt and Hay (1989) showed that red deer preferred legumes to grasses. While fallow deer did not distinguish between grasses, legumes and herbs, they rejected high endophyte ryegrass, cocksfoot, sainfoin and sulla. There is a need to conduct experiments of this kind, since results from such trials will help in determining if specialist pastures are needed for deer production.

Table 1.4 Mean proportion (DM) of sward components and digestibility of OM in oesophageal extrusa from goats, sheep and calves grazing similar ryegrass/white clover swards. (Source: Hughes *et al* 1984).

	Mean of ungrazed herbage masses	Kid	Goat	Lamb	Sheep	Calf
Grass	0.41	0.64ab	0.79a	0.56b	0.59ab	0.76a
Clover	0.26	0.35ab	0.20b	0.42a	0.36ab	0.19b
Dead matter	0.33	0.01b	0.01b	0.02b	0.05a	0.05a
OM digestibility (%)		81ab	83ab	77ab	76ab	76ab

Note: Subscripts a, b and c were not defined in the original publication.

1.5 MEAT PRODUCTION FROM DEER IN NEW ZEALAND

1.5.1 The New Zealand deer population

Ten species and subspecies of deer were introduced into New Zealand between 1861 and 1920, mainly from Europe and North America. Seven, possibly 8 species namely, red deer (*Cervus elaphus scoticus*), fallow deer (*Dama d. dama*), North American wapiti (*Cervus elaphus nelsoni*), sambar deer (*Cervus u. unicolor*), sika deer (*Cervus nippon*), white-tailed deer (*Odocoileus virginianus borealis*), rusa deer (*Cervus timorensis rusa*) and possibly moose (*Alces alces andersoni*) survived in the wild, and of these the red and the fallow deer are the most successful (Challies 1985). The sambar and rusa deer originated from the tropics and the rest from temperate climates.

Successful cross-breeding occurred in the wild, between the North American wapiti and the red deer. They form a high proportion of the feral Fiordland (South west of New Zealand) herd, now called the New Zealand wapiti (Drew and Hogg 1990; Fennessy and Pearse 1990).

Deer farming in New Zealand has grown very rapidly; in 1985, there were 330,513 red and fallow deer in captivity on farms, in 1990, there are 902,793 deer on farms, of which 831,789 (92%) are red deer and 71,004 (8%) are fallow deer. Of this total population, 93,125

(10%) are venison stags comprising 83,408 red deer stags and 9,716 fallow deer bucks. The estimated deer population on New Zealand farms by 1995 is 2,519,023 (Table 1.5, GIB, pers. comm.).

Table 1.5 Deer population summary. (Source: GIB 1990)

	RED DEER HERD			FALLOW DEER HERD			Total
	Breeding Hinds	Stag Herds Velvet	Venison	Breeding Hinds	Stag Herds Velvet	Venison	
1982	50 421	57 640	0	14 339	6 211	3 257	131 868
1983	96 349	61 884	7 541	14 052	6 089	2 428	188 344
1984	139 754	81 629	7 468	16 620	6 029	3 084	254 584
1985	181 808	87 591	32 061	19 579	6 019	3 455	330 513
1986	228 392	91 697	44 913	23 735	6 093	4 113	398 942
1987	287 042	91 794	61 832	32 197	6 278	5 039	484 182
1988	361 141	100 901	69 373	39 676	6 694	7 113	584 898
1989	457 115	135 277	65 224	44 443	7 265	8 541	717 865
1990	568 838	179 543	83 408	53 342	7 946	9 716	902 793
1991	711 222	233 985	102 516	63 627	8 799	11 515	1 131 664
1992	869 332	302 358	128 692	74 233	9 880	13 749	1 398 244
1993	1 067 194	379 726	160 907	86 230	11 151	15 959	1 721 166
1994	1 296 228	473 222	197 942	98 849	12 591	18 526	2 097 358
1995	1 546 770	585 490	239 4239	112 191	13 972	21 162	2 519 023
1996	1 805 660	718 653	284 410	124 109	15 569	23 978	2 972 379

(Pers. comm. from General Manager, NZ GIB).

1.5.2 Venison production from male deer

Drew (1985) suggested that the age at slaughter for most New Zealand farmed deer is about 15 or 27 months, at the end of the growth spurts in March. This is dictated by the seasonal pattern of VFI and liveweight gain, which is characterised by high rates of weight gain in spring and summer and low gain in autumn and winter. The cyclical pattern of weight change is very pronounced in older stags, who may lose about 25% of their weight during the rut and winter. Of particular importance was the zero growth of rising two year old stags over the 6-7 month autumn-winter period (Adam 1984), leading to the observation that slaughtering at 15 months would be economically preferable to 27 months. However, the demands of the market place may necessitate slaughter of stags at other times of the year as

New Zealand's main export markets in Europe and North America have peak requirements for venison during the autumn hunting season (September-December), it is therefore pertinent for venison to be ready at this time to satisfy the demand. This is the main drive behind the current market-led approach in the New Zealand venison industry. This means that young red deer stags have to be grown faster and be ready for slaughter at 92 kg LW (> 50 kg carcass) by August-November (10-12 months old).

Options for achieving a desirable carcass weight at 10-12 months of age include the use of large deer species such as Canadian Wapiti x red deer sires to produce hybrids (Drew and Hogg 1990; Fennessy and Pearse 1990). The hybrid animals have a much superior carcass at a young age (69 kg carcass at 11 months of age; Drew and Hogg 1990). The hybrid could also be used as a terminal sire over red deer.

Other options are advancement of the breeding season using melatonin implants (Fisher *et al* 1988; Wilson 1989; Wilson *et al* 1990; Wilson and Staples 1990), and manipulation of pasture growth patterns and composition. The use of Moata annual ryegrass by the virtue of its high pasture production during winter and early spring and its high nutritive value, direct drilled into perennial ryegrass/white clover, along with hormonal manipulation of the animal, could be used as a means of increasing LWG from 6-12 months of age, during winter and spring.

One of the most remarkable aspects of the New Zealand deer industry is its rapid growth. During the year ended December 1989, deer product exports earned a total of \$75.4 m, an increase of 58% over the previous year, and 54% of this earning came from the export of venison. A total of 3,770 tonnes of venison was exported in the year ended December 1989 as against 3,550 tonnes in 1988 representing an increase of 6% (Table 1.6). This small increase was due to the considerable retention of stags for velvet production and is not representative of average annual increase in production. Annual growth in live deer population in New Zealand was about 24% in 1988 and increased to 32% in 1989 (Department of Statistics, pers. comm.). It is estimated that the total revenue from deer product exports by 1995 will be \$125m with earnings from the sale of venison contributing about \$108m (86%), representing the sale of 20,585 tonnes of venison (Spiers 1987).

Table 1.6 Deer product exports for year ended December 1989. (Source: GIB 1990)

Product	Year ended Dec 1988		Year ended Dec 1989	
	Kg	NZ\$FOB	Kg	NZ\$FOB
Venison	3 550 210	32 558 030	3 770 135	40 718 984
Velvet	-	13 763 98	-	32 649 813
Deer Hides/Leather	-	1 338 469	-	2 023 599
Total	-	47 660 488	-	75 392 396

(Pers. comm. from General Manager, NZ GIB).

1.5.3 Efficiency of meat production from deer

An important variable in assessing the efficiency of meat production from various species is the proportion of liveweight which is clean carcass (dressing-out %). Mature pasture-fed stags at Invermay dressed out at 59%, compared with 40-50% for young sheep and cattle (Drew 1985). Deer have a superior carcass weight to liveweight ratio compared with other farmed ruminants. The high-priced cuts from any meat animal come from the hind leg and back. The deer has a different muscle distribution compared with cattle, with muscle groups in the hind leg and saddle areas being 8 and 23% heavier respectively in deer than the same muscle groups in cattle (Berg and Butterfield 1976). Deer carcasses comprise 52-54% of high-priced cuts, 39-42% of second class cuts, and about 6% of discarded bone (Drew 1985). In terms of boned-out meat from the leg, saddle and shoulder, the carcass of young deer yielded 40% more first class meat than that of young sheep (Blaxter *et al* 1974). On average, commercial deer carcasses contain 8-12% fat which is much lower than 22-27% for ram lamb and 18-22% for bull carcasses (Table 1.7a). One kg of carcass gain in young stags comprises 0.23 kg of fat compared with 0.41 kg fat/kg gain in ram lambs (Fennessy *et al* 1982). The anatomical advantage, coupled with the low rate of fat deposition, makes deer a greater producer of lean meat than sheep or cattle. This may be a reflection of the efficiency with which the deer converts feed into lean tissue compared with sheep or cattle (Table 1.7b). The low fat content of venison is likely to become increasingly important as consumers become increasingly health conscious, and discriminate against fatty ruminant meats.

Table 1.7a Carcass weight (CW) and fatness in lambs, bulls and stags. (Source: Drew 1985).

	CW range (kg)	Carcass fat (% CW)
Ram lambs	15 - 20	22 - 27
Bulls	200 - 240	18 - 22
Stags	55 - 70	8 - 12

Table 1.7b Comparative efficiency of feed conversion of ruminants. (Source: Yerex and Spiers 1990).

	Dry matter (kg)	Meat produced (kg)
Deer	30	3
Cattle	30	1
Lambs	30	1
Dairy cows (Butterfat)	30	1.5

1.5.4 Export market requirements

Europe remains the major volume market for New Zealand venison, taking about 74% of venison exported in 1989, with West Germany accounting for the bulk (47%) of sales (Table 1.8). The United States and Japan are also important and growing markets.

West Germany is largely a commodity market, absorbing high volumes at lower returns than some of the newer export markets. The market takes the full range of venison cuts, mostly in frozen primal form, and is founded on a tradition of eating wild game. Germany is a particularly important market for forequarter and boneless B or trim which is utilised in game goulash in particular (Pattison 1988).

The United States is New Zealand's third largest market for venison and it is significantly different from the traditional West German market. Higher prices are obtained for the most sought after saddle and hind primal cuts and at peak season, as much as 50% of the product goes to the U.S.A. in chilled form (Pattison 1988).

Table 1.8 Venison exports to top ten markets. (Source: GIB 1990)

Country	Year ended Dec 1988		Year ended Dec 1989	
	Kg	NZ\$FOB	Kg	NZ\$FOB
West Germany	1 430 697	10 234 046	1 623 890	13 986 395
Switzerland	369 375	3 640 811	389 217	4 442 004
United States	351 034	4 345 874	387 891	6 144 199
Sweden	260 348	1 786 740	294 006	2 194 615
Australia	162 630	966 715	246 361	1 570 184
Japan	199 739	3 472 323	197 038	4 202 205
Netherlands	105 021	653 748	94 216	1 014 174
Denmark	158 307	1 565 330	75 453	816 159
Canada	68 283	976 046	74 965	1 284 091
Belgium	74 296	1 280 651	60 571	1 153 615
Total 10 Countries	3 179 9730	28 922 284	3 443 608	36 807 641
Total All Countries	3 550 210	32 558 030	3 770 135	40 718 984

(Pers. comm. from General Manager, NZ, GIB).

Japan is a similarly high value market. Venison's versatility, leanness and lack of odour by comparison with lamb, all point to excellent potential in the Japanese market.

Obviously, requirements for venison vary from market to market, and the Game Industry Board (GIB) has identified these differences. In order to satisfy these various requirements it comes down to being able to produce enough venison for the markets at the required time, and in the required forms. The different approaches to achieving this goal have been mentioned earlier. Healthy characteristics of venison, such as its higher protein and lower fat and cholesterol levels than beef, and low calories attract American consumers who are looking for exotic and different eating experiences, and who are also increasingly nutrition conscious. The rising standards of living among the Japanese is increasing the demand for exotic imported food products. With such markets available, together with continued research and development of new markets by the GIB, New Zealand should be able to maintain its position as the world leader in venison production by being able to deliver the product to the consumers when and how they require it.

1.5.5 Seasonal fluctuations in price schedule of venison

In New Zealand, the price (\$/kg carcass) that the venison exporter pays the producer varies with season (Figure 1.1; The NZ Deer Report, pers. comm.). It is reasonably well established that the venison schedule peaks from September to November, in response to the N. Hemisphere export market demand for chilled product during winter. For the producer to achieve maximum returns per kg for his venison from stags, he must produce venison at this time of the year, hence a market-led approach in the venison industry. In order to capitalise on the high venison price, the producer has the choice of either slaughtering rising two-year-old stags which do not exceed 127 kg LW (70 kg CW at 55% dressing-out) or to slaughter rising one-year-old stags at a target slaughter weight of 92 kg (50.6 kg CW).

The usual practice of slaughtering farmed deer at 15 or 27 months of age (February-March) means that the producer gets minimum returns per kg for his venison, which translates into a loss of more than \$1.00/kg carcass (Figure 1.1) compared with producing venison at a time when the price is at its peak (September-November).

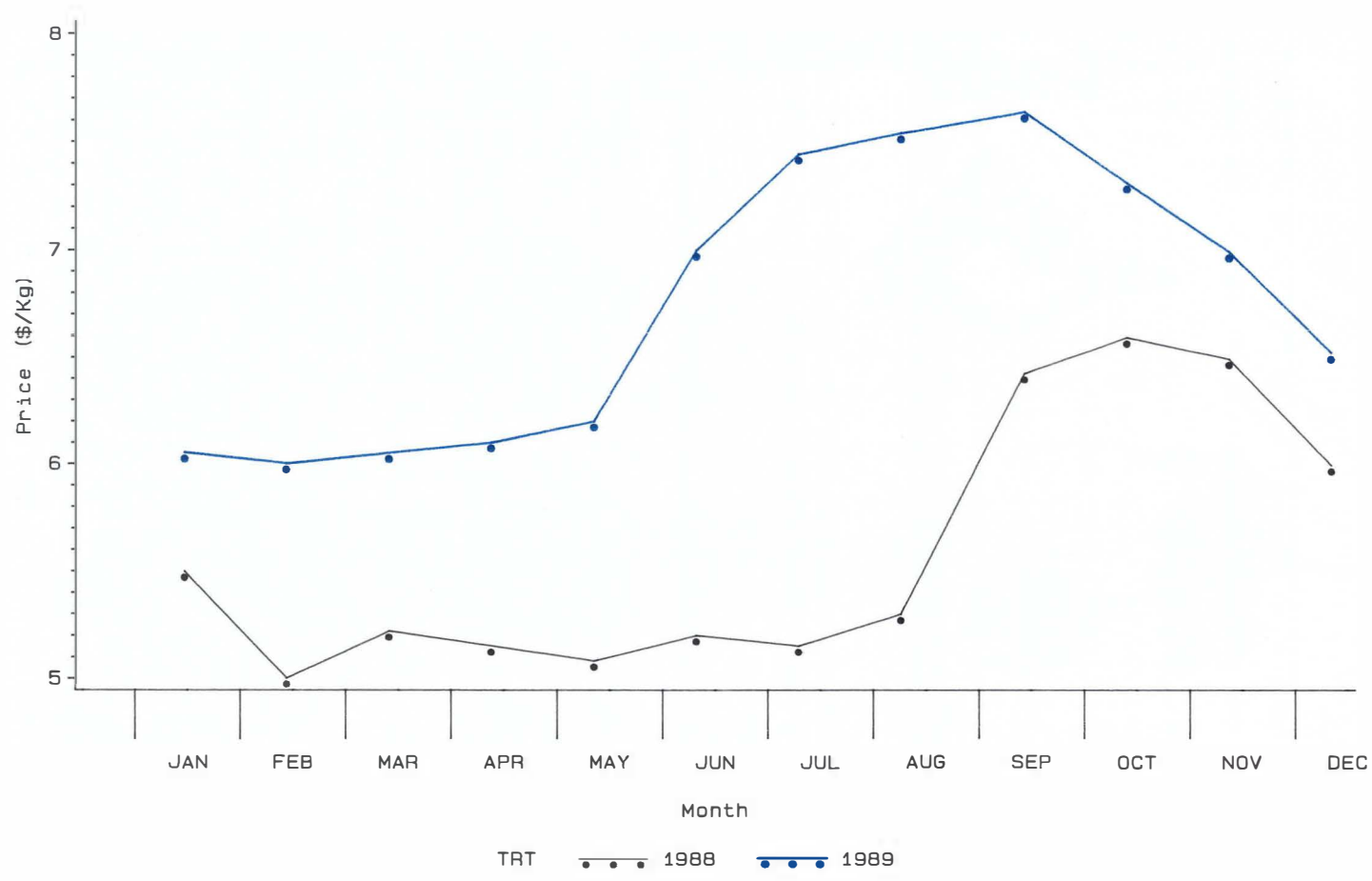


Figure 1.1. Seasonal variations in venison schedule (Dollar/Kg), prime 50–70 Kg carcass during 1988 and 1989.

CHAPTER 2

INITIAL STUDIES ON THE EFFECTS OF PASTURE DM ALLOWANCE, THE INTRODUCTION OF ANNUAL RYEGRASS AND IMMUNIZATION AGAINST MELATONIN UPON EARLY VENISON PRODUCTION

2.1 INTRODUCTION

Deer farming in New Zealand is modelled after the more traditional sheep management system, with animals grazing mainly perennial ryegrass/white clover pastures. Whilst efficient meat production systems have been developed for sheep and cattle grazing perennial ryegrass/white clover pastures, there is no well defined system of meat production from the red deer. Therefore, the objective of this experiment was to define an efficient system of meat production from stags less than 12 months of age.

There is no published information on the temperament of red deer grazing under controlled experimental conditions (behind electric fences), the VFI and LWG of weaner and red deer stags grazing improved pasture (direct drilled with Moata annual ryegrass) at high herbage allowance (6.3 kg DM/animal/day) and the effects of active immunisation against melatonin upon VFI and LWG during winter and spring. The present experiment was designed to investigate the suitability of farming the red deer using the sheep management system and the effects of active immunisation against melatonin as a potential means of increasing VFI and LWG of weaner stags during winter and spring.

2.1.1 **Objective**

The objective of this experiment was to evaluate different systems of growing weaner red deer stags to a suitable slaughter weight defined here as 92 kg LW (> 50 kg CW) by one year of age or less. The proposed system therefore critically depends upon achieving high rates of LWG at all times, especially during winter. There are two main constraints in such an approach

1. Availability of grazed pasture and its nutritive quality.
2. Seasonal intake cycle of deer - low winter LWG and high spring/summer LWG.

Both feed supply and feed quality reach low values during autumn/winter. Maximum levels of pasture production of about 73 kg DM/ha/day (Radcliffe 1975) and nutritive value of 12 MJ ME/kg DM (Ulyatt 1980) both occur in late spring, whilst low levels of both production (16 kg DM/ha/day) and nutritive value of 11.2 MJ ME/kg DM occur during winter. The introduction of Moata was to boost winter/spring herbage production in order

to reduce winter/spring feed deficits common with traditional pastures, and also to improve the nutritive quality of feed.

Deer have a pronounced seasonal pattern of VFI. They show high VFI during the spring and summer months and low voluntary intake during autumn and winter (Kay and Staines 1981). These changes are associated with respectively long and short hours of daylight, and it is believed a major factor responsible for the decline in intake during autumn/winter is increased secretion of the hormone melatonin. Melatonin released from the pineal gland during the hours of darkness, relays the photoperiodic time-cues through which seasonal species respond to the annual cycle in daylength (Wurtman et al. 1968; Herbert 1981). Low voluntary intakes over autumn/winter, due to this mechanism, are a major reason for low LWG of deer over this period. Thus low autumn/winter LWG in young deer can be attributed to the low intake point in the animal's 'biologic clock' occurring at the same time as the seasonal low points in pasture production and quality. This research project is aimed at simultaneously increasing feed supply and nutritive value by altering pasture growth and composition, and also increasing VFI (and growth) potential of stags during periods of low growth by hormonal manipulation.

The period for which melatonin is at a high level in the blood appears to convey 'night length' and to cause specific changes in the hypothalamic control of reproduction, moulting, food intake and other seasonal characteristics (Lincoln 1983). By giving animals melatonin it has been possible to interfere with this subtle time-keeping mechanism, thus inducing the short-daylength response normally seen in winter in the mammalian species studied to date. Whilst the administration of melatonin is a convenient method of inducing winter changes during the summer, achieving the reverse presents more of a problem. To do this, young red deer stags were immunized against melatonin using an anti-melatonin vaccine. This is to generate immune response by producing melatonin antibodies which will bind and inactivate the melatonin produced by the pineal gland during autumn/winter. By producing anti-melatonin antibodies it may be possible to induce an increase in appetite of farmed deer in winter.

It is important that any grazing/immunization procedures developed do not lead to undesirable carcass attributes, notably excess fatness. The present experiment was designed to examine effects of feed availability (ie pasture DM allowance), of introduction of a cultivar of improved nutritional value (Grasslands Moata) and of immunization against melatonin on seasonal growth rate and carcass attributes of young red deer stags.

2.2 MATERIALS AND METHODS

2.2.1 **Experimental design**

Forty-eight weaner red deer stags were rotationally grazed at two feeding allowances on either permanent perennial ryegrass/white clover pasture, or the same that had been direct-drilled with an annual ryegrass in autumn (cv 'Grasslands Moata'). The trial was conducted during 1987 on the Massey University deer research unit. Balanced numbers of animals within each grazing treatment group were given a vaccination treatment designed to immunize against melatonin, with the objective of increasing LWG during winter.

2.2.2 **Animals**

Forty-eight weaner red deer stags aged approximately 5.5 months were purchased from a hill country property at Wairoa, Hawke's Bay and transported to Massey University on May 9, 1987, where they were then allotted at random into four groups of twelve stags. The four animal groups were randomly allocated to the four pasture treatments; permanent pasture high allowance (pasture high group), direct-drilled high allowance (Moata high), permanent pasture medium allowance (pasture medium) and direct-drilled medium allowance (Moata medium). Each group was further divided at random into three subgroups of four stags, for the purpose of vaccination against melatonin; this will be described in detail in a subsequent sub-section (2.2.4). All twelve deer in each pasture treatment were grazed together as a single group.

All animals were ear tagged and drenched with "IVOMEK" (0.4% w/v ivermectin at 200 µg/kg LW; Merck, Sharp and Dohme, N.Z.) upon arrival at the University deer unit. Thereafter they were weighed straight off pasture between 10.00 a.m. and 12 noon at three weekly intervals, and further drenched with IVOMEK at monthly intervals.

As the animals attained the target liveweight, they were sent for slaughter at the Fielding DSP of Venison New Zealand Limited. Stags in the present experiment were slaughtered at the weight of 92 kg LW.

2.2.3 Pasture

The animals were rotationally grazed using electric fences (a back fence was always used) at two feeding levels - High allowance (6.3 kg DM/head/day) and Medium allowance (4.5 kg DM/head/day) on two types of mixed pasture swards; 1. permanent pasture and 2. Moata (the permanent perennial ryegrass/white clover pasture direct drilled with the annual Italian ryegrass 'Grasslands Moata'), at the seed rate of 15 kg/ha single pass band sprayed. The direct drilling technique was as reported by Baker (1976). The animals were grazed on two paddocks of each pasture, and changed between each at monthly intervals to avoid paddock effects.

The Moata paddocks were overdrilled on March 14-15, 1987. Yates "Blitzem" pellets (Metaldehyde; Yates N.Z. Ltd, Auckland) was applied to the overdrilled paddocks at the rate of 12 kg/ha on March 17, to kill slugs and other molluscs that might feed on the Moata seeds. Between April 10-12, the Moata paddocks were grazed by a mob of sheep (9-10 months old) for two days to check the competition from other grass species and to allow the Moata to tiller. All the pasture treatments were top-dressed with urea on May 5, and July 3, at the rate of 50 kg and 100 kg urea/ha representing 23 and 46 kg N/ha, respectively, to ensure optimum pasture production during winter. All paddocks were top-dressed with superphosphate at the rate of 200 kg/ha (12 kg Phosphorous/ha) on May 5, 1987.

Pre-grazing pasture cuts to estimate the herbage mass (kg DM/ha) were done once per week using a portable shearing hand piece (Clipmaster Clipper, Sunbeam, Australia), powered by a portable Kawasaki generator. Five quadrat (size = 0.1 m²) sample cuts made to the soil level were taken from each area. The herbage samples taken were washed, dried in an oven at 90°C for 17 hours, and weighed. Areas were measured and fenced off to be grazed by the animals for one week (7 days) according to their feeding allowance. These areas were further divided into two portions with temporary electric tapes to be grazed for 4 and 3 days respectively. Post-grazing cuts were done by taking five quadrat sample cuts from areas corresponding to the mean sward height in each grazed area, to determine the residual DM and the amount of feed eaten by the animals. Random herbage samples were taken from all the paddocks (pre-grazing) at two week intervals for dissection into various botanical components - Moata, perennial ryegrass (PRG), white clover (WC), other species (OS) and dead matter (Dm). Herbage samples were also taken every week from three areas protected by cages in each pasture treatment for laboratory in vitro digestibility analyses and for total nitrogen determination.

Pasture rationing was achieved by the use of electric fences (Gallagher Power Fencing System, N.Z.). Four reel systems, with four polytapes or a combination of two polytapes and two polywires were set across each paddock. Orange and white tapes were used. The tapes were held in place clipped to fibre-glass rods. The fibre-glass rods were 1.5 m long and 10 mm in diameter and were placed about 4 m apart. The tapes were clipped to the rods at regular intervals to produce a fence of about 1.5 m high. The live tapes carried 6-8 Kvolts of electricity. The system worked initially, except for one odd stag in the pasture medium group that kept creeping out most of the time. As the trial approached mid August, the stags became very temperamental and it was increasingly difficult to hold them behind the electric fences. While some animals in other groups jumped out occasionally and were put back in their respective grazing areas, the animals in the pasture medium group were constantly jumping over the fence. Attempts to contain them by removing the ring leader out of the trial, the use of double reels of eight polytapes in both front and back fences, the use of longer fibre-glass rods (2 meters) placed more closely together failed initially, but worked later due to persistency. The animals were under complete control once more by early October. That group has been deleted from some analyses because of inability to contain it adequately.

2.2.4 Vaccination procedures and blood sampling

A single dose of the anti-melatonin vaccine was composed of:

- 1 mg antigen ARH-291 (5-methoxy-tryptamine hemisuccinamide conjugated to human serum albumin (HSA)).
- 1 ml physiological saline (9 g NaCl/l)
- 1 ml Freund's complete adjuvant (FCA)

A single dose of the vehicle was composed of:

- 1 ml physiological saline (9 g NaCl/l)
- 1 ml Freund's complete adjuvant (FCA).

About 40 ml (20 doses) each of anti-melatonin vaccine and vehicle was prepared by Dr R.W. Hoskinson at the C.S.I.R.O.'s Division of Animal Production, Sydney, Australia, and flown to Massey University, Palmerston North for use on deer. The preparation was drawn into four labelled 10 ml syringes fitted with 18 G hypodermic needles and packed in ice.

In each grazing group, four stags were vaccinated with the anti-melatonin vaccine (to produce an immunological response), four stags were vaccinated with the vehicle and four

Table 2.1 Definitions of the carcass linear measurements.

Measurement	Definition
1. Carcass length (LB)	From the point where the gambrel is inserted through the Gastrocnemius tendon to a point just anterior to the point of the humerus (Moxham and Brownlie, 1976).
2. Leg length (T)	From the distal end of the tarsals to the centre of the tuberosity of the tibia, which is visible on the ventral aspect of the hanging carcasses (Palsson, 1939).
3. Hind width (G)	Maximum width of the gigots, with the carcass suspended from a gambrel. The measurement was taken at right angles to the length of the carcass at a line level with the femoral trochanter (Palsson, 1939).
4. Forequarter width (WF)	Maximum width of the shoulder, measured at the level of the scapula from one lateral surface to the other, using a caliper (Palsson, 1939).
5. Tail-bone fat depth (TF)	The depth of subcutaneous fat 50 mm lateral to the middle of the third sacral vertebra.
6. Maximum muscle depth	Maximum depth of <i>M. longissimus</i> measured at the leg end of the saddle.
7. Fat depth	Fat thickness over the maximum depth of <i>M. longissimus</i> at the leg end of the saddle cut.
8. Maximum saddle width	Maximum width of the saddle, measured at the shoulder end.

2.2.6 Laboratory methods

All herbage samples were stored at -20°C , freeze dried and ground (1 mm diameter sieve) prior to laboratory analyses. *In vitro* digestibility was determined by the method of Roughan and Holland (1977), using six standards derived from *in vivo* digestion trials with sheep, and ranging in organic matter digestibility (OMD) from 72.10-80.90% to derive a regression relating the laboratory *in vitro* digestibility to their known *in vivo* digestibility values.

Total nitrogen (N) was determined by the Kjeldahl procedure, using a selenium catalyst with the sulphuric acid digestion, and with the ammonia being determined by automatic titration against 0.1 M HCl in a Kjeltac Auto 1030 Analyser (Tecator A.B. Sweden).

Leaf tensile strength was measured on freshly collected samples, using the apparatus and method described by Evans (1967). On each occasion, 50 leaves of either perennial ryegrass or annual ryegrass were used for each determination.

Fresh herbage samples taken for botanical dissection were stored at 4°C. Five samples were taken for each pasture treatment. On each occasion, the Moata samples were dissected into Moata annual ryegrass (MAR), perennial ryegrass (PRG), white clover (WC), other species (OS) and dead matter (Dm) components using a pair of forceps. The permanent pasture samples were dissected into PRG, WC, OS and Dm components in the same manner. The dissected components were dried in an oven at 85°C overnight and weighed.

Anti-melatonin antibody titre was determined as the dilution of plasma necessary to bind 10 pg of [³H] melatonin/ml when 20 pg of [³H] melatonin/ml was available. The results were expressed as reciprocal values as reported by Abraham (1974). The lowest titre measured (detectable antibody) was 1:10. All determinations of melatonin antibody titre were performed at the C.S.I.R.O. Division of Animal Production's Prospect Laboratory, Sydney, Australia.

LH concentrations were determined using a heterologous radioimmunoassay procedure described for sheep plasma by Scaramuzzi *et al* (1970) and validated for fallow deer plasma (Asher *et al* 1986). The intra-assay coefficients of variation for multiple determinations, calculated from determinations of red deer control plasma samples was 11.4%. All samples were included within a single assay. The least discernible amount from 0 was 0.48 ng/ml.

Plasma testosterone concentrations were determined using an extraction radioimmunoassay similar to that described by Peterson *et al* (1978), but omitting the chromatographic step used to separate androgens. The inter-assay coefficients of variation, calculated from determinations of low (mean concentration = 1.28 ng/ml) and high (9.30

ng/ml) red deer control plasma samples in each assay (n = 5) were 21.7% and 13.1% respectively. The intra-assay coefficients of variation for multiple determinations of the same control samples were 13.1% and 8.8%, respectively. The least discernible amount from 0 was 0.1 ng/ml. The LH and testosterone assays were performed at Ruakura Agricultural Centre, Hamilton, New Zealand.

Prolactin was determined using the method of van Landeghem and van de Weil (1978), as modified by Peterson *et al* (unpublished) and validated for red deer plasma (McCutcheon unpublished) as in Appendix 1. The antiserum was supplied by National Institute of Arthritis, Diabetes & Digestive & Kidney Diseases, National Institute of Health, Bethesda, Maryland, U.S.A. in association with National Hormone & Pituitary Program, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A., Code and lot # NIADDK-Anti-oPRL-1, AFP-973269. It was stored frozen at a 1:100 dilution in assay buffer and was further diluted to 1:40,000 for the assay. Rabbit gamma globulin was added to the first antibody mix to provide 1 µg per assay tube to facilitate formation of the antibody pellet. The second antibody was a Donkey anti-rabbit precipitating serum (IDS Gamma-B precipitating antiserum for radioimmunoassay, Code APPTI, Lot # 11656, Washington, Tyne & Wear, England). The dilution range for the ovine reference standard was 1-1200 ng/ml. The sensitivity of the assay was an average of 0.2 ng/ml and the inter-assay coefficient of variation was 14.0% and the intra-assay coefficient of variation was 9.1%.

2.2.7 Statistical analyses and calculation of data

The experimental data was analysed using General Linear Models Procedure (GLM), as a 2x2x3 factorial design, with two levels of pasture allowance (high and medium), two pasture types (pasture and Moata) and three types of vaccination (non immunized or control, vehicle or adjuvant only, and anti-melatonin vaccine or adjuvant plus antigen). Least Squares Means (LSM) was used to test the differences between treatments. As there were no interactions (P > 0.10) between type of pasture and immunisation procedure, only main effects for both are given in the results.

The winter LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at August 27} - \text{Liveweight (kg) at May 14}}{105 \text{ days}} \times 1000$$

using the LW at the start of the experiment (May 14) as a covariate.

The spring LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at November 29} - \text{Liveweight (kg) at August 27}}{95 \text{ days}} \times 1000$$

using the LW at August 27 as a covariate.

The leaf strength is here defined and calculated as:

$$\frac{\text{breaking load (g)}}{\text{dry wt. (mg) of 5 cm length}}$$

as reported by Evans (1964).

The herbage M/D value (MJ ME/kg DM) was calculated from in vitro digestibility measurements as:

$$\frac{\text{Digestible organic matter digestibility (DOMD)} \times 16.3}{100}$$

MEI (MJ/day) during winter was calculated as:

$$\text{Mean group DMI (1.7 kg DM.day)} \times \text{Mean winter pasture M/D.}$$

MEI (MJ/day) during spring was calculated as:

$$\text{Mean group DMI (2.1 kg DM/day for Pasture high group and 2.2 for Moata group)} \times \text{Mean spring pasture M/D}$$

The botanical composition (%) of the pasture on dissection was calculated as:

$$\frac{\text{dry wt. of individual components} \times 100}{\text{total dry wt. of sample}}$$

Plasma prolactin concentrations were analysed using GLM, and LSM was used to test the differences between treatments. Least Squares Means are presented.

2.3 RESULTS

2.3.1 **Botanical composition of pastures**

Table 2.2 shows the percentage presence of the various components in the two sward types at two feed allowances during winter and spring. Moata swards contained less perennial ryegrass than the pasture swards during both seasons, with the difference being largest in spring (46 vs 73%). Moata content was relatively low during winter (17-19%) and was similar for both high and medium allowance treatments. In spring, the high allowance treatment contained more Moata than the medium allowance treatment (36 v 27%). All swards had similar composition for white clover, other species and dead matter.

2.3.2 **Chemical composition of pastures**

The data shows high OMD, total N and M/D values, indicating that the pastures were kept in the vegetative state and of high nutritive quality (Table 2.3). Herbage nitrogen concentration was especially high during winter, which could be due to urea application to the pastures in order to boost DM production. The presence of Moata had no effect upon pasture N concentration during winter, but pastures containing Moata appeared to have lower N concentration during spring. Calculated MEI was 28% greater in spring than during winter. The M/D values for all swards were high and similar in both seasons, with no effect due to presence of Moata.

2.3.3 **Leaf Strength**

The mean leaf tensile strength and standard deviation for the two species over 5 samplings are shown in Table 2.4. The species means are significantly different ($P < 0.001$), with Moata annual ryegrass being lower in leaf tensile strength than the perennial ryegrass.

There were differences in mean leaf strength between sampling dates, but there was no seasonal trend in these differences. Evans (1964) reported a lower mean strength in the winter months.

Table 2.2 Botanical composition (% DM) of the swards.

Allowance	Sward type		Perennial ryegrass	Moata Annual ryegrass	White Clover	Other species	Dead matter
<u>Winter (June-August)</u>							
High	Pasture	Mean (SD)	79 (2.3)	0	5 (1.1)	8 (3.9)	8 (1.2)
	Moata	Mean (SD)	67 (2.1)	17 (2.6)	6 (0.6)	4 (2.2)	6 (1.7)
Medium	Pasture	Mean (SD)	78 (6.2)	0	7 (3.7)	8 (2.7)	9 (1.8)
	Moata	Mean (SD)	64 (3.5)	19 (1.3)	6 (0.9)	8 (2.1)	4 (1.5)
<u>Spring (September-November)</u>							
High	Pasture	Mean (SD)	73 (8.5)	0	7 (2.9)	8 (2.5)	12 (4.9)
	Moata	Mean (SD)	45 (8.6)	36 (10.6)	7 (1.0)	3 (2.5)	10 (1.2)
Medium	Pasture	Mean (SD)	72 (5.1)	0	10 (2.9)	10 (2.0)	8 (1.2)
	Moata	Mean (SD)	47 (1.9)	27 (1.4)	10 (1.3)	11 (1.0)	5 (0.9)

No. of dissections per season = 3 (15 samples/sward type)

Table 2.3 Organic matter digestibility (OMD), total nitrogen concentration, calculated concentrations of metabolisable energy (M/D values) and estimated metabolisable energy intakes (MEI) of grazing stags during winter and spring.

Allowance	Herbage type		OMD	Total N (%)	M/D (MJ ME/kg DM)	MEI (MJ/day)
<u>Winter (June-August)</u>						
High	Pasture	Mean (SD)	82.1 (1.95)	4.7 (0.42)	11.8 (0.35)	20.0 (0.59)
	Moata	Mean (SD)	83.3 (2.05)	4.8 (0.44)	11.9 (0.39)	20.2 (0.67)
Medium	Pasture	Mean (SD)	82.3 (1.20)	4.4 (0.56)	11.7 (0.17)	19.9 (0.30)
	Moata	Mean (SD)	84.6 (2.02)	4.6 (0.43)	12.1 (0.31)	20.5 (0.52)
<u>Spring (September-November)</u>						
High	Pasture	Mean (SD)	83.5 (5.08)	3.8 (1.28)	12.0 (0.79)	25.1 (1.66)
	Moata	Mean (SD)	84.0 (3.40)	3.3 (0.90)	12.0 (0.50)	26.4 (1.06)
Medium	Pasture	Mean (SD)	83.9 (2.71)	3.9 (0.74)	12.0 (0.38)	*
	Moata	Mean (SD)	83.9 (3.08)	3.5 (0.83)	12.0 (0.44)	26.4 (0.99)

No. of samples per season: Winter = 8; Spring = 10

* value not recorded because of problems keeping stags behind electric fence.

Table 2.4 Leaf tensile strength comparison between perennial ryegrass and Moata annual ryegrass.

Variety	Tensile strength (g/mg of 5 cm length)	SD
Perennial ryegrass	133.3	11.5
Moata annual ryegrass	87.7	19.8
Significance of difference	***	

Means of 5 dates; July - November 1987

*** P < 0.001

2.3.4 Seasonal liveweight

The seasonal nature of growth in the young red deer can be seen in Figure 2.1. It shows two phases in the growth curve; slow growth during the winter period (56-66 kg) and faster growth during the spring period (66-82 kg). The slowest growth was recorded between late July and early August. Animals in all groups showed similar growth patterns.

2.3.5 Liveweight gain and VFI

The winter and spring LWG (g/d) and percentage of stags attaining slaughter weight by the end of November, are shown in Table 2.5. The winter LWG were similar for all treatment groups and there were no significant differences (91-110 g/d; P > 0.10). During spring, the LWG of animals grazing the Moata high treatment tended to be greater than that of animals grazing the Moata medium treatment (P = 0.08), and almost greater than that of animals grazing the pasture high treatment (P > 0.10). The LWG recorded for the pasture medium group in spring (186 g/d) is not a true figure, due to the fact that they were grazing ad lib during late winter/early spring. This group was particularly difficult to keep behind electric fences. The dry matter intake for all animals were similar during winter (1.7 kg DM/animal/d) and spring (2.2 kg DM/animal/d) with the presence of Moata having no effect (P > 0.10). Due to a temperament problem, the VFI for stags in the pasture medium group was not recorded in spring.

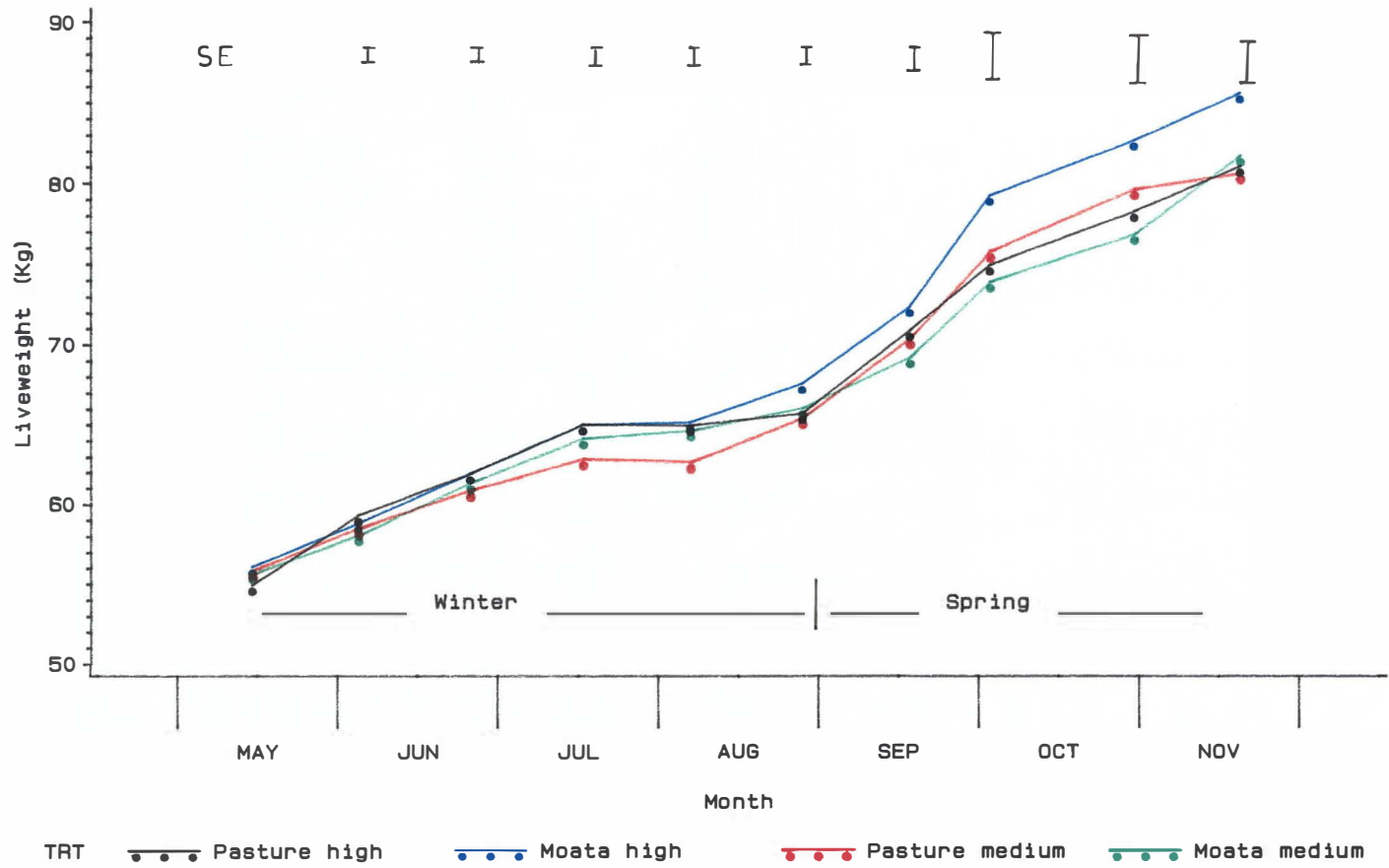


Figure 2.1. Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high and medium DM allowance.

Table 2.5 Liveweight gain (g/day), VFI (g/day) and percentage of stags attaining slaughter weight (92 kg), of grazing stags during winter and spring.

	High Allowance		Medium Allowance		S.E.
	Pasture	Moata	Pasture	Moata	
Liveweight gain:					
Winter	103	110	91	99	18.7
Spring	184	222	186*	176	18.8
VFI:					
Winter	1739	1695	1654	1665	95.0
Spring	2109	2244	-	2207	105.0
Stags to slaughter by end of November:					
(% of total)	0	25	0	17	

* not true figure due to problems of stags jumping through electric fences and out of defined grazing area.

Table 2.6 Carcass characteristics of deer carcasses (n = 45)

	Mean	S.E.
Carcass wt (kg)	51.9	0.29
Dressing-out %	56.1	0.41
GR (mm)	4.8	0.59
Component (% carcass weight)		
Hind legs	37.4	0.06
Saddle	13.7	0.08
Shoulder	22.6	0.06
Ribs and Neck	26.3	0.06

Carcass component was analysed using carcass weight as a covariate.

Whilst 25% (3/12) of Moata high group and 17% (2/12) of Moata medium group attained slaughter weight (92 kg LW) by the end of November, no animals from the pasture groups attained the target liveweight by this date.

2.3.6 Carcass composition

Table 2.6 gives some carcass characteristics of the young stags. There were no treatment effects on the percentage composition of carcass cuts, and the mean values shown in the table are similar to those reported by Drew (1985) for animals of a similar age range.

2.3.7 Melatonin antibody titre

The pattern of melatonin antibody titre development is shown in Figure 2.2. There was a small secondary response in the titre following the first booster vaccination, then a decline to $1:9 \pm 6$ (mean \pm S.E.) 'negative phase' by the time of the second boost (early August). The titre increased gradually to $1:1571 \pm 583$ in November when the experiment was terminated. The mean titre reported here is for 9 out of 16 (56%) antigen vaccinated animals. Seven antigen vaccinated animals did not develop any detectable melatonin antibodies (non-responders; 44%). There was neither a significant antigen nor vehicle treatment effect ($P > 0.10$) on either the LWG, testes size $40.8 \text{ g} \pm 1.6$ (mean \pm S.E.) or carcass characteristics. Within the antigen vaccinated group, this result was the same for both responders and non-responders.

2.3.8 Plasma hormone concentrations

Table 2.7 shows the plasma concentrations of LH and testosterone during spring (October and November). Generally, there was an increase in the plasma LH levels in November, with vaccination treatments having no effect ($P > 0.10$). The testosterone levels were generally slightly lower in November than in October, with the vaccination treatments having no effect ($P > 0.10$). The seasonal plasma concentrations of prolactin are shown in Figure 2.3. The concentrations were low during winter with a rise in spring. Vaccination treatments had no effect ($P > 0.10$).

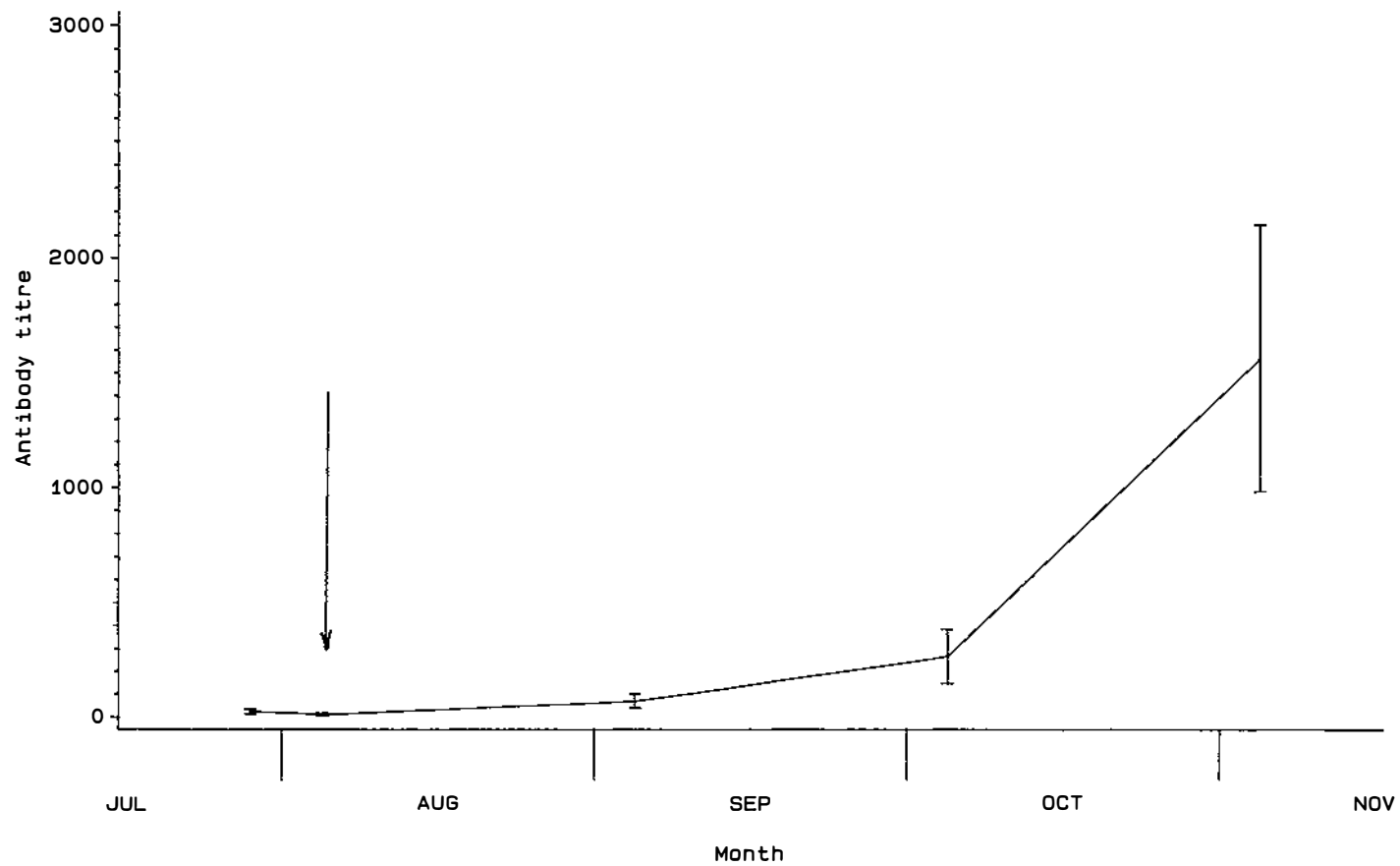


Figure 2.2. Pattern of anti-melatonin antibody titre development in the red deer. (↓) indicates booster, (I) indicates SE.

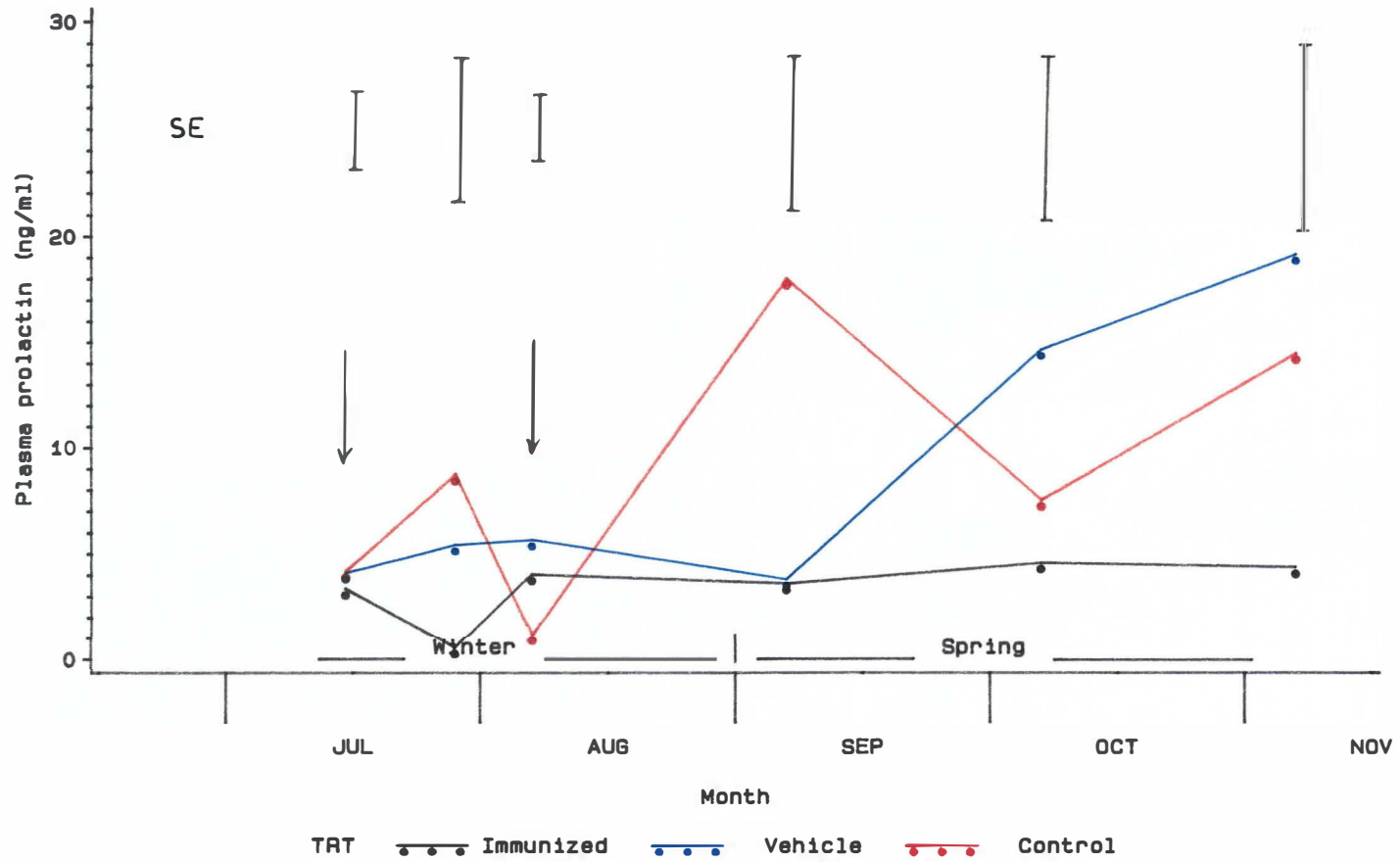


Figure 2.3. Plasma prolactin concentrations of weaner red deer stags immunized with melatonin antigen and vehicle only and the non-immunized (control) group. (↓) indicates booster.

Table 2.7 Plasma concentrations of LH and testosterone (ng/ml) in red deer stags during October and November 1987.

	Vaccination treatment group		
	Control (SE)	Immunised ¹ (SE)	Vehicle (SE)
No. of animals	15	9	16
	<u>LH</u>		
October 8	0.85 (0.18)	0.83 (0.22)	1.15 (0.17)
November 5	1.39 (0.44)	1.47 (0.54)	0.95 (0.43)
	<u>Testosterone</u>		
October 8	2.02 (0.40)	2.22 (0.50)	1.47 (0.39)
November 5	7.40 (0.37)	1.90 (0.45)	1.57 (0.36)

¹ Responders to the anti-melatonin vaccination only

2.4 DISCUSSION

The present experiment was based on the concept that providing young stags with high nutritive value food in generous amounts (Milne *et al* 1987), and removing physiological constraints that limit their VFI during winter, should improve their liveweight gains. The economics of venison production in New Zealand means that it is important that young stags gain weight as fast as possible during winter, as compensatory growth during spring usually fails to fully make up weight deficits at the end of winter (Fennessy and Milligan 1987).

Good liveweight gains during both winter and spring are essential for young stags to attain suitable target slaughter weights (92 kg LW; > 50 kg carcass) by one year of age or less, to produce venison at the peak time required by overseas markets (August-November).

In this experiment, 25% of the animals on Moata high treatment and 17% of those on Moata medium treatment attained a suitable slaughter weight (92 kg LW) by the end of November.

2.4.1 Seasonal Liveweight and VFI

Growth in farmed red deer is seasonal (Blaxter *et al* 1974; Drew 1976; Moore and Brown 1977; Fennessy *et al* 1981). The result of the present experiment is in agreement with this very well documented fact, with the animals growing slowly during winter and faster during spring (Fig. 2.1). This is because the VFI is much higher during spring/summer than during winter (Blaxter *et al* 1974; Pollock 1975; Milne *et al* 1978; Kay 1979). This is also shown in the present experiment, with estimated MEI during spring being 28% higher than the MEI during winter. The calculated ME intakes in the present study are also very close to those reported by Fennessy and Milligan (1987; Table 2.8) in both winter and spring.

Table 2.8 Comparison of the estimated ME intakes of growing red deer stags.

Author	Liveweight range (kg)	Liveweight gain (g/d)	Estimated ME Required (MJ/d)
	<u>Winter</u>		
Fennessy and Milligan (1987)	48-65 ¹	89 ¹	20.9
Present experiment	55-68	91-110	20.2
	<u>Spring</u>		
Fennessy and Milligan (1987)	65-90 ¹	243 ¹	27.0
Present experiment	66-86	176-222	25.9

¹ calculated from Fennessy and Milligan (1987).

2.4.2 Liveweight gain

Winter LWG was similar for all treatments, indicating that high allowance feeding did not have any significant advantage over medium allowance feeding during this period. To achieve high growth rates of about 200 g/d in autumn, it is necessary to offer a pasture allowance of about 3 times the daily dry matter intake (Fennessy and Milligan 1987). This

obviously does not apply in winter because the 3.5 times the estimated daily DM intake (6.3 kg DM/animal/d - high allowance) in the present experiment did not show any advantage over the medium allowance (4.5 kg DM/animal/d) or 2.5 times the estimated daily DM intake. The winter LWG (91-110 g/d) achieved in this trial falls short of the upper limit of 100-150 g/d suggested as suitable target value for young stags on high quality diet by Fennessy and Milligan (1987), but is greater than 45 g/d reported by Moore and Brown (1977). It is also better than most of the figures (6-122 g/d) published by Moore *et al* (1988).

During spring, the LWG of the Moata high group showed a slight superiority over the pasture high and Moata medium groups. This may be due to the rise in the Moata component of the sward - from an average of 17% in winter to 36% in spring (up by 112%). This is an indication that a higher percentage of Moata annual ryegrass in the sward may produce a significant response in spring weight gains, and should be evaluated in future experiments.

2.4.3 Nutritive value of Moata annual ryegrass and perennial ryegrass

There was no treatment effect on the OMD and M/D values (Table 2.3), the high values during winter and spring showing that high quality pasture was maintained during both seasons. There were clear differences in leaf tensile strength between the two ryegrass varieties, with Moata annual ryegrass leaves being weaker than those of perennial ryegrass. This is consistent with the results published by Evans (1964). Ryegrass types of low leaf strength have a lower cellulose and reduced sclerenchyma percentages (Evans 1964). Animal production trials conducted on the same pure sward varieties using sheep showed that the liveweight gains on Italian (i.e. annual) ryegrass were greater than those on perennial ryegrass (Rae *et al* 1964). In experiments with perennial ryegrass, it has been shown that selection for low leaf shear strength resulted in increases in the rate of DM consumption, voluntary DM intake and rate of rumen degradation by sheep (Mackinnon *et al* 1988; Inoue *et al* 1989). It is possible that superior growth of sheep grazing annual (Italian) compared with perennial ryegrass pastures can also be explained by similar mechanisms.

The nutritional and non-nutritional benefits of Moata were not very large in the present experiment, probably because the mixed sward did not have a high enough Moata component. This needs to be ensured in future comparisons.

2.4.4 Melatonin antibody titre

Antibody development was still increasing when the experiment was terminated in early November (5 months after the primary vaccination). Therefore the peak antibody titre in this trial is unknown. Using the same antigen as in the present experiment, McConnell *et al* (1987) raised a titre against melatonin in the tamar Wallaby (*Macropus eugenii*), that peaked at $1:3749 \pm 1200$ (mean \pm s.e.m.) about 12 weeks after the primary vaccination. The booster vaccination was given after about 8 weeks. In both of these cases, the time taken to reach peak antibody titre during the secondary response is longer compared with cases of conventional vaccination against infections. Following a primary vaccination against tetanus, with a booster 2 weeks later, it takes about 4 weeks after the primary vaccination for animals to develop peak antibody titre (Tizard 1977).

The highest titre was recorded in late spring, which is a period of low melatonin secretion. Ideally, the antibody should be raised by late autumn/early winter and remain high during winter, when melatonin production is high. To achieve this, with such a long lag period, it seems that the primary vaccination should be given several months before the start of winter (May), i.e. February-March of the same year. With the vaccination given much earlier than in the present experiment, and a high antibody titre raised at an earlier time, the vaccination treatment should have a better chance of increasing winter LWG. Duckworth and Barrell (1989) obtained increases in LWG to melatonin immunisation in young red deer using this concept.

2.4.5 Plasma hormones

Mean LH concentrations of entire red deer stags were lowest from September to March and highest between May and August (Suttie *et al* 1984) whilst Asher *et al* (1989) reported that the concentrations were lowest for the fallow deer bucks from May to December and highest between February and April. The seasonal patterns of mean plasma testosterone concentrations were similar to those of LH with peak concentrations for testosterone occurring in late April (Asher *et al* 1989). The plasma LH levels (0.83 - 1.15 ng/ml) recorded in October in this present experiment were similar to the value recorded by Suttie *et al* (1984) for red deer stags in summer (N. Hemisphere). Except for a slight decrease in concentration for the vehicle group, the immunised and control groups showed increases in concentrations in November, indicating that the LH level was following the

normal seasonal pattern. The plasma testosterone levels in October in the present experiment (1.47 - 2.22 ng/ml) were similar to the concentration recorded by Suttie *et al* (1984) during spring (N. Hemisphere). The vehicle group showed a slight increase in concentrations in November, whilst the immunised and control groups showed a decline in concentrations. An equally seasonal pattern of change was recorded for plasma prolactin (Fig. 2.3); low during winter, with elevated concentrations occurring during spring as reported for red deer stags by Barrell *et al* (1985). The present experiment shows that the plasma concentrations of LH and prolactin generally followed the normal seasonal patterns with the vaccination treatment having no effect. This is consistent with lack of vaccination treatment effect on the growth rate of the stags, which could be attributed to late commencement of vaccination of the stags in June 1987.

2.4.6 Carcass cuts

This experiment did not show any treatment effects on the dressing-out (%), proportions of different cuts, fatness, or any other carcass characteristics measured. This is probably a reflection of the lack of clear treatment effects on the LWG of the animals.

2.5 CONCLUSIONS

1. Perennial ryegrass/white clover pastures direct-drilled in late summer with Moata annual ryegrass contained 17-19% DM as Moata during winter and 27% DM (medium allowance) and 36% DM (high allowance) as Moata during spring. Direct-drilled pastures contained correspondingly lower proportions of perennial ryegrass, the drilling having no effect on the proportions of white clover, other species and dead matter. White clover comprised low proportions of the feed on offer, in both winter (6% DM) and in spring (9% DM).
2. OMD, total N and M/D values of all pastures were high at all times, indicating that the feed on offer was of high nutritional quality.
3. Leaf tensile strength of Moata annual ryegrass was substantially lower than that of perennial ryegrass ($P < 0.001$), indicating that its nutritive value should be higher than that of perennial ryegrass.

vaccinated and control, excluding vehicle treatment, since the adjuvant alone did not show any effect in the present trial.

- (b) A system of management that is more suited to deer should be developed, since the management system used as normal for sheep and cattle experiments poses problems when applied to deer experiments, because of the difficult temperament of the red deer stags. Weaned calves should be fed grains (barley) 100-300 g/animal/d for about 5 weeks to get them used to contact with people. They should be introduced to electric fences in the paddock and other facilities in the handling yard regularly for about one month before the experiment starts.
- (c) Adoption of a management practice that is both suitable for animal handling and for pasture quality control, e.g. set stocking system.
- (d) Increasing the Moata annual ryegrass component of the swards to 50-70% by using a higher seed rate and a cross-pass drilling technique (i.e. drilling the paddocks in two directions).

CHAPTER 3

**STUDIES ON THE EFFECTS OF DIFFERENT SWARDS HEIGHTS,
THE INTRODUCTION OF ANNUAL RYEGRASS AND IMMUNIZATION
AGAINST MELATONIN UPON EARLY VENISON PRODUCTION**

3.1 INTRODUCTION

A previous experiment (Chapter 2) showed that it was possible for weaner red deer stags to attain LWG of 103 g/d in winter and 184 g/d in spring when grazing perennial ryegrass/white clover pasture. Although annual ryegrass supported greater LWG than perennial ryegrass in experiments with sheep (Ulyatt 1981; Rae *et al* 1964), responses to introducing Moata annual ryegrass into perennial ryegrass/white clover deer pastures through direct drilling were present in spring but of low magnitude. The possible reason was low percentage of Moata present in the pasture.

Major problems of animal temperament were encountered in the previous experiment (Chapter 2), and it was considered crucial to have an experimental design in future experiments that was more appropriate for deer. To counteract the problems of animal temperament, the present experiment was done under continuous stocking instead of rotational grazing. During the pre-experimental period, the weaner stags were fed small supplements of barley in order to quieten them. They were also trained to respect electric fences and introduced to the handling yard and facilities during March and April, before the experiment commenced in May.

Because immunising stags at 6 months of age against melatonin in the previous experiment failed to produce a significant effect, there was a need to re-evaluate the effect of immunisation in the present experiment by commencing at an earlier date; 3 months of age (at weaning).

The overall objective was to investigate systems for growing weaner red deer stags as rapidly as possible over winter and spring, to attain a target slaughter liveweight of 92 kg (> 50 kg carcass) by under one year of age. The following experimental treatments were investigated as possible methods for achieving this objective.

1. Effects of different sward heights (5 cm v 10 cm) upon animal growth.
2. The effect of inclusion of Moata annual ryegrass at a higher seed rate (20 kg/ha) on the winter and spring LWG, and upon pasture growth rate and composition.
3. Effect of earlier immunisation of stags against melatonin (at weaning in early March) upon the rate of LWG, especially in winter.

4. Diet selection studies using rumen fistulated stags.

A preliminary report of this experiment has been published (Ataja *et al* 1989).

3.2 MATERIALS AND METHODS

3.2.1 **Experimental design**

Fifty-two weaner red deer stags were grazed under a continuous stocking system at two different sward heights (5 cm and 10 cm) on either perennial ryegrass/white clover pasture or the same direct-drilled with Moata annual ryegrass. Balanced numbers of animals within each grazing treatment group were given a vaccination treatment designed to immunise against melatonin, with the aim of increasing LWG during winter. The experiment was conducted on the Massey University deer research unit between May and December 1988.

3.2.2 **Animal temperament**

Fifty-two weaner red deer stags of about 5 months of age were purchased from Ben Nevis Station, Dannevirke, Hawke's Bay and transported to Massey University on April 12, 1988.

The problems of animal temperament were a major factor in the 1987 grazing experiment (Chapter 2). Based on that experience, it was found very necessary to quieten the young stags before the commencement of the present experiment. In order to get the young stags used to handling, they were fed barley from about two weeks prior to weaning (March 15), and this was then continued until the end of April. Barley was fed to the stags in small amounts initially and was steadily increased to 300 g/head/day, over a period of eight weeks. Grain feeding was not intended as a source of energy, but was more aimed at getting the young stags used to human presence so that they might settle down quickly. This method had a marked effect in the present experiment of making the young deer of quieter temperament.

The stags were constantly exposed to electric fences in the pre-experimental period, and were also herded into the handling yards at intervals. They were also introduced to

various handling facilities twice per week for four weeks to get them used to the handling routine before the experiment started.

3.2.3 Animal allocation

On April 15, 1988, the stags were then allotted at random into four groups; two groups of fourteen stags each, and two groups of twelve stags each. The two groups of fourteen stags were each randomly allocated to the two Moata treatments (5 cm and 10 cm), whilst the other two groups of twelve stags were each randomly allocated to the two pasture treatments (5 cm and 10 cm). Each animal group was further sub-divided at random into two sub-groups of seven stags (Moata treatments) and six stags (pasture treatment), for the purpose of vaccination against melatonin. All fourteen or twelve stags in each treatment grazed together as a single group. Mean liveweight (kg) at the time of allocation to grazing treatments was 55.2 ± 3.63 (mean \pm SD). All animals were ear tagged and drenched with "IVOMEC" the same day. The stags were also vaccinated against clostridial infections using "Convax 5" Vaccine (Aluminium hydroxide Adjuvant and 0.015% thiomersal; Coopers Animal Health N.Z. Limited) on April 22. Dose rate was 2 ml/animal subcutaneously, on the side of the neck in the anterior half region. Thereafter, they were weighed straight off pasture at three weekly intervals, and further drenched with "IVOMEC" at monthly intervals.

As the animals attained the target liveweight of 92 kg, they were sent for slaughter in batches at the Feilding DSP of Venison New Zealand Limited.

3.2.4 Rumen fistulated stags

Eight 3.5 year old, castrated, hand reared and rumen fistulated red deer stags weighing 99 ± 9.1 kg (mean \pm SD) were randomly allocated amongst the four grazing groups (2 stags/group), for the purpose of diet selection studies. Diet selection studies are normally done using oesophageal fistulated animals.

In June and November, the fistulated stags were allowed to graze with their respective groups for four days and then were brought into the yard, where they were sedated, using 10% "Rompun" at the dose rate of 0.2 ml/stag, intramuscularly. Under mild sedation, the

entire rumen digesta was bailed out into a bucket, then covered with an airtight lid and left standing in a container of hot water. One litre of artificial saliva prepared by the method of Baumgardt *et al* (1962) was poured into the rumen and the fistula replaced. The stags were each given an injection of 2 ml "Reccrvyl" (Yohimbine hydrochloride; Aspiring Animal Services, Wanaka, N.Z.) intravenously, for the reversal of "Rompun"-induced sedation. The stags were kept in the yard for at least another forty-five minutes before being turned back to their respective grazing groups, where they were left to graze for about two hours. They were then brought back into the yard and the freshly eaten ingesta was bailed out of the rumen into aluminium foil containers without further sedation, the warmed rumen digesta returned to the rumen and the stags returned to their paddock. Bailing was done over a period of 3 days, using two or three stags per day.

3.2.5 Pasture management

The stags were grazed under a continuous stocking system at two different sward heights (5 cm v 10 cm), on either perennial ryegrass/white clover pastures (hence referred to as 'pasture') or the same direct-drilled with Moata annual ryegrass (hence referred to as 'Moata'; Appendix Figure 2).

There were a total of six paddocks used in the present experiment. The six paddocks consisted of four main paddocks (1 ha each) and two reserve paddocks (0.75 ha each). The four main paddocks consisted of two paddocks each for the Moata (one 5 cm and one 10 cm) and pasture (one 5 cm and one 10 cm) treatments, respectively. The two reserve paddocks were allocated either Moata and pasture treatments, and were both maintained at 10 cm sward height. The reserve paddocks were thought necessary especially during winter when the herbage production would be lowest, to take grazing pressure off the main paddocks (10 cm sward height treatment). At the stocking rate of twelve or fourteen stags/ha, it was not possible to maintain a sward height of 10 cm during winter.

The Moata paddocks were direct drilled on March 1, 1988 at the seed rate of 20 kg/ha using a cross-pass (i.e. in both directions) drilling technique (Baker 1976), band sprayed, at 10 kg seed/pass. Yates "Blitzem" pellets were applied to the direct drilled paddocks at the rate of 12 kg/ha on March 2, 1988, to kill slugs and other molluscs that might feed on the Moata seeds. All paddocks were top-dressed with urea on May 15, at the rate of 100 kg urea (46 kg N)/ha, and on June 29 and July 19, with 50 kg urea (23 kg N)/ha, respectively. On October 20, 1988, the four main paddocks were top-dressed with 100 kg urea (46 kg N)/ha.

The target sward heights of an average of 5 cm and 10 cm were established on the Moata treatments at the same time as the pasture 5 cm treatment by May 6, and the paddocks were stocked with stags. The target sward height of 10 cm was achieved on the pasture treatment on May 23, and it was stocked with stags the same day. The experiment commenced on May 30, 1988.

Sward heights were monitored three times a week (Monday, Wednesday and Friday). This was done by the use of a rising plate meter (the Hammond Doyle Co. Pty Limited, Australia) and a sward stick (for the purpose of comparing the two instruments). Fifty random plate meter readings were recorded for each paddock and the average sward height for the paddock calculated. The method of stocking rate adjustments to compensate for sward height changes was as published by Hodgson *et al* (1986). During winter, the stock shifting was from the 10 cm treatment main paddocks to the reserve paddocks. During spring the reserve paddocks were no longer required and stock was shifted back into the main experimental paddocks to keep up with increased herbage production. Extra stock was moved into all treatment paddocks and in addition, the grazing areas in the 5 cm treatment paddocks were reduced by half using electric fences (i.e. the animals were grazing 0.5 ha), as groups of animals were sent for slaughter.

3.2.6 Pasture production and composition

Pasture growth rates (kg DM/day) and herbage mass on offer (kg DM/ha; Appendix II) were determined during winter and spring. Five quadrat (size = 0.2 m²) herbage sample cuts made to soil level were taken from areas corresponding to the target sward heights (5 cm or 10 cm) in each main paddock. The herbage samples were then washed, oven dried at 90 °C for 17 hours and weighed to determine the herbage mass (kg DM/ha). Five adjacent areas of similar sward height were protected by metal cages (90 cm x 46 cm x 33 cm). Three weeks later, five quadrat sample cuts, made to soil level were taken from inside the cages. The herbage samples were washed, oven dried and weighed. Pasture production rate over the three week period was obtained from the difference between the mean herbage mass (kg DM/ha) of the two cut dates. Herbage sample cuts were made every three weeks. The cages were shifted to new areas and the same process was repeated for the duration of the experiment.

Five random herbage sample cuts made just above soil level were taken from each main paddock every month for laboratory *in vitro* digestibility analyses and for total nitrogen

determination. The herbage samples were not washed. Five sub-samples were taken monthly from each of these herbage samples for botanical dissection into various components.

3.2.7 Vaccination procedures and blood sampling

A single dose of the anti-melatonin vaccine was composed of:

- 1 mg antigen ARH-291 (5-methoxy-tryptamine hemisuccinamide conjugated to human serum albumin (HSA)).
- 1 ml physiological saline (9 g NaCl/litre)
- 1 ml Freund's complete adjuvant (FCA)

Vaccine for the primary injections was prepared using Freund's complete adjuvant, while vaccine for the subsequent booster injections was prepared using Freund's incomplete adjuvant. The vaccine which was a white emulsion was drawn into 10 ml syringes carefully, avoiding air bubbles, and 18G needles were fitted. The vaccine was stored at 4°C ready for use.

In each group, seven or six stags (Moata or pasture treatments, respectively) were vaccinated with the anti-melatonin vaccine and seven or six stags likewise were left unvaccinated (control). The stags received primary subcutaneous injections at weaning in March 4-15, 1988, 1 ml at two separate sites either side of the neck at the rate of 1 mg antigen/stag. First and second booster injections were given in the same manner on June 9, and July 7, 1988, respectively.

Blood (10 ml) was taken from the jugular vein of all animals by venipuncture on the day of the first booster injection (bleeding before booster vaccination given), 7 days post-booster, 4 weeks post-booster and at monthly intervals thereafter until November. The blood samples were collected in 10 ml vacutainers (Nipro Medical Industries Ltd, Japan), using Na heparin as anti-coagulant. The blood samples were centrifuged at 4°C, at 3000 RPM (1851 g) for 20 minutes to harvest plasma used for measuring melatonin antibodies (titre) and for hormone determinations. Each plasma sample was stored at -20°C in five 1 ml lots.

3.2.8 Slaughter and carcass data

Stags that attained the target weight were treated as described in the previous experiment (Chapter 2) and were sent in groups to the Fielding DSP for slaughter starting on November 17, 1988. The experiment was terminated on December 23, 1988 and those stags that did not attain the target weight were grazed on ad lib for the purpose of finishing and a further experiment (Chapter 4).

At the DSP, the rump fat width (from the vertebra column to the lateral margin of the fat depot; mm) was measured for all carcasses, the carcass weights (kg) were recorded, the GR (mm) was recorded for both left and right sides of all carcasses and the testes were collected and weighed (g) at the Massey University meat laboratory.

3.2.9 Laboratory methods

All herbage and rumen ingesta samples were stored at -20°C, freeze-dried and ground (1 mm diameter sieve) prior to laboratory analyses. In vitro digestibility was determined by the methods of Roughan and Holland (1977) and the total nitrogen (N) was determined by the Kjeldahl procedure as described in detail in the previous experiment (Chapter 2).

Fresh herbage samples for botanical dissection were stored at 4°C, and the dissection in this experiment was done as described in the previous experiment (Chapter 2). The results were expressed as % DM.

Dissection of fresh rumen ingesta was done using a flotation technique (D.A. Clark, pers. comm.) Results were expressed as proportion (% contact).

The anti-melatonin antibody titre was determined by the method of Abraham (1974) as described in detail in the previous experiment (Chapter 2). The lowest titre measured (detectable antibody) was 1:100.

The plasma LH concentrations were determined using the procedure described for sheep plasma by Scaramuzzi et al (1970) and validated for fallow deer plasma by Asher et al (1986). Plasma testosterone concentrations were determined using procedures similar to the one described by Peterson et al (1978), and plasma prolactin concentrations were measured using the method of van Landeghem and van de Weil (1978) as described in Chapter 2.

3.2.10 Statistical analyses and calculation of data

The experimental data was analysed using General Linear Models procedure (GLM), as a 2x2x2 factorial design, with two different sward heights (5 cm v 10 cm), two pasture treatments (pasture and Moata) and two types of vaccination (not immunized or control and anti-melatonin vaccine immunized). LSM was used to test the differences between treatments.

The winter LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at August 31} - \text{Liveweight (kg) at May 30}}{93 \text{ days}} \times 1000$$

using the initial LW at April 15 as a covariate.

The spring LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at November 14} - \text{Liveweight (kg) at August 31}}{76 \text{ days}} \times 1000$$

using LW at the start of spring (August 31) as a covariate.

The botanical composition (% contact) of the rumen ingesta on dissection was calculated as:

$$\frac{\text{individual grass component counts}}{\text{total grass sample counts}} \times 100$$

The daily rate of pasture production (kg DM/d) was calculated as:

$$\frac{\text{Difference (kg DM) between cuts}}{\text{period between cut dates (days)}}$$

The plasma prolactin concentrations were analysed as described in section 2.2.7 (Chapter 2).

3.3 RESULTS

3.3.1 **Seasonal pattern of sward components**

Figures 3.1a - 3.1e show the percentage composition (% DM) for the various components in the two sward types and their seasonal patterns of change. There was a marked decrease in the Moata annual ryegrass component in the Moata swards starting in early July (Fig. 3.1a). The perennial ryegrass component in the Moata swards increased during winter and remained fairly steady throughout spring. The dead matter component in the 10 cm swards and the white clover component in the 5 cm swards both increased during spring (Figs 3.1c and 3.1e)

The Moata annual ryegrass component in both 5 cm and 10 cm Moata swards was greater in winter than in spring ($P < 0.001$). During winter the Moata annual ryegrass component in the 5 cm sward (46%) was higher than that in the 10 cm sward (33%), (Tables 3.1a and 3.1b).

Tables 3.1a and 3.1b show that pasture swards had a greater component of perennial ryegrass than the Moata swards ($P < 0.001$) during both winter and spring. The ryegrass component of the Moata 10 cm swards was greater than that of the 5 cm swards ($P < 0.05$).

The dead matter component was greater during spring than during winter ($P < 0.001$; Tables 3.1a and 3.1b), with the 10 cm swards having higher dead matter than the 5 cm swards ($P < 0.001$).

The white clover component of the swards was significantly greater during spring than during winter ($P < 0.01$), with the 5 cm swards having higher white clover component than the 10 cm swards ($P = 0.06$, Tables 3.1a and 3.1b) during spring.

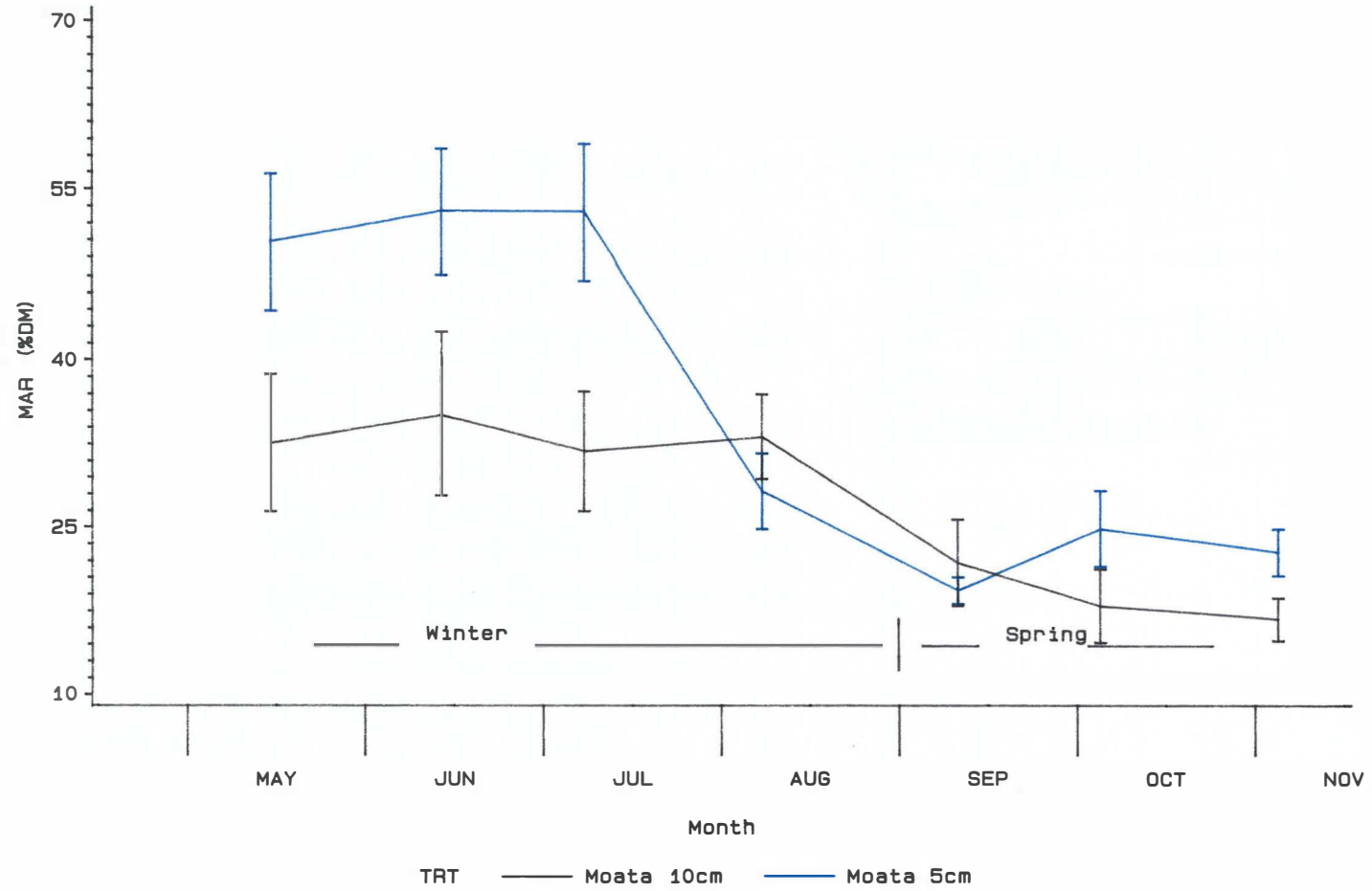


Figure 3.1a. *The proportion of Moata annual ryegrass on offer in the grazed pastures. (I) indicates SD.*

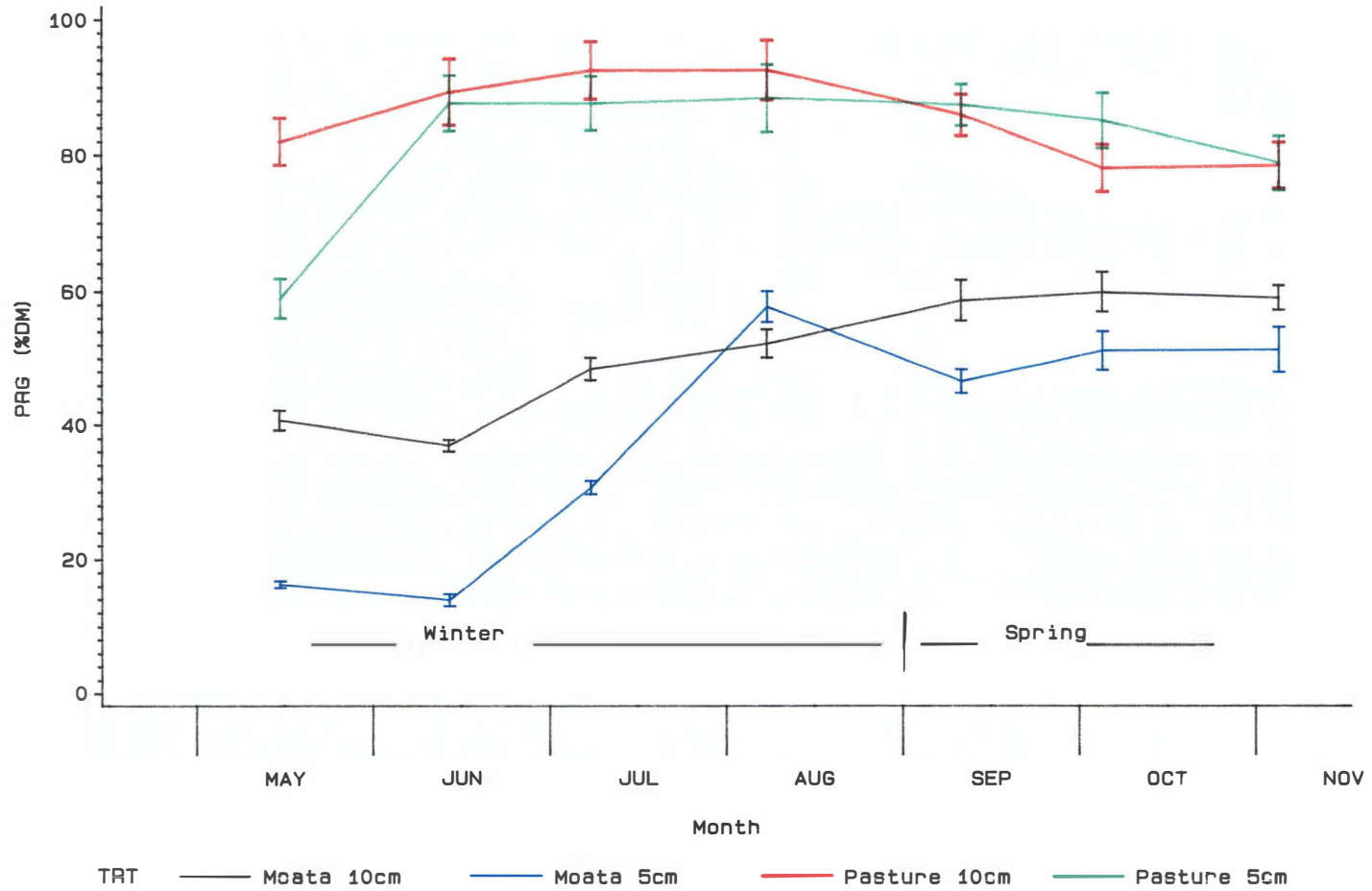


Figure 3.1b. The proportion of perennial ryegrass on offer in the grazed pastures. (I) indicates SD.

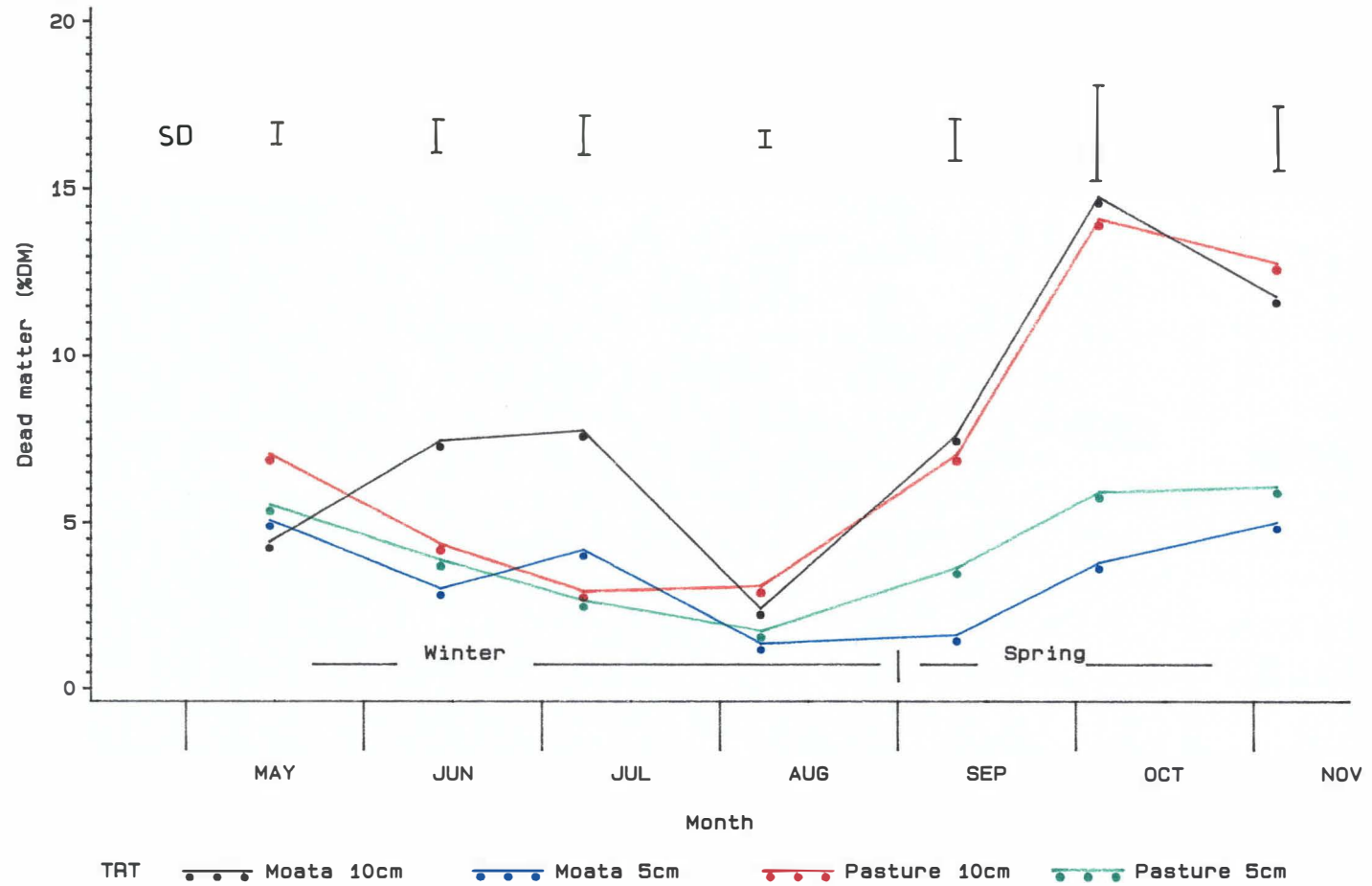


Figure 3.1c. The proportion of dead matter in the grazed pastures.

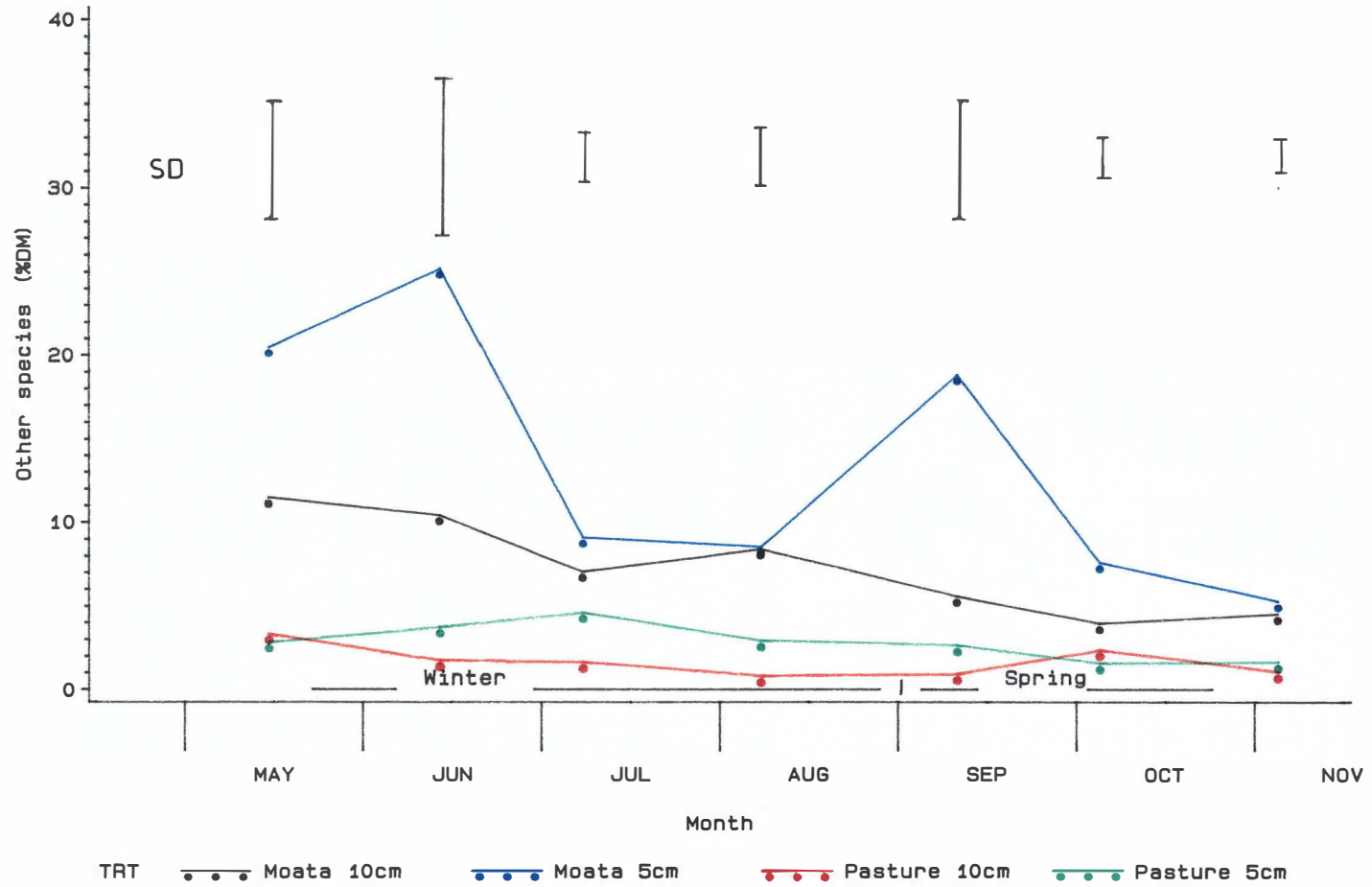


Figure 3.1d. The proportion of other species in the grazed pastures.

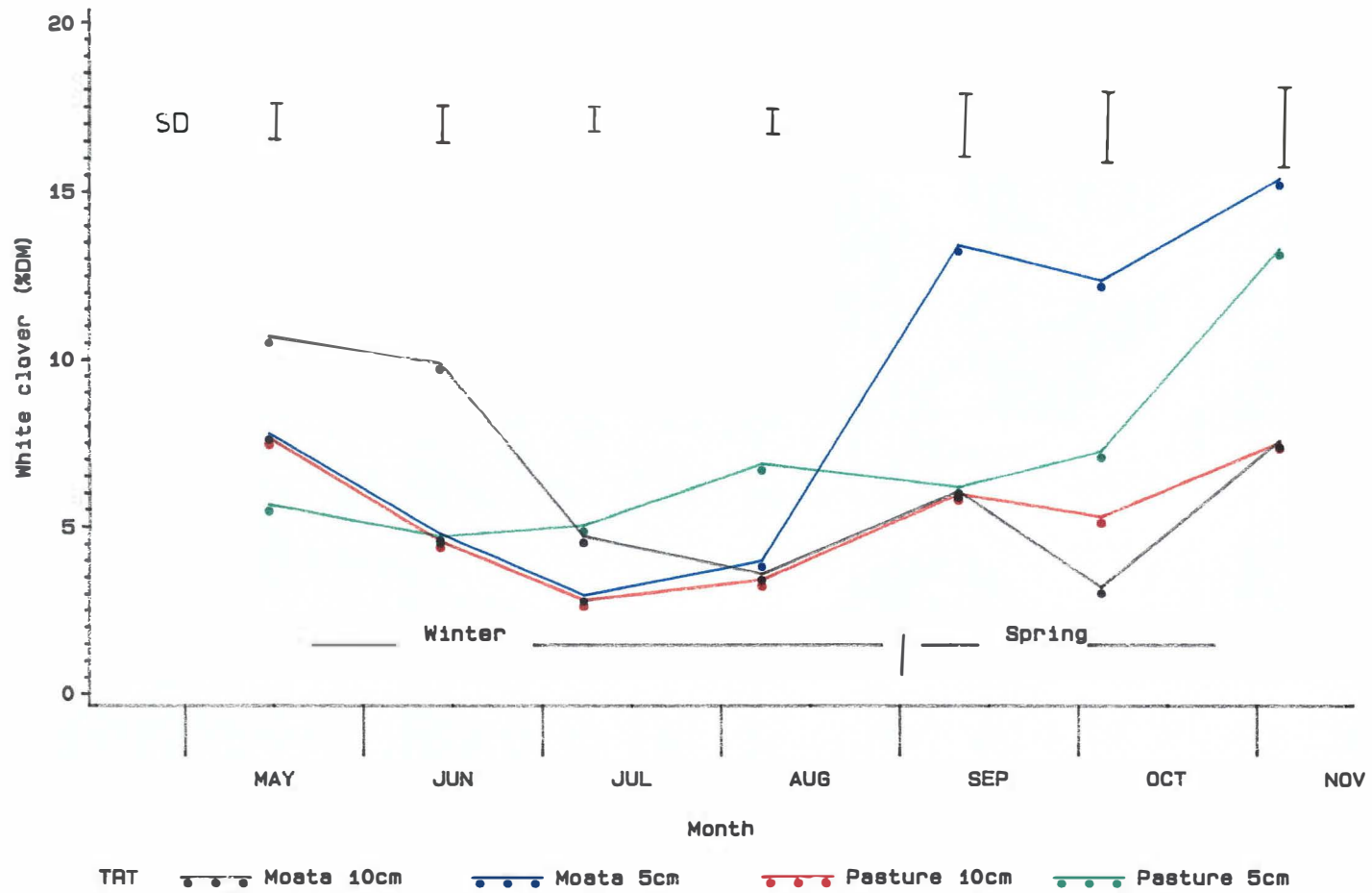


Figure 3.1e. The proportion of white clover on offer in grazed pastures.

Table 3.1a Botanical composition (% DM) of the swards during winter (May-August) 1988.

Sward Height	Sward type		Perennial ryegrass	Moata Annual ryegrass	White Clover	Other species	Dead matter
10 cm	Pasture	Mean (SD)	89 (5.0)	0	5 (2.1)	2 (1.1)	4 (1.9)
	Moata	Mean (SD)	45 (7.0)	33 (1.4)	7 (3.6)	9 (2.0)	6 (2.6)
5 cm	Pasture	Mean (SD)	88 (0.5)	0	6 (1.2)	4 (0.8)	3 (1.1)
	Moata	Mean (SD)	30 (20.2)	46 (12.0)	5 (2.1)	16 (8.3)	4 (1.6)

No. of dissections = 4 (20 samples/sward type)

Table 3.1b Botanical composition (% DM) of the swards during spring (September-November) 1988.

Sward Height	Sward type		Perennial ryegrass	Moata Annual ryegrass	White Clover	Other species	Dead matter
10 cm	Pasture	Mean (SD)	81 (4.4)	0	6 (1.1)	1 (0.8)	11 (3.7)
	Moata	Mean (SD)	59 (0.6)	19 (2.6)	6 (2.2)	5 (0.8)	11 (3.6)
5 cm	Pasture	Mean (SD)	84 (4.4)	0	9 (3.8)	2 (0.6)	5 (1.4)
	Moata	Mean (SD)	50 (2.7)	22 (2.8)	14 (1.5)	11 (7.3)	3 (1.7)

No. of dissections = 3 (15 samples/sward type)

The Moata swards had higher other species component than the pasture swards ($P < 0.001$; Tables 3.1a and 3.1b), with the other species component in the 5 cm sward being greater than that in the 10 cm sward ($P < 0.05$). The other species component in the swards was higher in winter than during spring.

3.3.2 Botanical composition of herbage and rumen ingesta

Table 3.2 shows the botanical composition of the diet on offer (herbage) and the diet selected by the grazing red deer stags (ingesta) in June and November. The data show that the values for the perennial ryegrass and other species component in the ingesta were greater than those in the herbage on offer ($P < 0.001$) during both months. The ingesta values for both white clover and Moata annual ryegrass components were smaller than the corresponding values for herbage on offer ($P < 0.001$) during June and November.

3.3.3 Chemical composition of pastures

The pattern of total N concentration and OMD of herbage during winter and spring are shown in Figures 3.2a and 3.2b respectively. The figures show a steady decrease in the values of both the total N concentration and OMD between June and December, with the values being lowest in December.

Herbage nitrogen concentration was similar for all swards, but it was greater during winter than during spring ($P < 0.001$; Tables 3.3a and 3.3b). The apparent increases in nitrogen concentration in August and November (Fig. 3.2a) could be due to urea application to the pastures in July and October respectively. The values of the OMD during winter were greater than those during spring ($P < 0.001$; Tables 3.3a and 3.3b), and the herbage maintained at 5 cm sward height appeared to have greater OMD values than that maintained at 10 cm sward height. Tables 3.3a and 3.3b show high total N, OMD and M/D values during both seasons, indicating that the pastures were kept in the vegetative state and of high nutritive quality. The total N concentration, OMD and M/D values for the ingesta were similar to those for the feed on offer during both months.

Table 3.2 Botanical composition of herbage (% DM) and rumen ingesta (% contact) of grazing stags during June and November 1988

Sward height	Herbage type		Perennial ryegrass and other species	White Clover	Moata annual ryegrass
<u>JUNE</u>					
10 cm	herbage	pasture	95.2	4.8	-
		Moata	51.3	10.7	38.0
	ingesta	pasture	99.1	0.9	-
		Moata	81.3	3.5	15.2
5 cm	herbage	pasture	95.1	4.9	-
		Moata	40.3	5.0	54.7
	ingesta	pasture	96.4	3.6	-
		Moata	90.1	4.6	5.3
<u>NOVEMBER</u>					
5 cm	herbage	pasture	85.8	14.2	-
		Moata	59.8	16.2	24.0
	ingesta	pasture	96.8	3.2	-
		Moata	77.8	6.9	15.4

No. of samples per month: herbage = 5/herbage type
 ingesta = 10

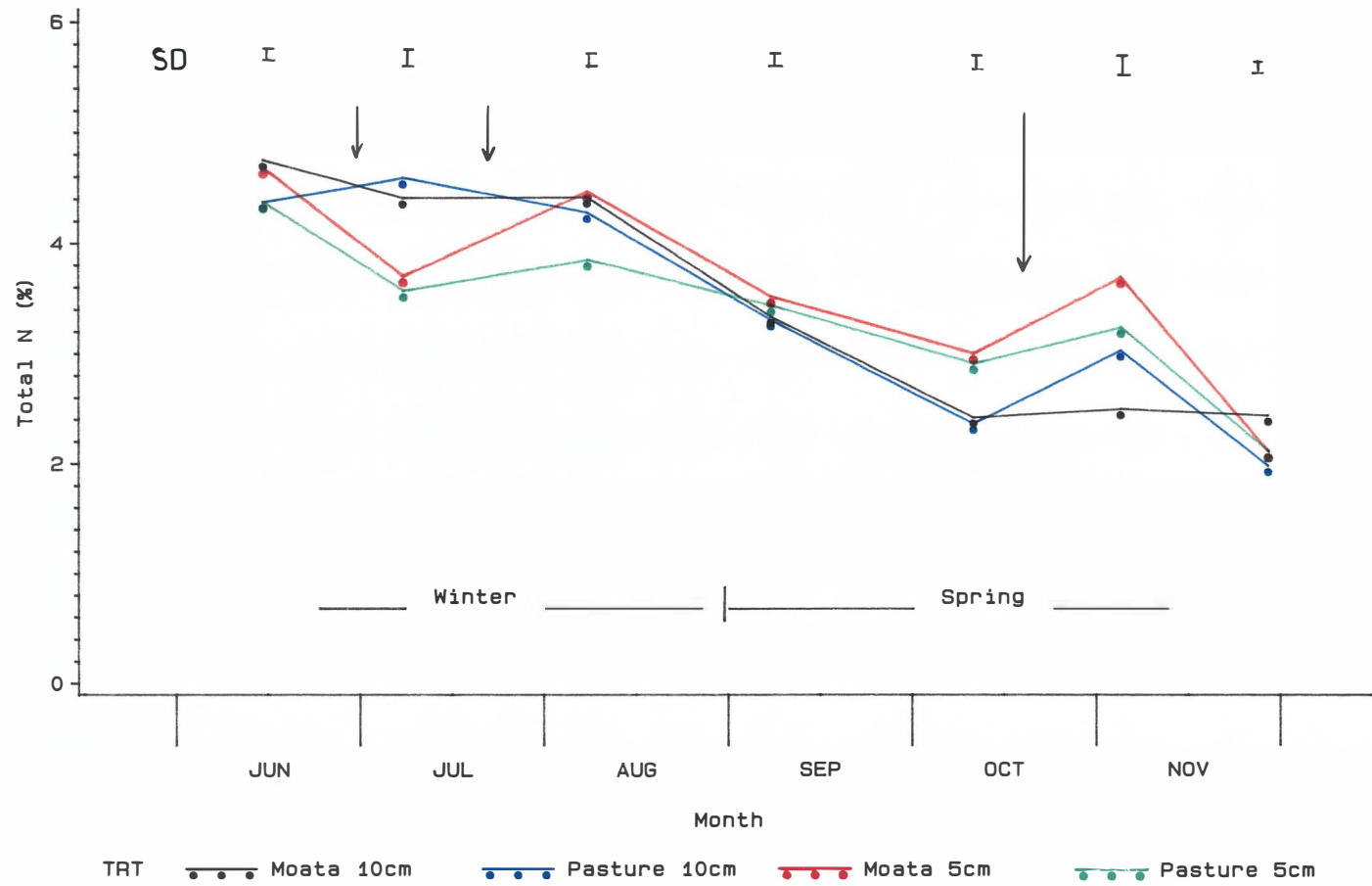
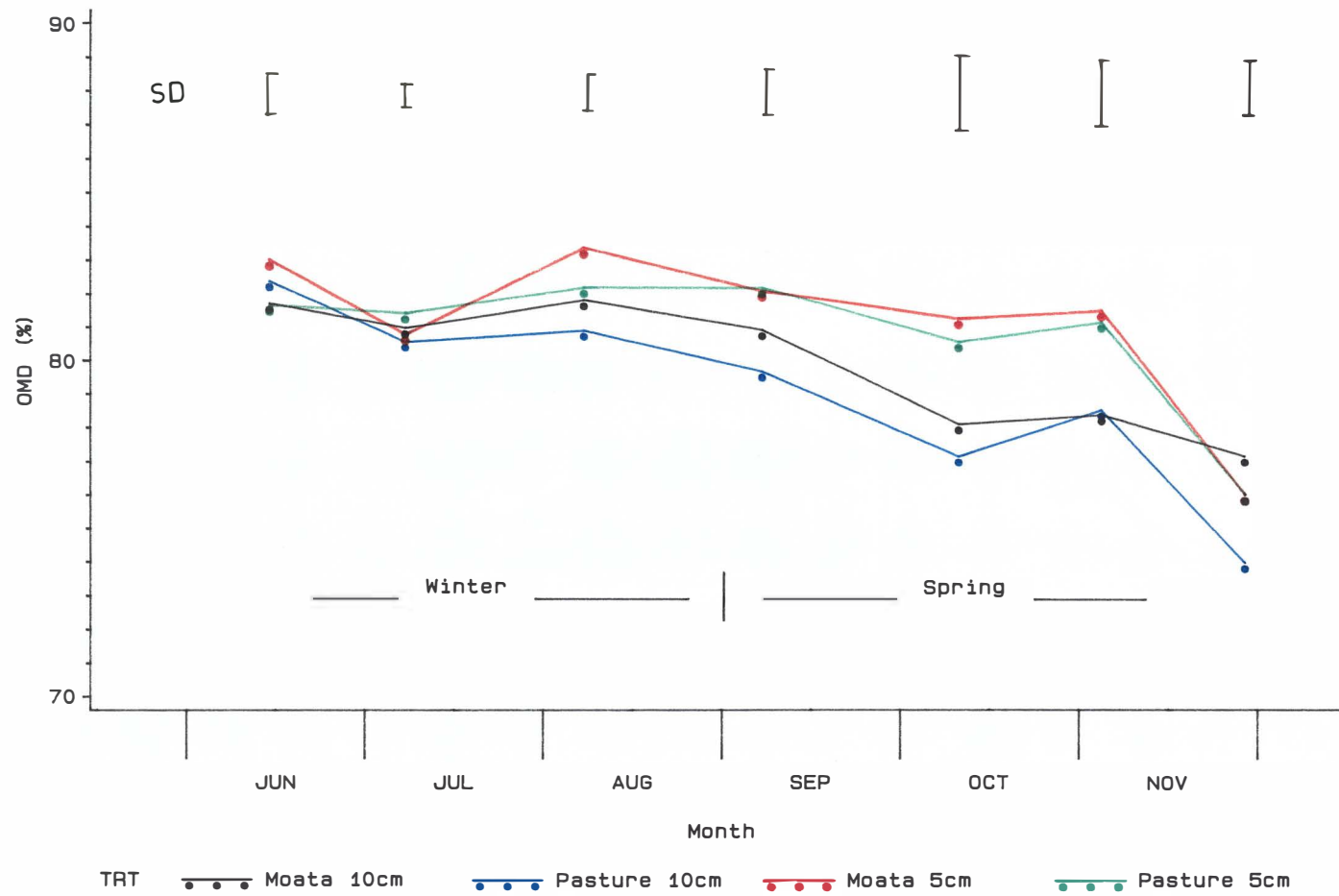


Figure 3.2a. Seasonal variations in total N concentration of feed on offer. (v) indicates urea application to pasture.



Figures 3.2b. Seasonal variations in OM digestibility of feed on offer.

Table 3.3a Organic matter digestibility (OMD), total nitrogen concentration and calculated concentrations of metabolisable energy (M/D values) of herbage and rumen ingesta of grazing stags during winter (June-August) 1988.

Sward Height (cm)	Herbage type		OMD (%)	Total N (%)	M/D (MJ ME/kg DM)
10 cm	Pasture	Mean (SD)	81.4 (0.96)	4.4 (0.16)	11.6 (0.38)
	Moata	Mean (SD)	81.6 (0.46)	4.5 (0.19)	11.3 (0.4)
5 cm	Pasture	Mean (SD)	81.9 (0.39)	3.9 (0.41)	10.7 (0.93)
	Moata	Mean (SD)	82.5 (1.40)	4.3 (0.52)	10.9 (1.12)
Rumen ingesta: (June)					
	Pasture	Mean (SD)	77.1 (4.11)	4.1 (0.69)	10.6 (0.64)
	Moata	Mean (SD)	79.8 (0.74)	4.1 (0.36)	10.3 (0.30)

No. of herbage samples = 3/herbage type

No. of rumen ingesta samples = 17

Table 3.3b Organic matter digestibility (OMD), total nitrogen concentration and calculated concentrations of metabolisable energy (M/D values) of herbage and rumen ingesta of grazing stags during spring (September-December) 1988.

Sward Height (cm)	Herbage type		OMD (%)	Total N (%)	M/D (MJ ME/kg DM)
10 cm	Pasture	Mean (SD)	76.4 (3.14)	2.5 (0.61)	10.5 (0.47)
	Moata	Mean (SD)	77.8 (2.39)	2.6 (0.45)	10.7 (0.36)
5 cm	Pasture	Mean (SD)	79.1 (3.21)	2.8 (0.59)	10.9 (0.51)
	Moata	Mean (SD)	79.0 (4.14)	2.9 (0.71)	11.0 (0.53)
Rumen ingesta: (November)					
	Pasture	Mean (SD)	80.0 (0.71)	4.4 (0.67)	11.2 (0.40)
	Moata	Mean (SD)	81.0 (2.68)	3.4 (0.61)	11.4 (0.64)

No. of herbage samples = 4/herbage type
 No. of rumen ingesta samples = 15

3.3.4 Seasonal distribution of herbage yields and carrying capacity

Figures 3.3a and 3.3b show the seasonal distribution of herbage yield for the two sward types at 5 cm and 10 cm sward heights. The Moata swards tended to have higher yields than the pasture swards during winter ($P = 0.09$; Table 3.4), and therefore had slightly greater carrying capacity. During spring, the herbage yield from the 10 cm Moata sward decreased markedly with a resultant decrease in carrying capacity. The pattern of seasonal herbage yield recorded for the pasture swards was similar to that described by Radcliffe (1975) for the Wairarapa area, with the peak herbage production occurring in November.

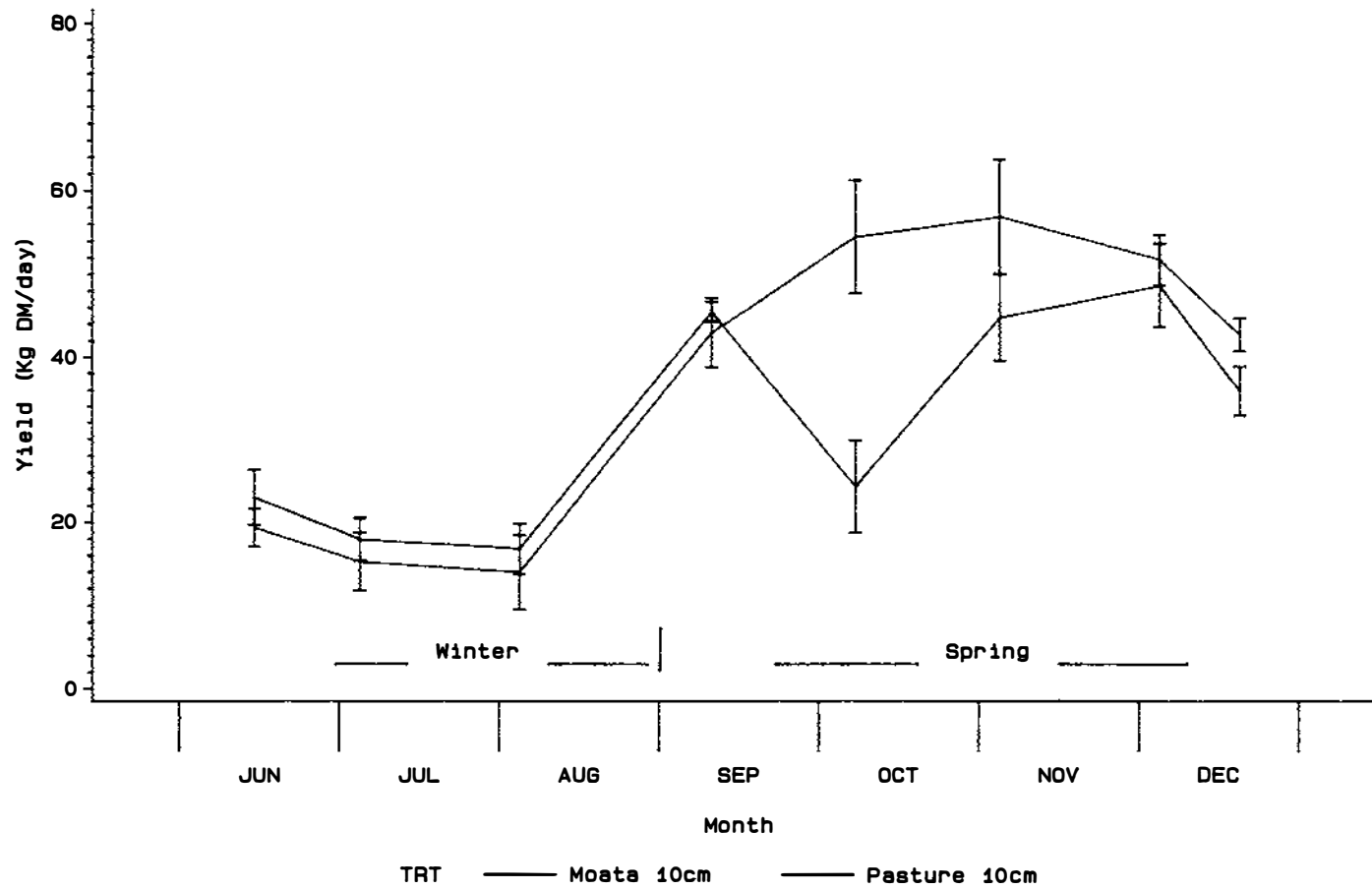


Figure 3.3a. Seasonal distribution of pasture yield (Kg DM/day) at Massey University deer research unit during the 1988 season. (I) indicates SD.

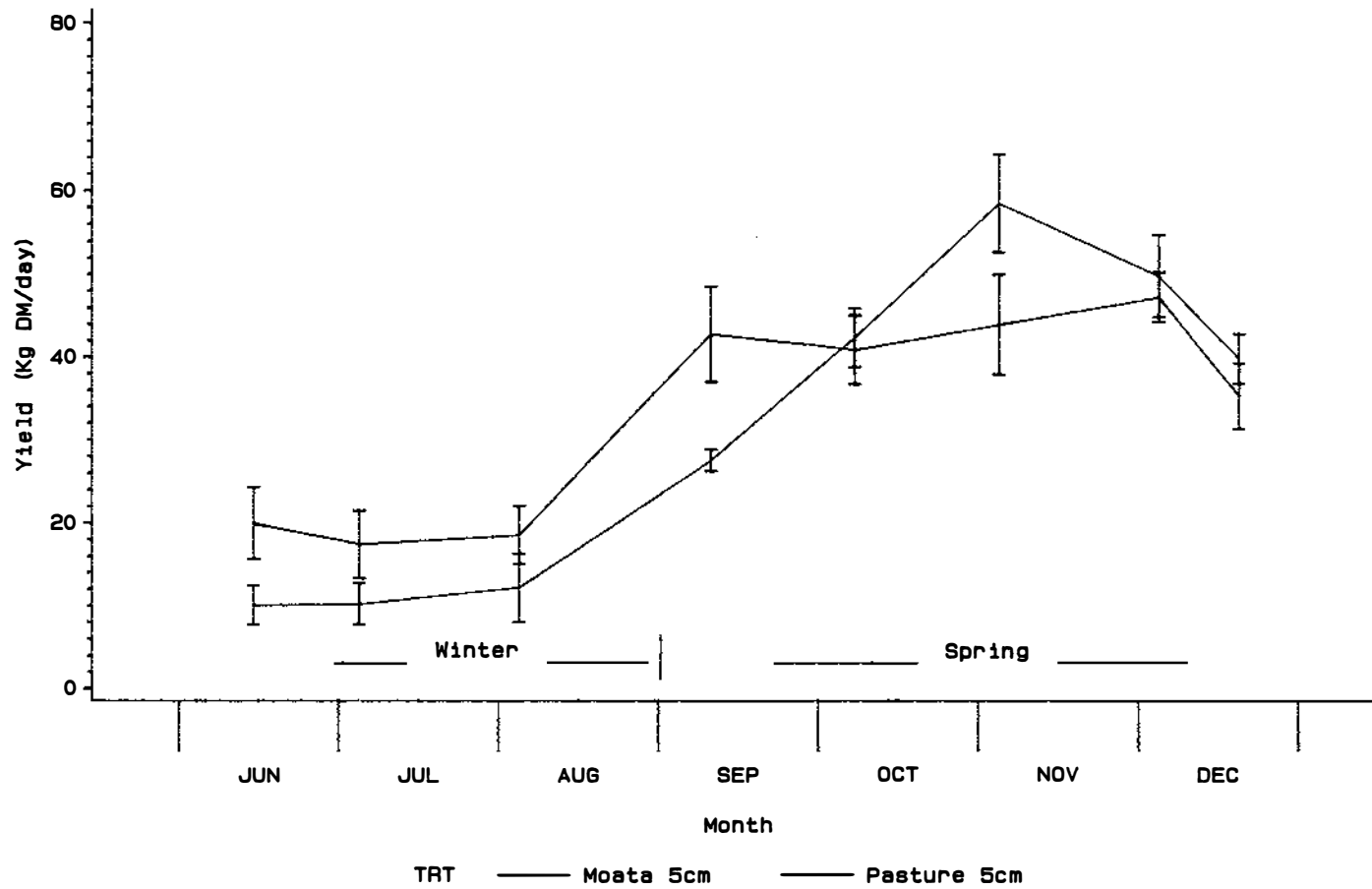


Figure 3.3b. Seasonal distribution of pasture yield (Kg DM/day) at Massey University deer research unit during the 1988 season. (I) indicates SD.

Table 3.4 Average seasonal herbage yields (kg DM/ha/day) and carrying capacity (animals/ha).

	10 cm sward		5 cm sward	
	Pasture	Moata	Pasture	Moata
<u>WINTER (June- August)</u>				
Herbage yield (SD)	16 (2.8)	19 (3.3)	11 (1.2)	19 (1.3)
Carrying capacity	10.5	13.1	12.4	15.4
<u>SPRING (September-November)</u>				
Herbage yield (SD)	50 (6.5)	40 (9.9)	44 (11.6)	42 (4.4)
Carrying capacity	12.4	9.4	14.3	14.8

3.3.5 Seasonal liveweight

Figure 3.4 shows the seasonal pattern in the growth of the young red deer. The growth pattern was similar for animals in all groups. The growth curve consists of two phases: slow growth during the winter period (60-69 kg LW) and faster growth during the spring period (69-85 kg LW).

3.3.6 Liveweight gain

The winter and spring LWG (g/day) and percentage of stags attaining slaughter weight by the end of November, are shown in Table 3.5. During winter, LWG was much greater in stags grazing the 10 cm swards than those grazing the 5 cm swards ($P < 0.001$), with the introduction of Moata having no effect. During spring, there was a significant interaction ($P < 0.001$) between sward height and the presence of Moata, with LWG being high on 10 cm swards and not affected by herbage type. LWG was lower in stags grazing the 5 cm pasture sward and was significantly increased by the presence of Moata ($P < 0.01$), with LWG of the stags grazing 5 cm Moata sward being similar to that of the stags grazing 10 cm

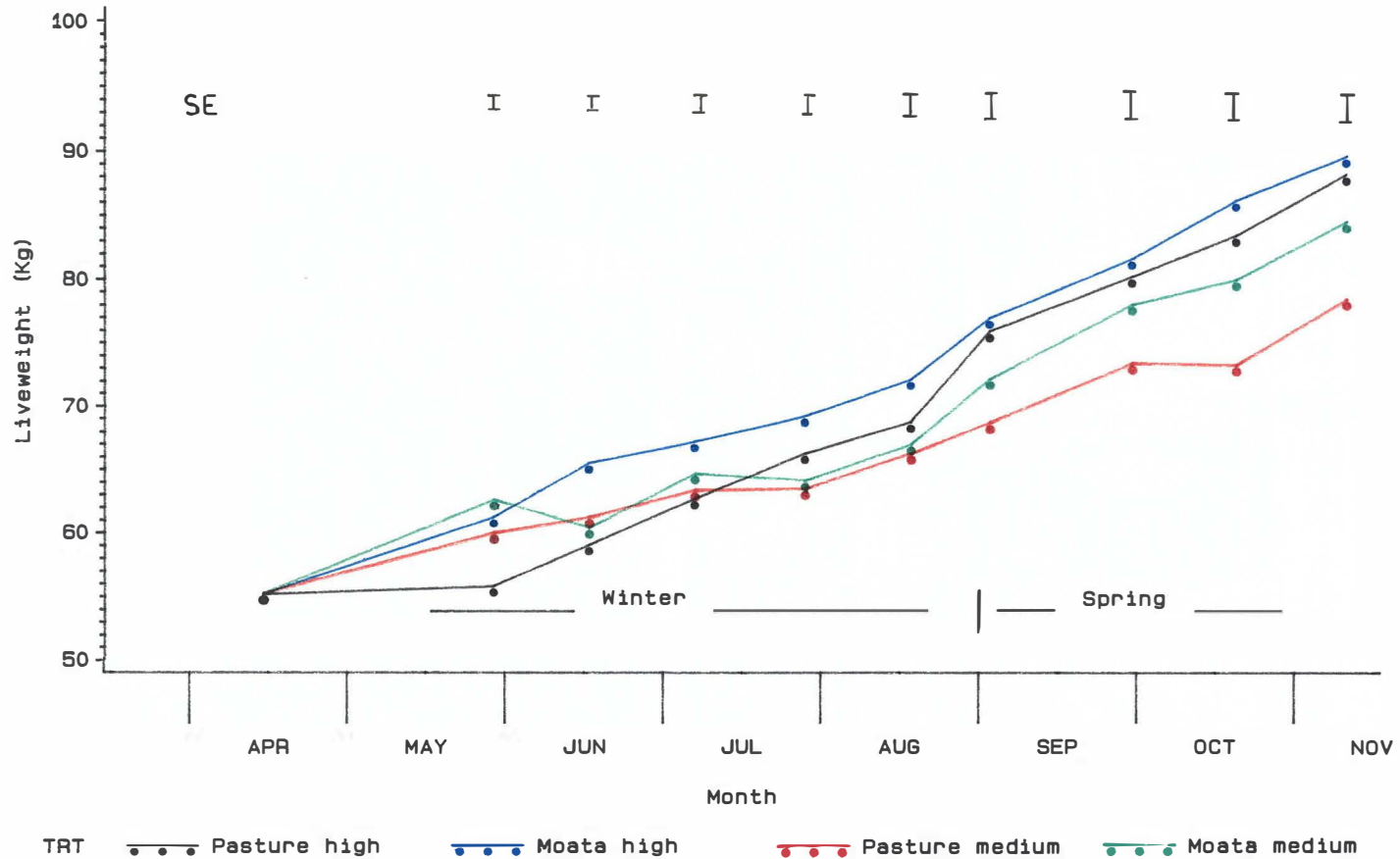


Figure 3.4. Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high (10cm) and medium (5cm) DM allowance.

swards. Forty-two - 50% of the stags grazing at the greater sward height and 21% of those grazing the 5 cm Moata sward reached the target liveweight (92 kg) by the end of November, whereas no animals grazing the 5 cm sward pasture attained the target liveweight by this date.

Table 3.5 Liveweight gain (g/day) of grazing stags during winter and spring of 1988, and percentage of stags attaining slaughter liveweight of 92 kg.

	10 cm sward		5 cm sward		S.E.
	Pasture	Moata	Pasture	Moata	
Stags/group	12	14	12	14	
Initial weight (kg)	56.9	60.7	59.8	60.2	
Liveweight gain:					
Winter	153	131	74	79	9.0
Spring	234	209	147	211	10.1
Stags to slaughter by end of November (% total)	42	50	0	21	

3.3.7 Melatonin antibody titre

Figure 3.5 shows the anti-melatonin antibody titre development pattern in red deer stags vaccinated against melatonin. There was a slight decline in mean titre following the first booster injection in June from $1:312 \pm 105$ to $1:160 \pm 18$ (mean \pm SE) in July. The titre increased following the second booster injection and was highest at $1:613 \pm 256$ in November, about 8 months after the primary injection was given in March 1988. The mean titre reported was for 19 animals (73%; responders) out of 26 antigen vaccinated stags. Seven animals (27%; non-responders) did not develop any detectable melatonin antibodies.

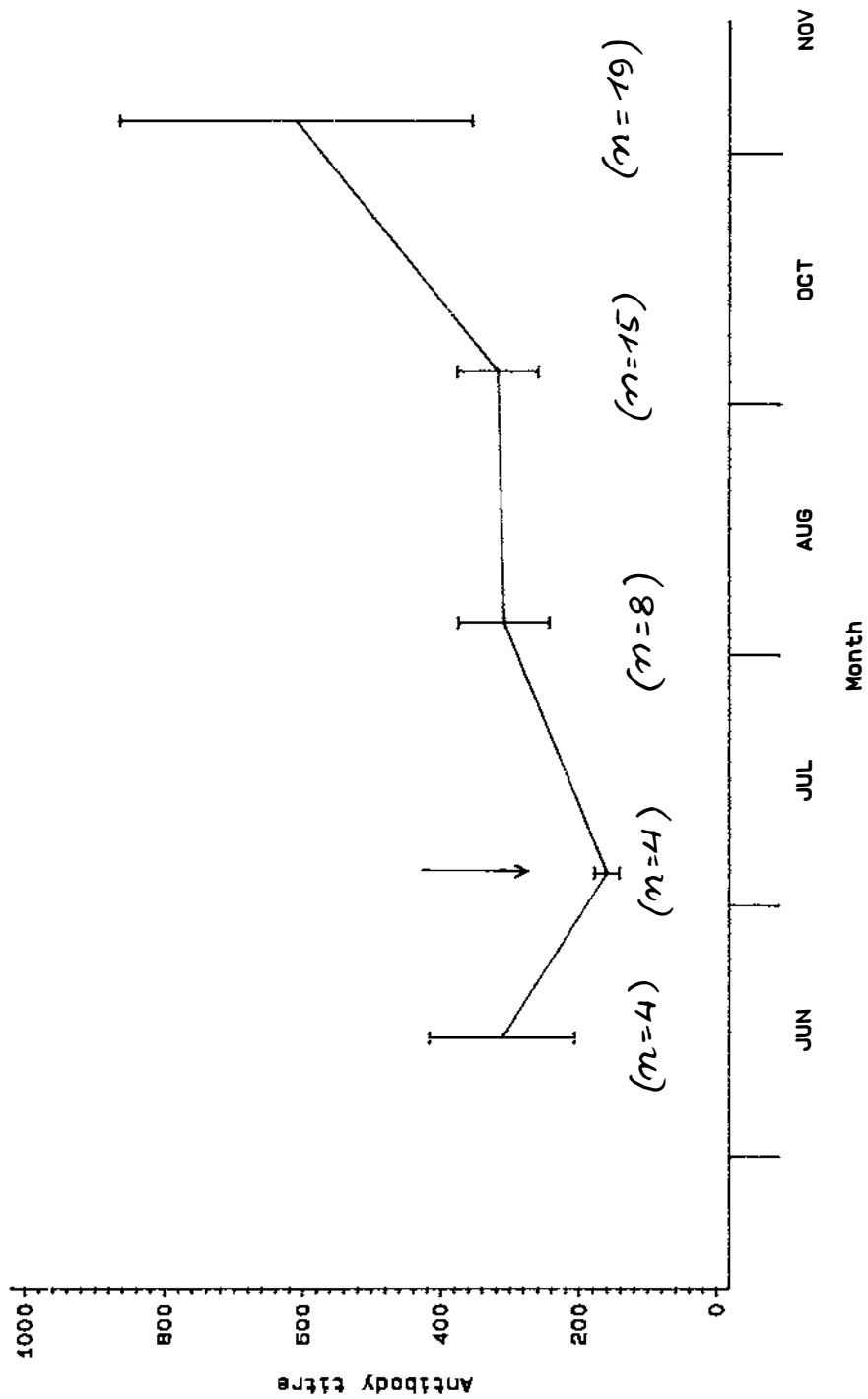


Figure 3.5. Pattern of anti-melatonin antibody titre development in the red deer. (♂) indicates booster. (|) indicates SE. (n) = respondents.

3.3.8 Plasma hormone concentrations

The plasma concentrations (ng/ml) of LH and testosterone are shown in Table 3.6. The LH values declined in November (0.49 and 0.68 ng/ml) for the control and immunised groups respectively with vaccination treatment having no effect ($P > 0.10$) during both months. Plasma testosterone concentrations showed a similar pattern as the LH concentrations with levels declining to 1.57 and 1.27 ng/ml for control and immunised groups respectively in November. Vaccination treatment had no significant effect ($P > 0.10$) on testosterone concentrations. Fig. 3.6 shows the plasma prolactin mean concentrations. The prolactin concentrations showed similar patterns for both control and immunised groups with low values during winter (June-August) and higher values during spring (September-November). The prolactin levels in the immunised group were higher than those of the control group during both seasons and had a higher peak (94.3 ng/ml) during spring compared with 31.8 ng/ml for the control group in the same season. The plasma prolactin concentration of the immunised group was greater ($P = 0.08$) than that of the control group in October.

Table 3.6 Plasma concentrations of LH and testosterone (ng/ml) in red deer stags during October and November 1988.

	Control (SE)	Immunised ¹ (SE)
No. of animals/group	26	19
	<u>(LH)</u>	
October 7	0.59 (0.23)	1.11 (0.26) ²
November 7	0.49 (0.09)	0.68 (0.10)
	<u>(Testosterone)</u>	
October 7	3.36 (0.55)	3.00 (0.62)
November 7	1.57 (0.14)	1.27 (0.16)

¹ responders to the anti-melatonin vaccination only

² ($P < 0.14$)

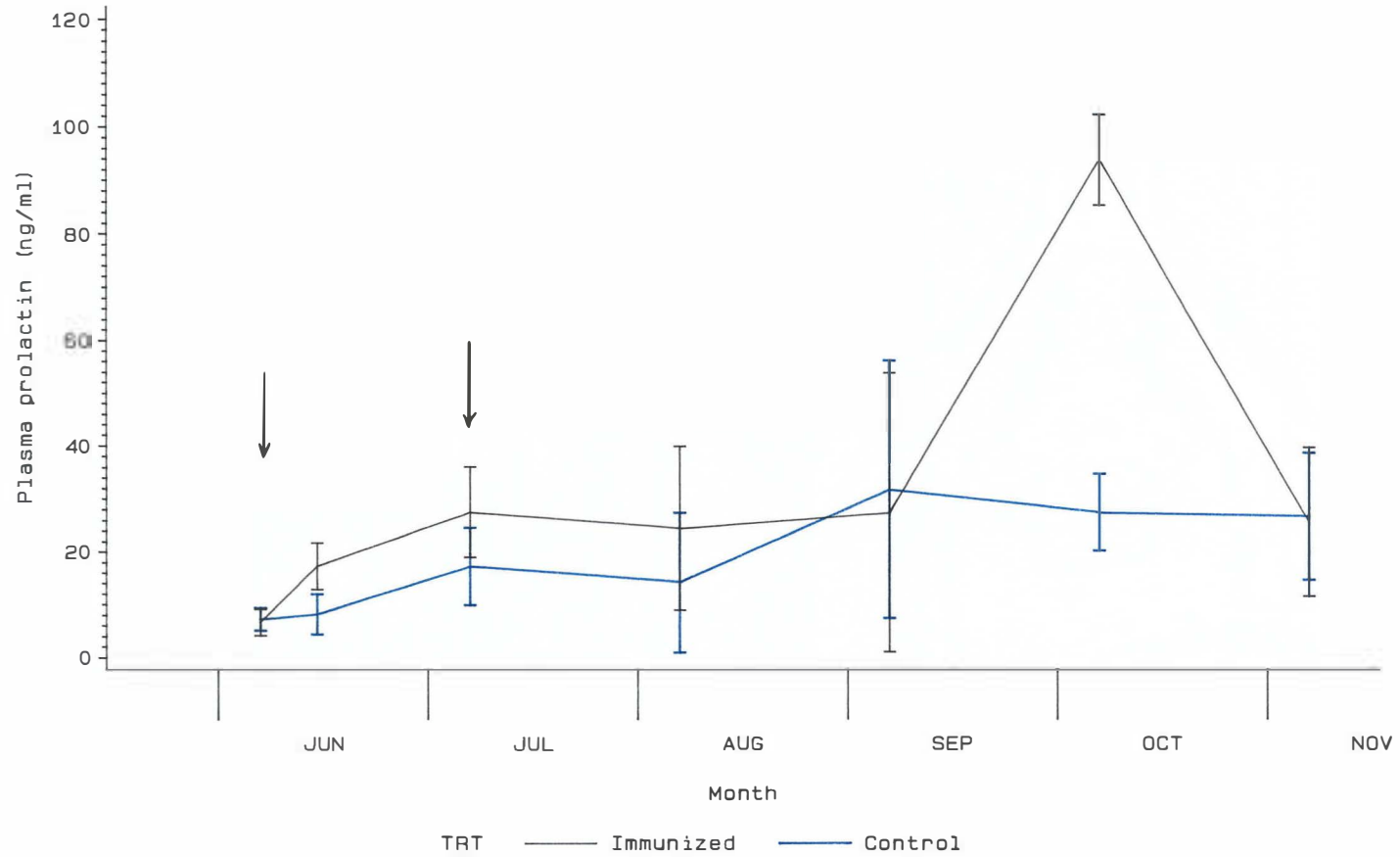


Figure 3.6. Plasma prolactin concentrations of weaner red deer stags immunized with melatonin antigen and the non-immunized (control) group. (↓) indicates booster, (I) indicates SE.

3.3.9 Carcass data

Table 3.7 shows the values for rump-fat width, carcass weight, dressing-out percent, testes weight and GR, with vaccination treatment having no effect ($P > 0.10$).

Table 3.7 Carcass data of red deer stags slaughtered in 1988, liveweight gain (g/day) during winter and spring and percentage of stags attaining slaughter liveweight of 92 kg.

	Control	Vaccinated	SE
Rump fat width (mm)	103.1	105.7	2.06
Carcass weight (kg)	51.5	52.5	0.44
Dressing-out	54.6	55.4	0.29
Testes weight (g)	41.2	41.8	2.51
GR (mm)	4.9	5.2	0.31
Liveweight gain:			
Winter	108	96	10.3
Spring	209	193	9.4
Stags to slaughter by end of November (% total)	34	23	

3.4 DISCUSSION

The present experiment is a follow-up to the 1987 grazing trial (Chapter 2). It was based on the same concept as the previous trial and had a similar objective of producing venison from young red deer stags by one year of age or less at the time required by overseas markets.

Based on the findings from the previous experiment, the following modifications were made in the design of the present experiment:

1. The weaner red deer stags were given the primary anti-melatonin vaccination at an earlier date (March 4-15, 1988).

sward could be due to different weather conditions at the time the paddocks were respectively direct drilled. The 10 cm paddock in contrast with the 5 cm paddock was direct drilled in very wet weather with a loss of Moata seeds, resulting in fewer seeds being actually drilled into the soil. This would explain the smaller Moata annual ryegrass component of the 10 cm Moata sward during winter (33%; Table 3.1a) compared with the greater Moata annual ryegrass component of the 5 cm Moata sward (46%; Table 3.1a), which was direct drilled in fine weather at the correct seed rate (20 kg/ha).

The white clover component of the swards showed a seasonal spring increase (Fig. 3.1e), as reported by Widdup and Williams (1982) and Chapman (1983), with the white clover component of the 5 cm swards being greater during the spring than during winter ($P < 0.01$; Tables 3.1a and 3.1b). There was also a seasonal trend in the increase of the dead matter component of the swards (Fig. 3.1c), being greater during the spring than during winter ($P < 0.001$; Tables 3.1a and 3.1b), especially in the 10 cm swards. This could be due to the fact that the rate of herbage production during spring was greater than the rate of herbage utilisation by the animals, therefore leading to greater percent of herbage senescence and death (Bircham and Korte 1984).

3.4.2 Seasonal distribution of herbage yields and carrying capacity

The herbage growth for both sward types were greater in spring than in winter ($P < 0.001$; Table 3.4). During winter, the herbage growth (DM) from the Moata swards was consistently higher than the growth from the pasture swards, consequently, the Moata swards had a higher carrying capacity (about 3 stags/ha more) than the pasture swards. At the peak herbage production during spring, the Moata swards had lower peak production than the pasture swards (Figs. 3.3a and 3.3b), but the overall herbage growth for both sward types were similar, which is also reflected in the similarity of their carrying capacities.

3.4.3 Diet selection by grazing stags

The values (% contact) for the perennial ryegrass and other species component in the ingesta were greater than those (% DM) in the herbage on offer ($P < 0.001$; Table 3.2) during June and November. The ingesta values for both white clover and Moata annual ryegrass components during both months were smaller than the corresponding values for herbage on offer ($P < 0.001$; Table 3.2). This suggests that the grazing animals selected

perennial ryegrass and other species over white clover and Moata annual ryegrass. Hunt and Hay (1989) reported that grazing yearling red deer stags showed much greater preference for white clover 'Grasslands Kopu' over both high and low endophyte ryegrasses 'Grasslands Nui'.

The suggestion that perennial ryegrass and other species were selected by the grazing stags over Moata annual ryegrass in the present experiment may be slightly exaggerated because of the difficulties in positively identifying and separating both species of ryegrass and other species (weeds) in the ingesta during dissection, but it is strongly supported by visual observations of the grazing patterns of stags in the paddocks. It was frequently observed that stags grazed along the fence lines, where there was little or no Moata annual ryegrass available and areas that were predominantly perennial ryegrass and other species, more severely than they grazed the Moata annual ryegrass dominated areas in the paddocks.

3.4.4 Nutritive value of Moata annual ryegrass and perennial ryegrass

There was a decrease in the total N and OMD values of both 10 cm swards during spring ($P < 0.001$; Tables 3.3a and 3.3b) which could be explained by the increase in dead matter component of the swards and also due to plant maturity. The decrease was less marked for the 5 cm swards. The M/D values were higher for the 5 cm swards than for the 10 cm swards during spring which could be due to the 5 cm swards containing less dead matter than the 10 cm swards (Table 3.1b).

The nutritive values for the rumen ingesta (diet selected) for both Moata and pasture were similar in June and November ($P > 0.10$; Tables 3.3a and 3.3b). There were no significant differences between the nutritive values of herbage on offer and diet selected by the grazing stags during both seasons ($P > 0.10$; Tables 3.3a and 3.3b). This would explain the similarity in growth of the animals grazing the two different sward types at the same feed allowance, especially during winter (Table 3.5).

Experiments conducted with sheep (Ulyatt 1981) showed that the feeding value of the annual Italian ryegrass was higher than that of the perennial ryegrass. Rae *et al* (1964) reported that the liveweight gains of sheep grazing the Italian annual ryegrass were greater than those of sheep grazing the perennial ryegrass. The present experiment has shown that there was no significant difference between the nutritive values of the Moata sward and that

of the pasture sward and that animals grazing these two different swards had similar growth, especially those on the high sward height treatment, but not at 5 cm sward height in spring. This could be attributed to the fact that the proportion of Moata annual ryegrass in the swards was not high enough (19-46%, Tables 3.1a and 3.1b). In future experiments, high proportions of the Moata annual ryegrass in the sward (about 80%) should be ensured and maintained at all times.

3.4.5 Seasonal pattern of growth

Figure 3.4 from the present trial shows a typical seasonal pattern of growth of the young red deer stags. The stags showed a slow rate of growth during winter (Kay 1985), a time when rate of pasture production (Korte *et al* 1987) is at its low point in the annual cycle and when pasture M/D values and the efficiency of ME utilisation are less than in spring (Waghorn and Barry 1987). The faster rate of growth during spring/summer is accompanied by a higher VFI during spring/summer than during winter (Suttie *et al* 1983; 1989). A similar trend in LWG was recorded in the present experiment. During winter, the stags grew an average of 9 kg LW (60-69 kg) compared with an average of 16 kg LW (69-85 kg) during spring. The fact that all animals in the present experiment showed this seasonal pattern of growth, clearly demonstrated that providing high quality forage at generous amounts all year round did not abolish the seasonal pattern of growth in the deer. Like other seasonal cycles, the growth and fattening cycle is therefore of physiological origin, but can be attenuated by environmental conditions and food availability (Barry *et al* 1990).

3.4.6 Liveweight gain

The winter LWG for stags grazing the 10 cm swards was much greater than that for those grazing the 5 cm swards ($P < 0.001$; Table 3.5), with the introduction of Moata annual ryegrass having no effect. The 131-153 g/day recorded for animals grazing the 10 cm swards is the same as the upper limit of 100-150 g/day suggested as suitable target value for young stags fed a high quality diet (Fennessy and Milligan 1987). It also showed that providing high quality pasture at high feed allowance (10 cm sward height) can greatly improve the rate of weight gain of the stags during winter, compared with grazing 5 cm swards. During spring, there was a significant interaction ($P < 0.001$) between height and the presence of Moata annual ryegrass, with LWG being high on 10 cm swards and not affected by sward type. LWG was lower in the animals grazing the 5 cm pasture sward and was significantly increased by

the presence of Moata annual ryegrass ($P < 0.001$), with LWG of the 5 cm Moata sward group being similar to that of the 10 cm sward groups. The Moata annual ryegrass proportion in the 5 cm sward was 22% compared with 19% present in the 10 cm sward. While the 10 cm swards had similar white clover components (6%), the 5 cm Moata sward had 14% compared with 9% present in the 5 cm pasture sward (Table 3.1b). The higher Moata annual ryegrass and white clover proportions may explain the superior growth of animals grazing the 5 cm Moata sward in spring. In experiments with sheep, the feeding value of the annual Italian ryegrass was higher than that of perennial ryegrass, and white clover consistently produced the highest feeding value, with sheep liveweight gains approaching double those achieved on perennial ryegrass (Ulyatt 1981). In studies on the causes of the differences in pasture quality between perennial ryegrass, short-rotation ryegrass 'Grasslands Manawa' and white clover, Ulyatt (1971) reported consistent difference in gross efficiencies of utilisation of digested energy for liveweight gain in sheep in the order white clover > Manawa > perennial ryegrass. In another experiment, Ulyatt and MacRae (1974) reported differences in nitrogen digestion; less nitrogen was lost from the rumen of sheep fed white clover and short rotation ryegrass than those fed perennial ryegrass. The result was that more protein was available for digestion in the small intestine of sheep fed white clover and short rotation ryegrass.

The present experiment reported no difference in OMD values between the two sward types. For a detailed explanation of the differences in growth of animals, the VFI and VFA proportions in the rumen are essential and should be measured in future. It is, however, known from experiments with sheep that perennial ryegrass has a relatively low fermentation rate and in addition, is very resistant to mechanical breakdown by chewing. Thus feed residues remain in the rumen for a long time and result in lower intakes than in the case of white clover.

3.4.7 Anti-melatonin titre and its effect on winter and spring LWG

The highest mean titre value ($1:613 \pm 256$) in the present experiment (Fig. 3.5) was recorded in November (8 months after the primary vaccination), emphasising the long lag phase in the anti-melatonin antibody titre development. The antibody titre development pattern in the present experiment was similar to that reported for the 1987 experiment in Chapter 2. In an attempt to raise high antibody titre in the stags during the critical winter period, the primary vaccination in the present experiment was given in March, 3 months

earlier than was given in 1987. The fact that the antibody titre development pattern was not affected indicates that giving primary vaccination in March was probably not early enough. Earlier vaccination (at birth), as reported by Duckworth and Barrell (1989) should be considered in future experiments. The immunisation treatment did not have any effect ($P > 0.10$; Table 3.7) on the winter and spring LWG, probably due to low antibody titre raised, especially during winter. Raising high antibody titre during winter seems to be the key factor in these trials.

3.4.8 Plasma hormone concentrations

The plasma LH and testosterone concentrations recorded in October in the present experiment (Table 3.6) for both treatment groups were similar to the values recorded for LH and testosterone, respectively, for red deer stags by Suttie *et al* (1984) during summer (N. Hemisphere). All hormone values in the present experiment declined in November, with the LH concentrations of the immunised group being greater than those of the control group. Given the limited data available in the present experiment, it is difficult to comment on the pattern of plasma hormone concentrations. It would be interesting to monitor the plasma LH and testosterone concentrations during all seasons to find out if the seasonal pattern is as described by other workers (Suttie *et al* 1984; Asher *et al* 1989), and also to assess treatment effects during these seasons. In the present experiment, the vaccination treatment had no effect ($P > 0.10$) on the plasma LH and testosterone levels during October and November. The plasma prolactin concentrations for both groups showed a classic seasonal pattern, low during winter and a rise commencing in spring. The immunised group tended to have higher mean prolactin levels than the control group during both seasons, which is an indication of treatment effect although this did attain significance ($P = 0.08$) only in October.

3.4.9 Carcass data

The dressing-out percent of 54.6-55.4 recorded in the present experiment was similar to 55.1% reported for red deer stags of the same age (Drew 1985). The mean carcass weight (52-53 kg) reported in the present experiment is higher than 41 kg reported for 12 month-old red deer stags (Drew 1985). The difference of 11-12 kg carcass weight is a reflection of the high level of nutrition on which these animals were reared. Allowable GR (mm) before penalty for carcasses within 50-70 kg carcass range is 12 (Drew and Hogg 1990). The present experiment reported GR of 5 for carcasses of 52-53 kg, indicating the degree of leanness of

these carcasses. There was no treatment effect ($P > 0.10$) on the dressing-out percent, carcass weight, or GR.

3.5 CONCLUSIONS

1. Perennial ryegrass/white clover permanent pastures direct drilled on March 1, 1988 with Moata annual ryegrass contained 33% DM (10 cm sward) and 46% DM (5 cm sward) as Moata during winter, but this decreased to 19% and 22% DM as Moata, respectively, during spring. The Moata swards contained lower proportions of perennial ryegrass and higher proportions of other species, the drilling having no effect on the proportions of white clover and dead matter. The proportions of white clover and dead matter in the swards increased during spring. White clover comprised low proportions of the feed on offer, in both winter (5-7% DM) and in spring (6-14% DM).
2. The Moata swards had greater DM production over winter and consequently had higher carrying capacity by about 3 animals/ha than the pasture swards. Peak DM production during spring was lower for the Moata swards, but the overall spring production and carrying capacity were similar to those of the pasture swards.
3. There was less white clover and Moata annual ryegrass in rumen ingesta than was present in the feed on offer, implying that the grazing stags selected against both species. In the case of white clover, this may have been a consequence of its lower height than either perennial or annual ryegrass.
4. The total N and OMD values for both sward types were slightly higher in winter (4.3% DM and 81.9%) than in spring (2.7% and 78.1%), especially for N. The nutritive values for rumen ingesta were similar to those for herbage on offer during both seasons. The M/D values were high at all times (10.5-11.6 MJ/kg DM), indicating that the feed on offer was of high nutritional quality.
5. The pattern of stag body growth was similar for all animals during both seasons, with slow growth during winter and faster growth during spring.

6. The animals grazing the 10 cm swards had greater winter LWG (131-153 g/day; $P < 0.001$) than those grazing the 5 cm swards (74-79 g/day). During spring, there was a significant interaction ($P < 0.001$) between the presence of Moata annual ryegrass and sward height, with LWG of the animals grazing the 5 cm Moata sward (221 g/day) being similar to values found for those grazing the 10 cm swards (209-234 g/day) and all three groups being higher than those grazing the 5 cm pasture sward (147 g/day).
7. Fifty percent of animals grazing the 10 cm Moata sward, 42% of those grazing the 10 cm pasture sward and 21% of those grazing the 5 cm Moata sward attained the target slaughter weight (92-95 kg LW) by the end of November, but no animals grazing the 5 cm pasture sward attained this slaughter weight.
8. The set stocking management practice used in this experiment was suitable for animal husbandry, but was not suitable for pasture management. The Moata annual ryegrass proportion of the swards decreased very markedly from 33-46% DM during winter to 19-22% DM during spring due to continuous defoliation by grazing.
9. Seventy-three percent (19/26) of the antigen vaccinated stags developed detectable melatonin antibody titres (responders). The mean titre was highest in late spring ($1:613 \pm 256$), 8 months after the primary vaccination. There was no vaccination effect on animal growth rate.
10. The plasma prolactin levels showed a seasonal pattern; low during winter and high during spring for both groups, with the immunised group having higher mean concentrations than the control group ($P = 0.08$) in October.
11. Points to consider for future experiments are as follows:
 - (a) Vaccination of calves at birth. This would appear to be necessary to allow enough time for the lag phase of antibody development, so that peak antibody production occurs during autumn/winter when melatonin is produced for the longest number of hours per day.
 - (b) Increase the Moata annual ryegrass proportions of the sward (to about 80% DM) by increasing the seed rate (30 kg/ha) using the double pass drilling technique and blanket spraying with "Roundup".

- (c) A management practice that is suitable for both animal handling and pasture management should be adopted; eg, a combination of set stocking/rotational grazing system to give Moata annual ryegrass enough time to recover in between grazings, and to maintain it as a high proportion of the sward all the time.
- (d) Animals should be grazed at 10 cm sward height or high feeding allowance for optimum LWG, rather than at 5 cm sward height.
- (e) To measure the VFI of stags under grazing conditions, intraruminal chromium controlled release devices (CRD) could be used, the VFA production in the rumen could be measured using hand-reared rumen fistulated stags and diet selected under grazing conditions could be sampled using hand-reared oesophageal fistulated stags.

CHAPTER 4

THE EFFECT OF ACTIVE IMMUNISATION AGAINST MELATONIN OR LHRH UPON THE GROWTH OF YEARLING RED DEER STAGS DURING AUTUMN AND WINTER, AND UPON PLASMA HORMONE PROFILES

4.1 INTRODUCTION

Seasonal changes in fertility in both male and female red deer are dictated by changes in the secretion of the gonadotrophic hormones, luteinising hormone (LH) and follicle-stimulating hormone (FSH), from the anterior pituitary gland. These changes are themselves regulated through the secretion of luteinising hormone releasing hormone (LHRH) from the hypothalamus. The increase in LHRH pulse frequency and amplitude constitutes the 'drive' to the reproductive system causing the resurgence of gonadal activity, leading to mating and conception occurring during the rut. The mechanism by which environmental factors influence the release of LHRH from the hypothalamus is poorly understood, although there is evidence that the pineal gland is involved in the photoperiodic control of reproduction through its secretion of melatonin (Lincoln 1985).

In New Zealand, red deer have their rutting season in the autumn, lasting 65 days from March to May (Fennessy and Milligan 1987), when the behaviour of the stags becomes greatly modified. However, some stags may continue rutting until August (P.R. Wilson, pers. comm.). Rutting involves aggression between rival males and intense interest in the females as they show oestrus. Often the adult males spend their entire time involved in rutting activities and do not feed (Lincoln 1985). Within a month, the most active stags lose almost 25% of their body weight (Lincoln 1971). Pollock (1975) reported that appetite fell to below maintenance and body weight fell by up to 10 kg in some adult stags, even though no hinds were present. In temperate deer species the rut marks the change from the growth phase in summer to the growth stasis in winter. When LHRH activity is blocked by active immunisation there is no breeding season (Bolt 1971; Lincoln 1985), thus in effect, creating temporary castrates. Studies with adult red deer stags have shown that following castration there is no seasonal rutting behaviour (Lincoln 1971). Ryg and Jacobsen (1982) reported loss of weight in intact male reindeer during the rutting season, whereas the weight of castrates was stable during this period.

In red deer, the secretion of melatonin from the pineal gland during the hours of darkness is responsible for the entrainment of seasonal reproductive rhythms with annual photoperiod. The melatonin effect is dependent on LHRH secretion from the hypothalamus (Lincoln *et al* 1984). Since melatonin acts on the hypothalamus and it is assumed to influence the secretion of LHRH, active immunisation against melatonin may prevent the secretion of LHRH and thus reproductive activities. This suggests the possibility that anti-melatonin immunisation may produce a similar effect as anti-LHRH immunisation.

The aim of the present experiment was to study the effect of active immunisation against LHRH or melatonin upon the LWG of yearling red deer stags during the breeding season and the following winter. Animals of this age, 15 months by March, normally undergo a growth stasis for the following five months. Active immunisation against LHRH or melatonin can be regarded as a temporary immuno-castration, through which it was desired to prevent the cessation of autumn growth in yearling stags.

4.2 MATERIALS AND METHODS

4.2.1 **Animals and vaccination procedures**

4.2.1.1 **Anti-LHRH trial**

On January 17, 1989 five 13-month old red deer stags (96.4 ± 3.04 kg initial LW; Mean \pm s.e.) received a primary s.c. injection (1 ml on either side of the neck) of antigen LHRH linked to ovalbumin in DEAE dextran adjuvant in oil base. One ml of the vaccine was composed of 0.5 mg antigen in 0.5 ml adjuvant and 0.5 ml physiological saline. They received a booster injection of the same amount (2 ml) on February 28, 1989. Five red deer stags of the same age (90.9 ± 1.16 kg initial LW) did not receive any injections and were used as controls.

4.2.1.2 **Anti-Melatonin trial**

Eight 13-month old red deer stags (89.9 ± 1.58 kg initial LW) that had previously received s.c. injections (1 ml on either side of the neck) of a 5-methoxy-tryptamine hemisuccinamine:Human serum albumin conjugate in Freund's complete/incomplete adjuvant in March, June and July 1988 were used. Each ml of the vaccine was made up of 0.5 mg antigen and 0.5 ml Freund's incomplete adjuvant and 0.5 ml physiological saline. They received further booster injections of the same amount (2 ml) on January 27 and May 25, 1989. Seven red deer stags of the same age (94.9 ± 1.99 kg initial LW) that were not previously immunised, did not receive any injections and were used as controls. The initial liveweight for both groups were recorded on February 28, 1989.

4.2.2 **Grazing management**

The two animal groups (25 stags) grazed together as a mob on perennial ryegrass/white clover pasture throughout the duration of the experiments. The stags grazed

pastures maintained above maintenance feed allowance. The anti-LHRH trial commenced on February 28 and ended on July 4, 1989, whilst the anti-melatonin trial started on February 28 and ended on August 18, 1989.

4.2.3. **Weighing and blood sampling procedures**

Every 3 weeks, the stags were injected i.m. with 0.2-0.3 ml of 10% "Rompun" to cause mild sedation for the purpose of easy handling and were weighed. Blood (10 ml) was also taken from the jugular vein of all animals by venipuncture. The blood samples were collected in 10 ml vacutainers using Na heparin as anti-coagulant and were kept on ice. The blood samples were centrifuged at 4°C, at 3000 RPM (1851 g) for 20 min to harvest plasma, to be used for measuring anti-LHRH and anti-melatonin antibody titres and for hormone assays. Each plasma sample was stored at -20°C in five 1 ml lots.

4.2.4 **Slaughter and carcass data**

The animals from the anti-LHRH trial were sent for slaughter at the Feilding DSP on July 13, 1989 and the animals from the anti-melatonin trial were slaughtered at the DSP on December 15, 1989. At the DSP, the carcass weights (kg) were recorded, the carcass GR tissue depth (mm) were determined and the rump fat width (mm) were measured for each carcass. Testes were collected and weighed.

4.2.5 **Laboratory analyses**

4.2.5.1 **Antibody titre determination**

Anti-melatonin antibody titres were determined as the dilution of plasma necessary to bind 10 pg of [³H] melatonin/ml when 20 pg of [³H] melatonin/ml was available (Chapter 2). The results were expressed as titres as reported by Abraham (1974). The lowest titre measured (detectable antibody) was 1:100.

The anti-LHRH antibody titre was measured by the procedure outline by Abraham (1974) but using ¹²⁵I-LHRH as ligand. The ¹²⁵I-LHRH ligand at pH 7.5 was prepared by the method reported by Djura and Hoskinson (1986). The antibody titre is defined as the dilution of antiserum which bound 50% of the ¹²⁵I-LHRH available and is expressed as a reciprocal. The lowest titre measured (detectable antibody) was 1:140. Determinations of

anti-melatonin and anti-LHRH antibody titres were performed at the CSIRO Division of Animal Production's Prospect Laboratory, Sydney, Australia.

4.2.5.2 Hormone assays

LH concentrations were determined using a heterologous radioimmunoassay procedure described for sheep plasma by Scaramuzzi *et al* (1970) and validated for fallow deer plasma (Asher *et al* 1986). The intra-assay coefficients of variation for multiple determinations, calculated from determinations of red deer control plasma samples was 11.4%. All samples were included within a single assay. The least discernible amount from 0 was 0.48 ng/ml.

Plasma testosterone concentrations were determined using an extraction radioimmunoassay similar to that described by Peterson *et al* (1978), but omitting the chromatographic step used to separate androgens. The inter-assay coefficients of variation, calculated from determinations of low (mean concentrations = 1.28 ng/ml) and high (9.30 ng/ml) red deer control plasma samples in each assay (n = 5) were 21.7% and 13.1% respectively. The intra-assay coefficients of variation for multiple determinations of the same control samples were 13.1% and 8.8% respectively. The least discernible amount from 0 was 0.1 ng/ml.

The LH and testosterone assays were conducted at the Ruakura Agricultural Centre, Hamilton, New Zealand.

Prolactin was determined using the method of Van Landeghem and va de Weil (1978) and modified by Peterson *et al* (unpublished) and validated for red deer plasma by McCutcheon (unpublished; Appendix 1). The first antibody was raised in rabbits against ovine prolactin (ie it was rabbit anti-ovine prolactin). The antiserum was supplied by National Institute of Arthritis, Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland, U.S.A., in association with National Hormone and Pituitary Programme, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A. Code and lot # NIADDK-Anti-oPRL-1, AFP-973269. It was stored frozen at a 1:100 dilution in assay buffer and was further diluted to 1:40,000 for the assay. Rabbit gamma globulin was added to the first antibody mix to provide 1 μ g per assay tube to facilitate formation of the antibody pellet. The second antibody was a Donkey anti-rabbit precipitating serum (IDS Gamma-B precipitating antiserum for radioimmunoassay, Code

APPT1, Lot # 11656, Washington, Tyne and Wear, England). The dilution range for the ovine reference standard was 1-1200 ng/ml. The sensitivity of the assay was an average of 0.2 ng/ml and the inter-assay coefficient of variation was 14.0% and the intra-assay coefficient of variation was 9.1%.

4.2.6 Statistical analyses and calculation of data

The experimental data were analysed using General Linear Models (GLM). The LWG (g/day) in the anti-LHRH trial during the rut season was calculated as:

$$\frac{\text{Liveweight (kg) at May 22} - \text{Liveweight (kg) at March 22}}{65 \text{ days}} \times 1000$$

using the weight at the start of the rut (March 22) as a covariate. Least Squares Means (LSM) was used to test the differences between treatments.

The LWG for the anti-Melatonin trial during the rut season was calculated as described above.

The winter LWG (g/day) was calculated as:

$$\frac{\text{Liveweight (kg) at August 18} - \text{Liveweight (kg) at May 25}}{85 \text{ days}} \times 1000$$

using the weight at the start of winter (May 25) as a covariate. LSM was used to test the differences between treatments.

Dressing-out percent was calculated as:

$$\frac{\text{Carcass weight (kg)}}{\text{Live weight (kg)}} \times 100$$

The plasma LH, testosterone and prolactin concentrations were analysed using GLM, and LSM was used to test the differences between treatments. The Least Squares Means are presented.

4.3 RESULTS

4.3.1 **Anti-LHRH trial**

4.3.1.1 **Anti-LHRH antibody titres**

Eighty percent (4/5) of the stags vaccinated with the LHRH antigen gave a significant anti-LHRH antibody response ($> 1:140$; designated responders). The antibody titres peaked in April at $1:694 \pm 231$ (mean \pm s.e.), declined slightly by early May and remained at an average of $1:520 \pm 52$ throughout the remainder of the experiment (Figure 4.1).

4.3.1.2 **Plasma hormone concentrations**

Figure 4.2a shows the patterns of mean plasma LH concentrations for both immunised and control red deer stags. Both groups show similar patterns with the mean plasma LH concentrations being lowest in May (0.50 and 0.77 ng/ml for immunised and control groups, respectively). The LH concentrations for the immunised group were generally lower than those for the control group with the difference being significant ($P < 0.05$) in May, but not significant at other sampling periods. The mean plasma testosterone patterns for both groups are shown in Figure 4.2b. They both show declining patterns, with highest values (6.7 and 7.2 ng/ml) in March and lowest values (2.3 and 2.1 ng/ml) in May for the immunised and control groups respectively. The immunised group generally had lower plasma testosterone levels than the control group except during May. In early May, the plasma testosterone concentration of the immunised group was greater ($P < 0.05$) than the control group.

4.3.1.3 **Liveweight patterns**

Patterns of liveweight change are shown for all animals (Figure 4.3a; $n = 5$ /group), and for control animals ($n = 5$) and responders to LHRH vaccination only ($n = 4$; Figure 4.3b). Patterns of liveweight change are essentially the same for both methods of presentation, with control animals losing live weight during the rut and immunised animals showing a small increase in live weight. Immunised animals were heavier than control animals at the end of the rut period ($P < 0.10$). Despite a fall in live weight for both groups during June, the immunised animals were still heavier than the control animals in early July ($P < 0.10$).

4.3.1.4 **LWG**

Table 4.1 shows that the LHRH vaccinated group (responders and non-responders; $n = 5$) grew better than the control group during the rut period ($P < 0.05$). Whilst the

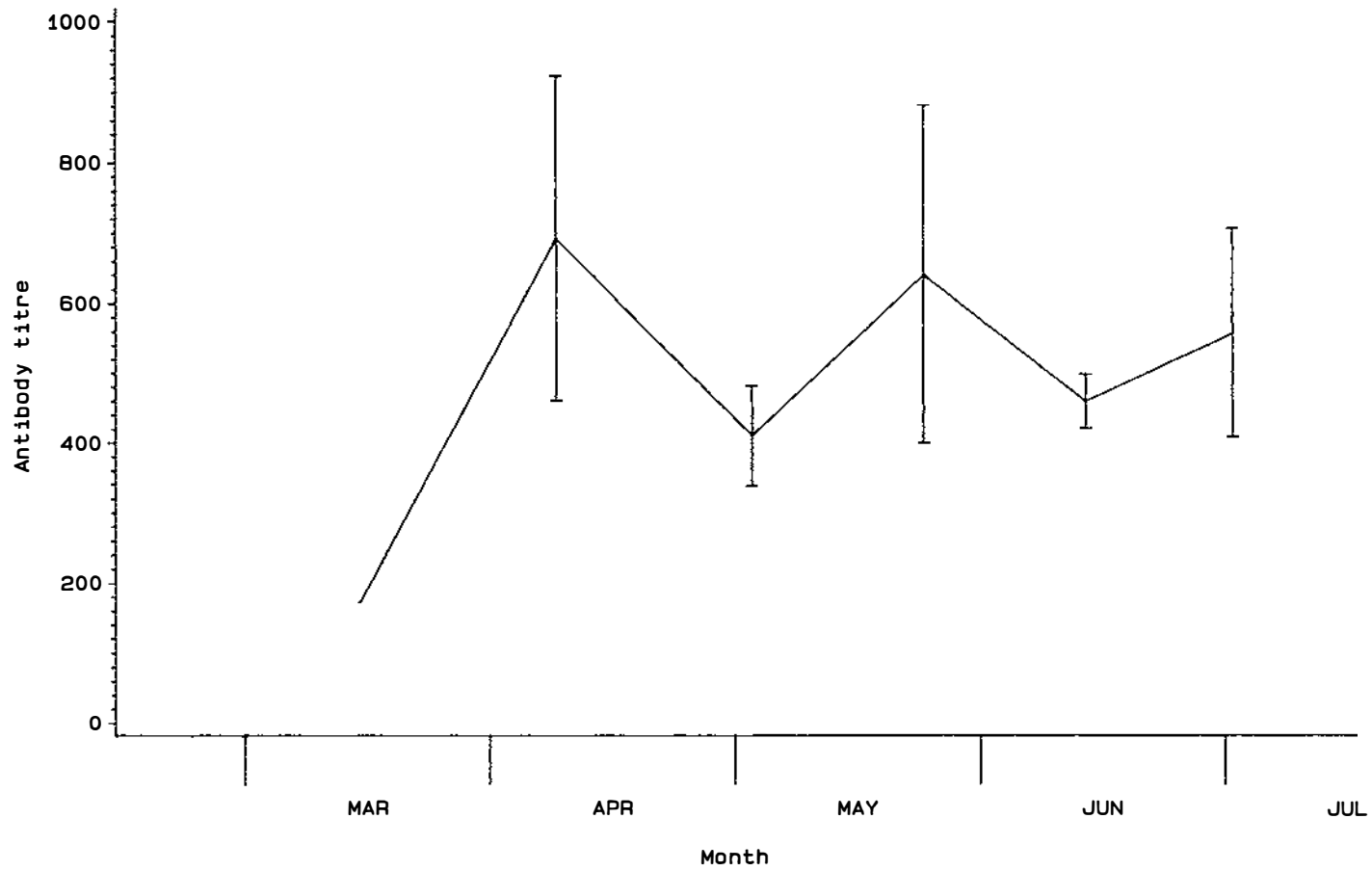


Figure 4.1. Pattern of anti-LHRH antibody titre development in the red deer. (I) indicates SE.

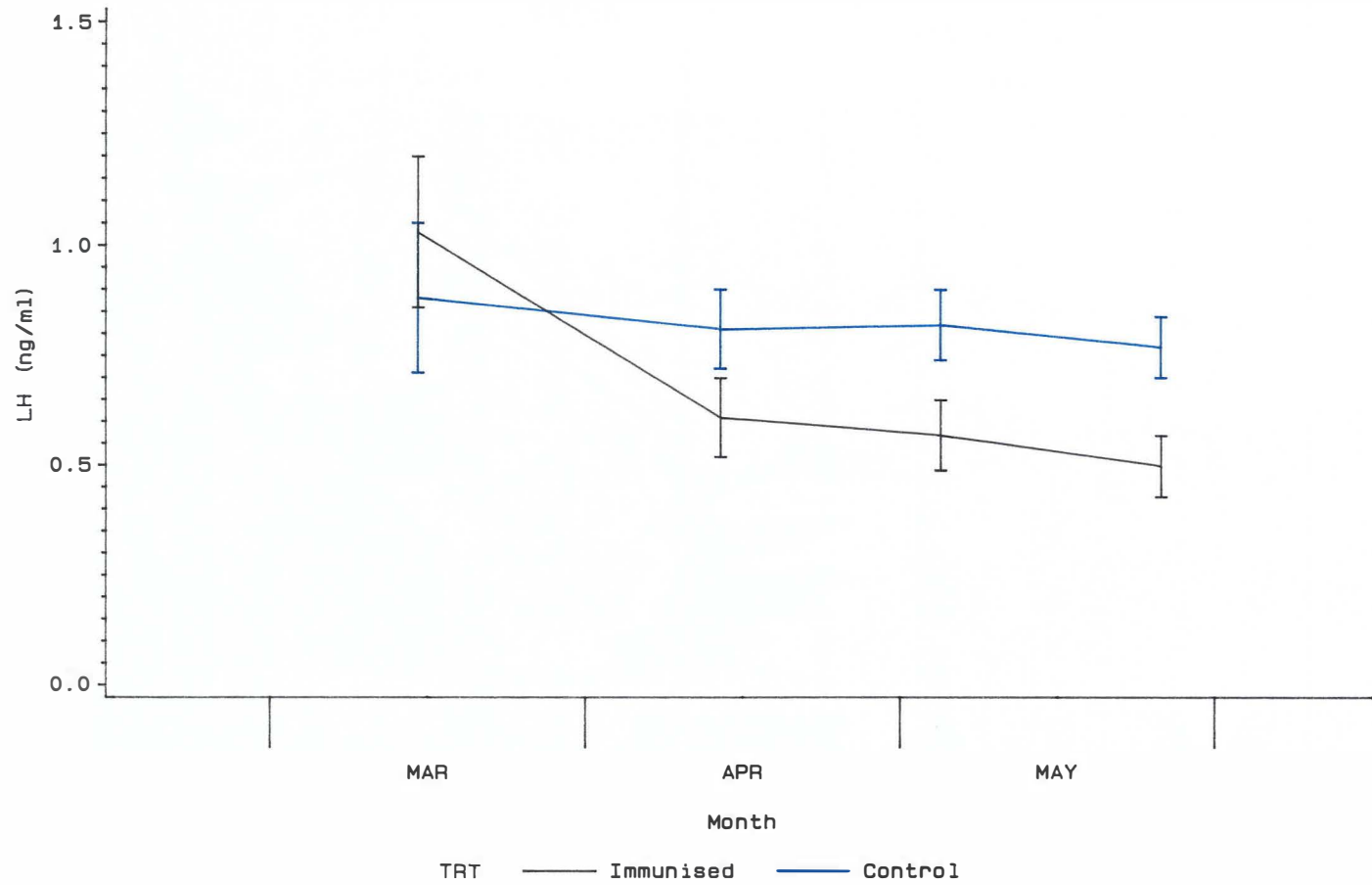


Figure 4.2a. Plasma concentrations of LH in immunised (n=4) and non-immunised (n=5) weaner red deer stags against LHRH. (I) indicates SE.

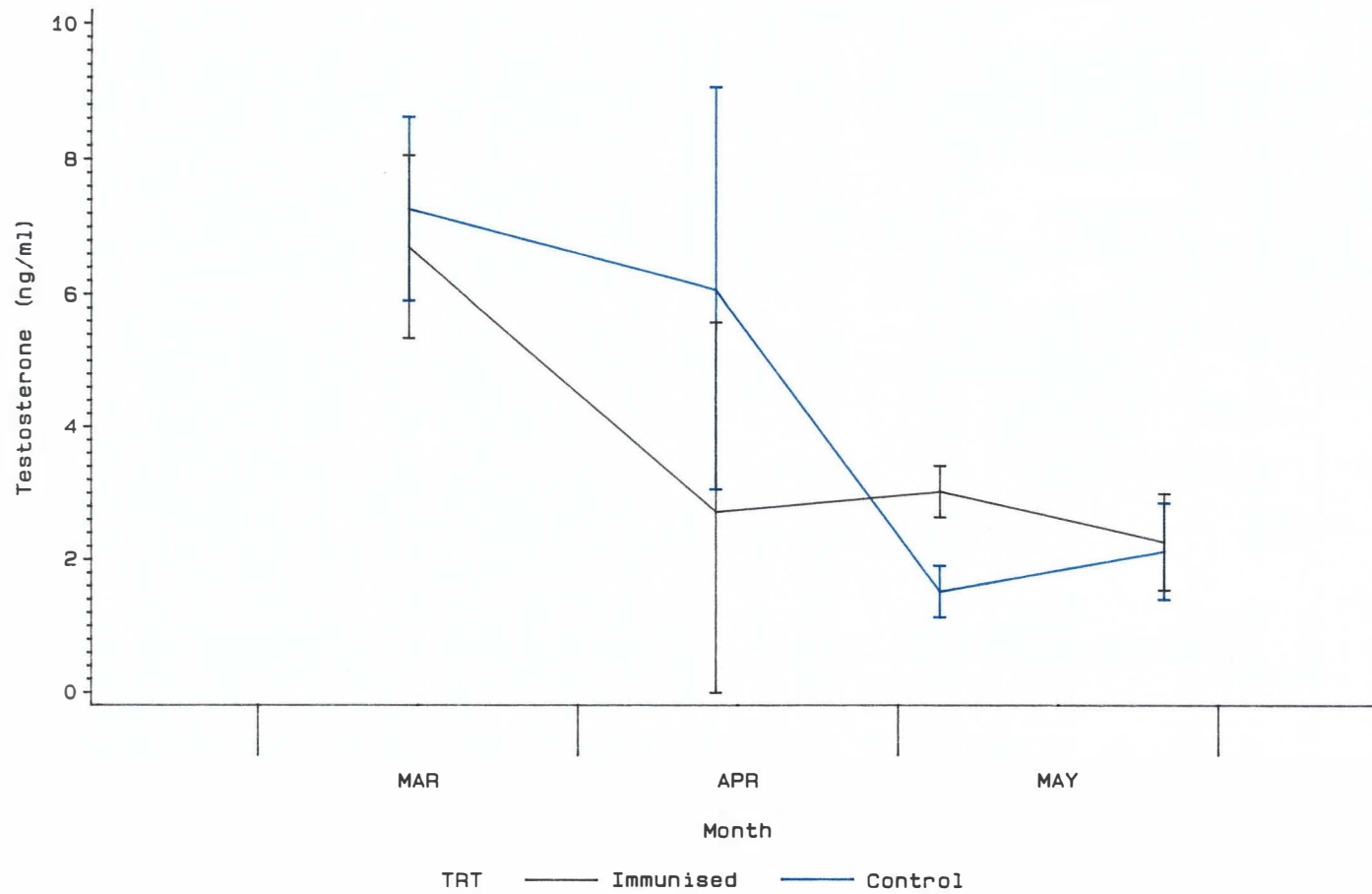


Figure 4.2b. Plasma concentrations of testosterone in immunised (n=4) and non-immunised (n=5) weaner red deer stags against LHRH. (I) indicates SE.

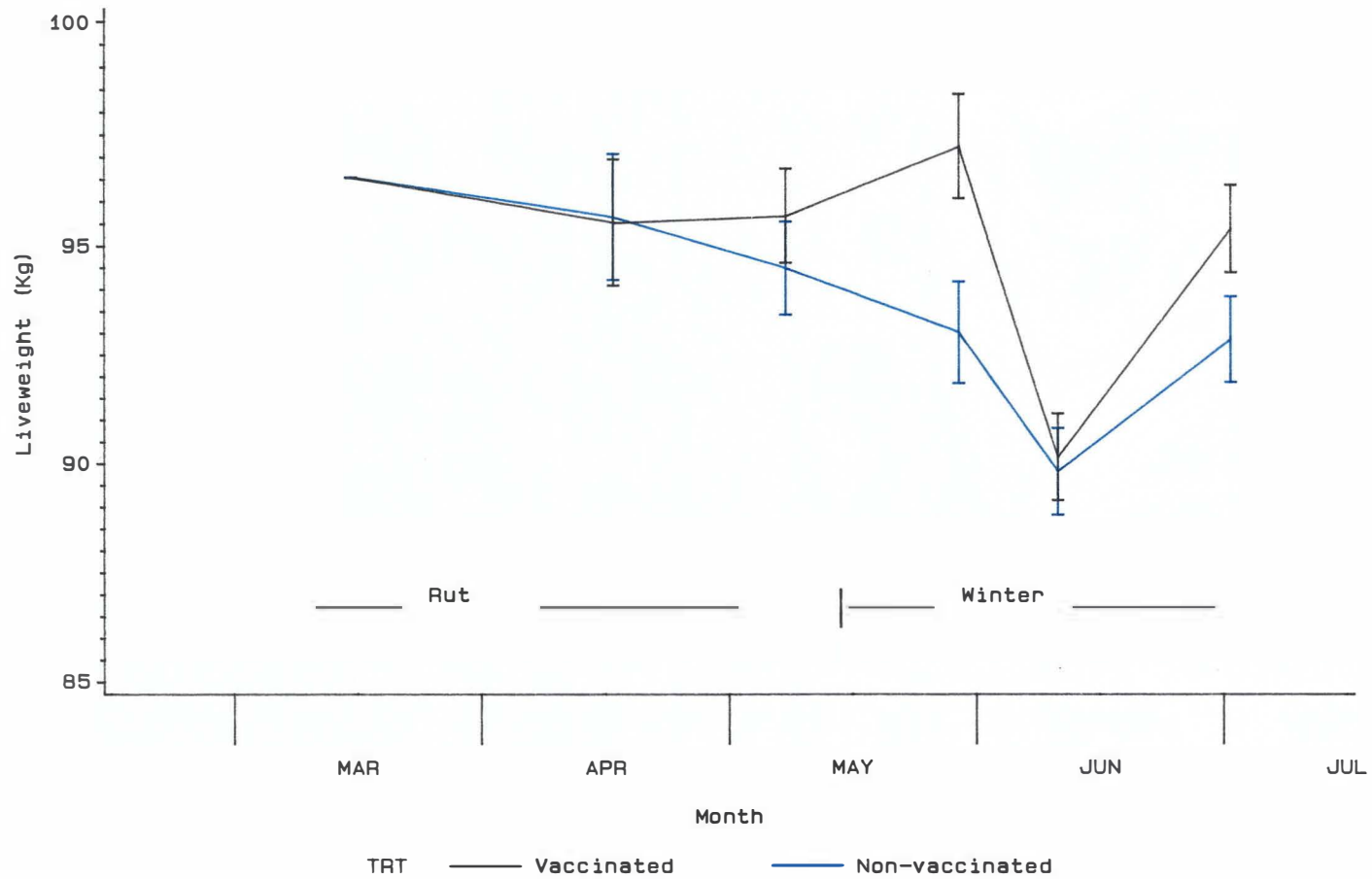


Figure 4.3a. Seasonal liveweight pattern of vaccinated (n=5) and non-vaccinated (n=5) yearling red deer stags against LHRH. (I) indicates SE.

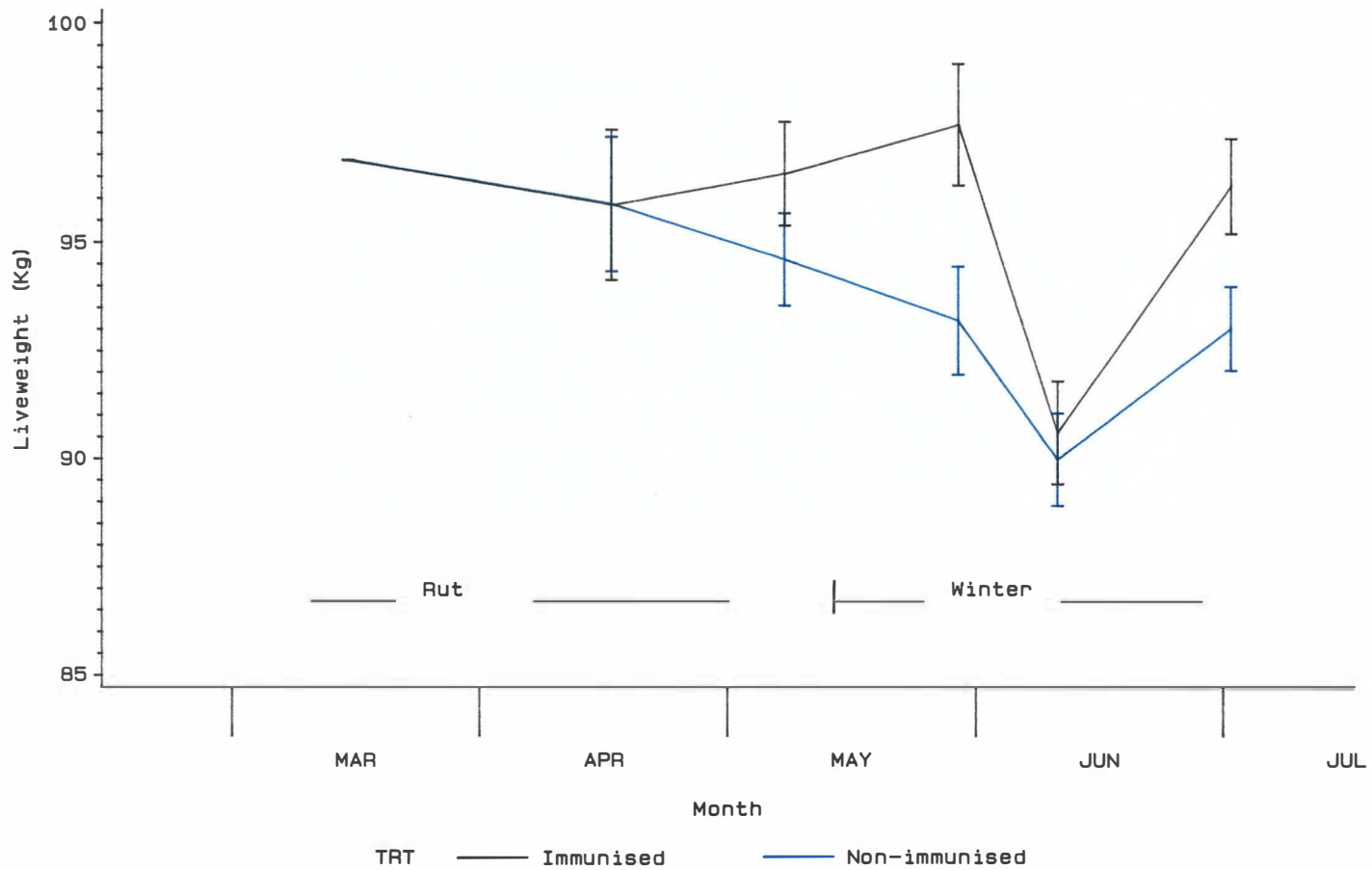


Figure 4.3b. Seasonal liveweight pattern of immunised (n=4) and non-immunised (n=5) yearling red deer stags against LHRH. (I) indicates SE.

vaccinated group gained weight slightly (11 g/day), the control group actually lost weight (54 g/day). Responders ($n = 4$) compared with the control group showed a similar result, with the responders gaining 13 g/day during the rut season.

4.3.1.5 Carcass data

Table 4.1 shows similar values for the rump fat width, testes weight and GR for both the LHRH vaccinated and the control groups. The dressing-out percent was slightly lower for the vaccinated group than for the control group ($P < 0.05$).

Table 4.1 Liveweight gain (g/day) of yearling red deer stags during the rut season (March 22-May 25, 1989) and carcass data.

	Control	LHRH Vaccinated	Difference	S.E.
No. animals/group	5	5 (4)	5 (4)	($n = 5$)
Initial weight (kg)	96.6	96.6 (96.9)		
LWG (g/day)	-54	11 (13)	* *	17.94
Carcass data:				
Carcass weight (kg)	53.5	53.0 (53.5)		0.44
Dressing-out (%)	57.3	55.9 (56.1)	*	0.38
Rump fat cover (mm)	105.2	102.8 (104.7)		5.39
Testes weight (g)	78.5	74.0 (77.4)		5.12
GR (mm)	3.4	3.0 (3.4)		0.45

* $P < 0.05$

($n = 4$) = responders to anti-LHRH vaccination (ie one non-responder deleted).

LWG (g/day) was calculated using liveweight at the beginning of rut season (March 22) as a covariate.

Rump fat width, testes weight and GR were analysed using carcass weight as a covariate (mean 53.3 kg).

4.3.2 Anti-Melatonin trial

4.3.2.1 Anti-melatonin antibody titres

Seventy-five percent (6/8) of the stags vaccinated with the anti-melatonin antigen gave detectable antibody titres. The mean antibody titres of the responders peaked in February at $1:1272 \pm 411$ (mean \pm s.e.) and declined to $1:486 \pm 97$ in April (Figure 4.4). It rose to $1:917 \pm 98$ in May and stabilised close to that value for the remaining duration of the experiment.

4.3.2.2 Plasma hormone concentrations

Figure 4.5a shows the mean plasma LH concentration patterns for red deer stags immunised against melatonin and those not immunised (control). Both groups show similar patterns of plasma LH levels which declined from 0.97 and 0.85 ng/ml in February to the lowest values of 0.50 and 0.48 ng/ml in May for the immunised and control groups, respectively, with vaccination treatment having no effect ($P > 0.10$). The mean plasma testosterone concentrations for both groups are shown in Figure 4.5b. The highest mean values of 7.8 and 9.2 ng/ml were recorded in February whilst the lowest mean values of 3.2 and 2.3 ng/ml were recorded in May for immunised and control groups, respectively. The mean plasma testosterone concentrations were generally lower for the immunised group than for the control group, though the difference did not attain significance ($P > 0.10$). Figure 4.5c shows the mean plasma prolactin concentration patterns for both groups. The two groups show similar patterns of prolactin levels, with a decline between February and May, followed by a peak (21.6 and 5.5 ng/ml) for immunised and control groups, respectively, in June, and a sharp decline in July. The mean plasma prolactin levels for the immunised group were generally higher than those for the control group, but the difference did not attain significance ($P > 0.10$) due to the large variation recorded.

4.3.2.3 Liveweight patterns

Seasonal patterns of liveweight change are shown for all animals (Figure 4.6a; $n = 8$ and 7 for antigen vaccinated and control groups, respectively), and for control animals ($n = 7$) and responders to melatonin vaccination (immunised, $n = 6$; Figure 4.6b). Patterns of liveweight change are similar for both methods of presentation, with both groups losing weight during the rut season, with the lowest liveweight recorded occurring in June. There was a rise in liveweight during winter, with vaccination treatment having no effect ($P > 0.10$) during both seasons.

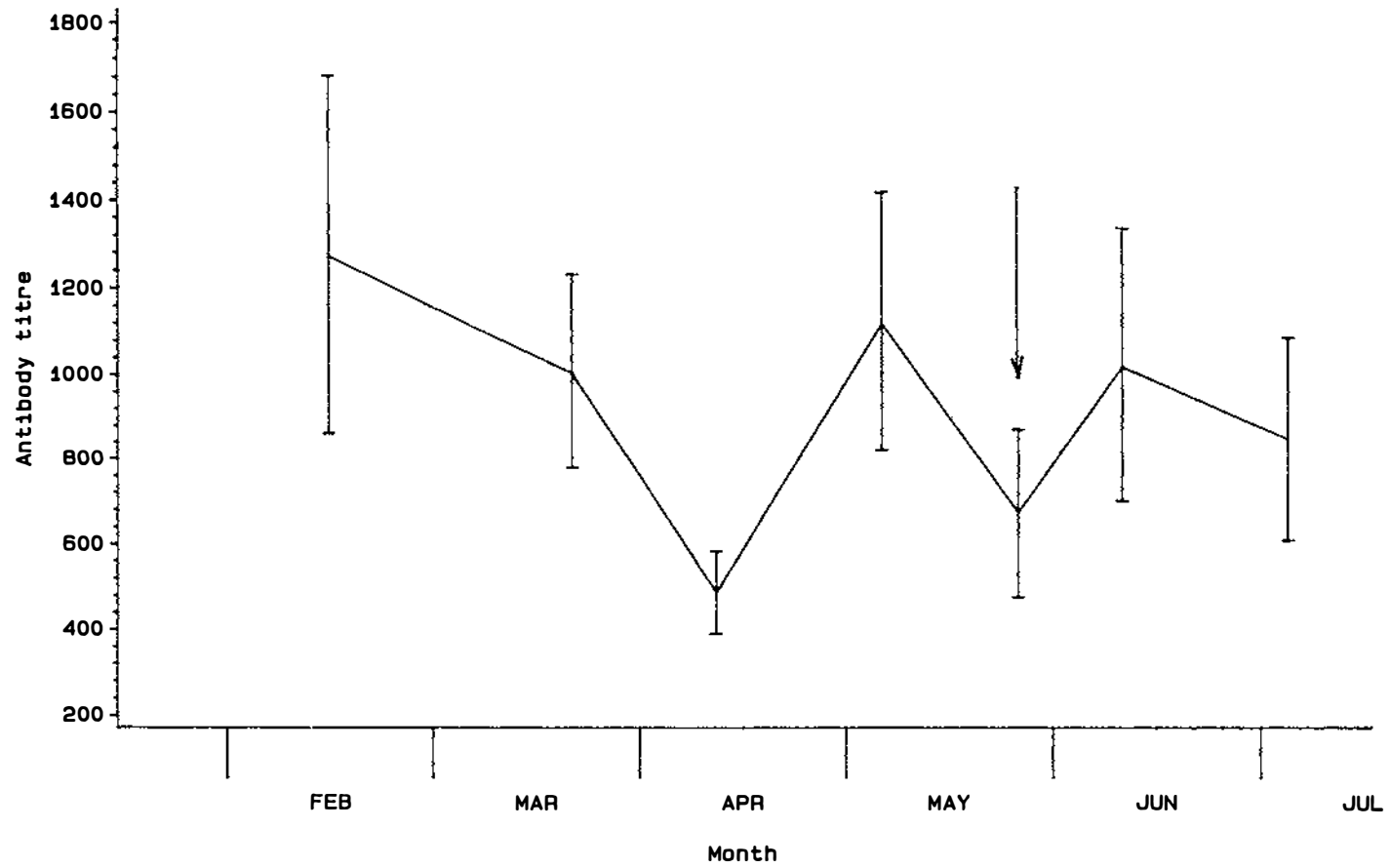


Figure 4.4. Pattern of anti-melatonin antibody titre development in the red deer stags. (↓) indicates booster, (I) indicates SE.

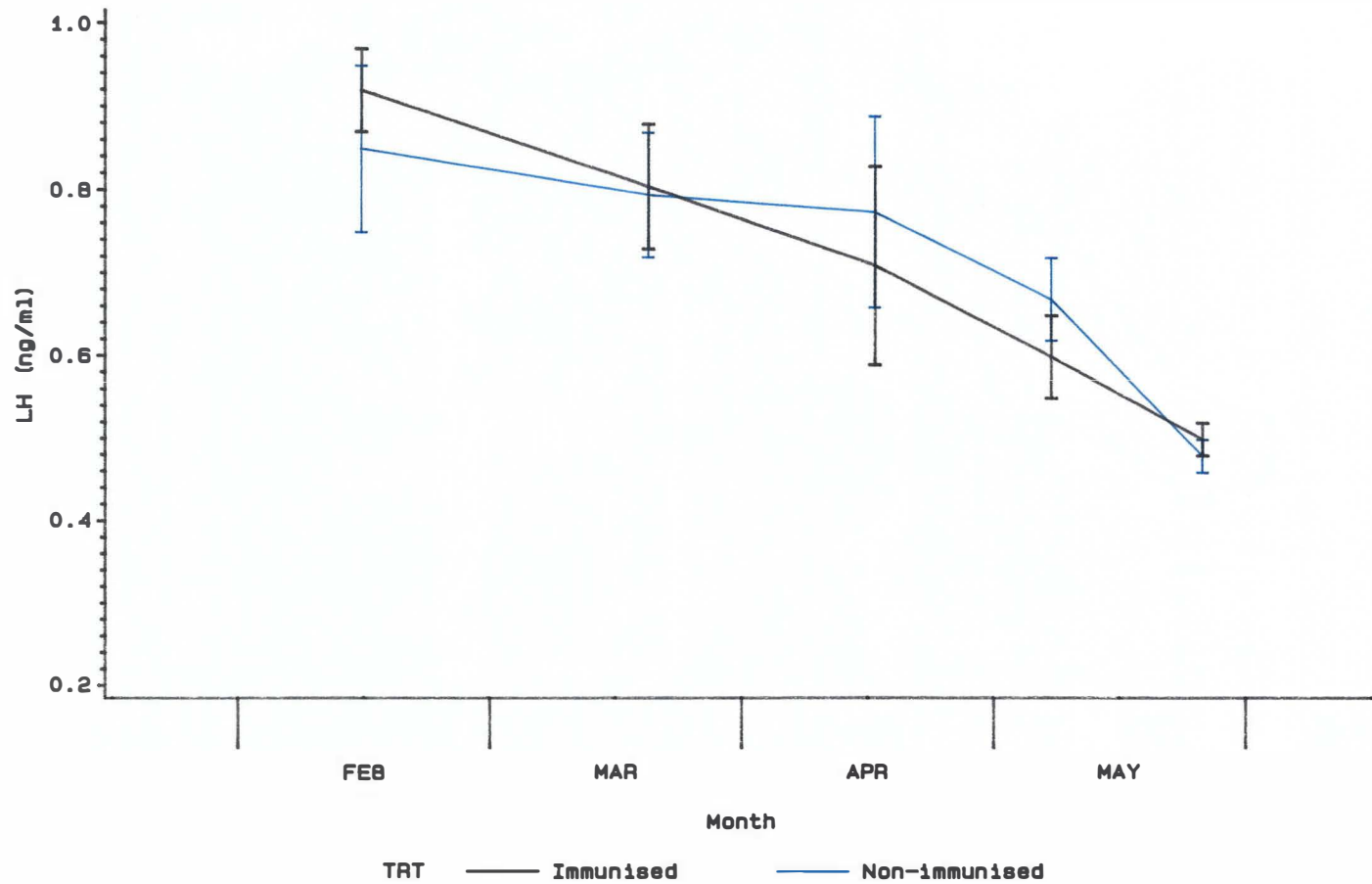


Figure 4.5a. Plasma concentrations of LH in immunised (n=6) and non-immunised (n=7) yearling red deer stags against melatonin. (I) indicates SE.

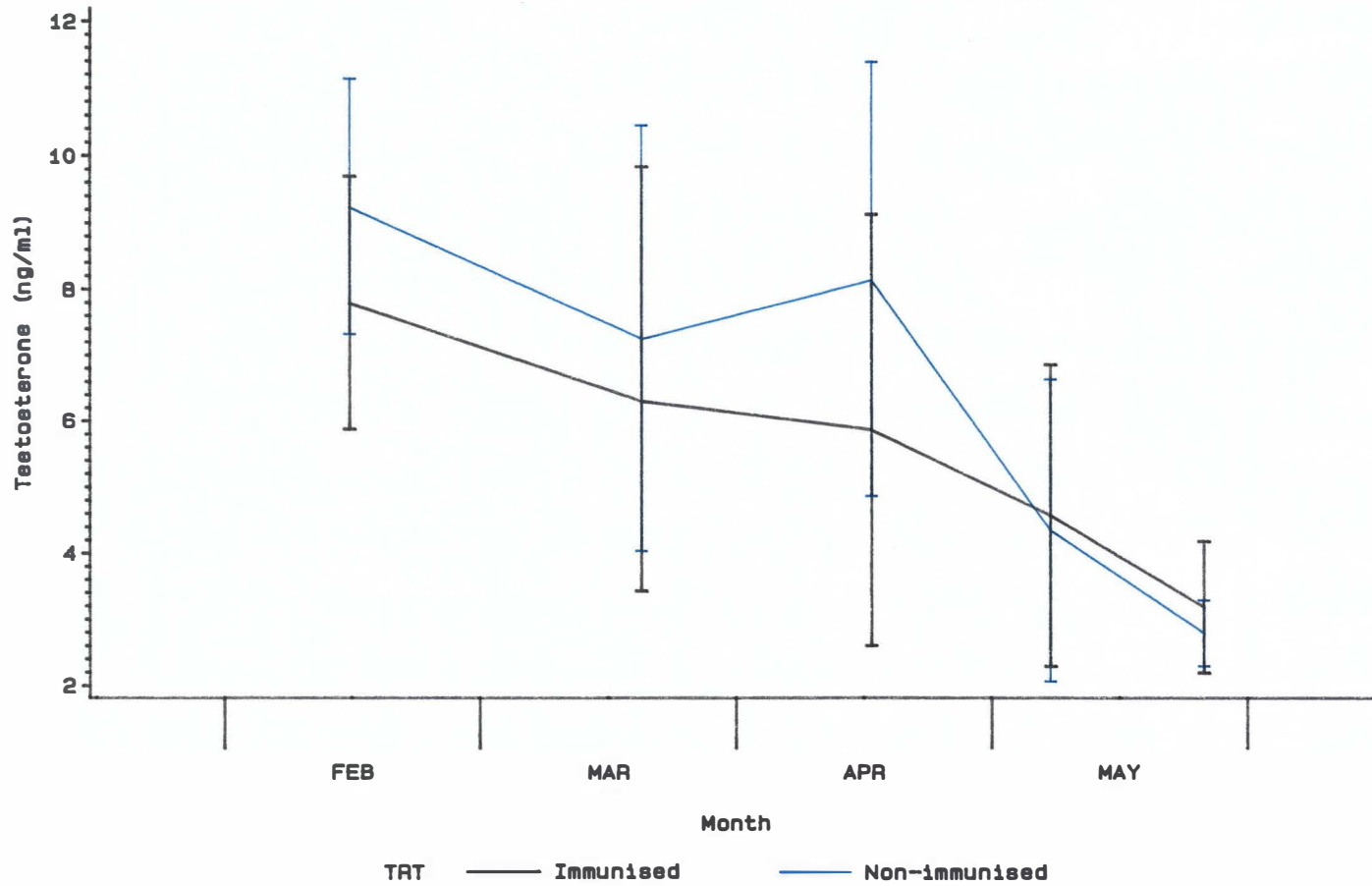


Figure 4.5b. Plasma concentrations of testosterone in immunised (n=6) and non-immunised (n=7) yearling red deer stags against melatonin. (I) indicates SE.

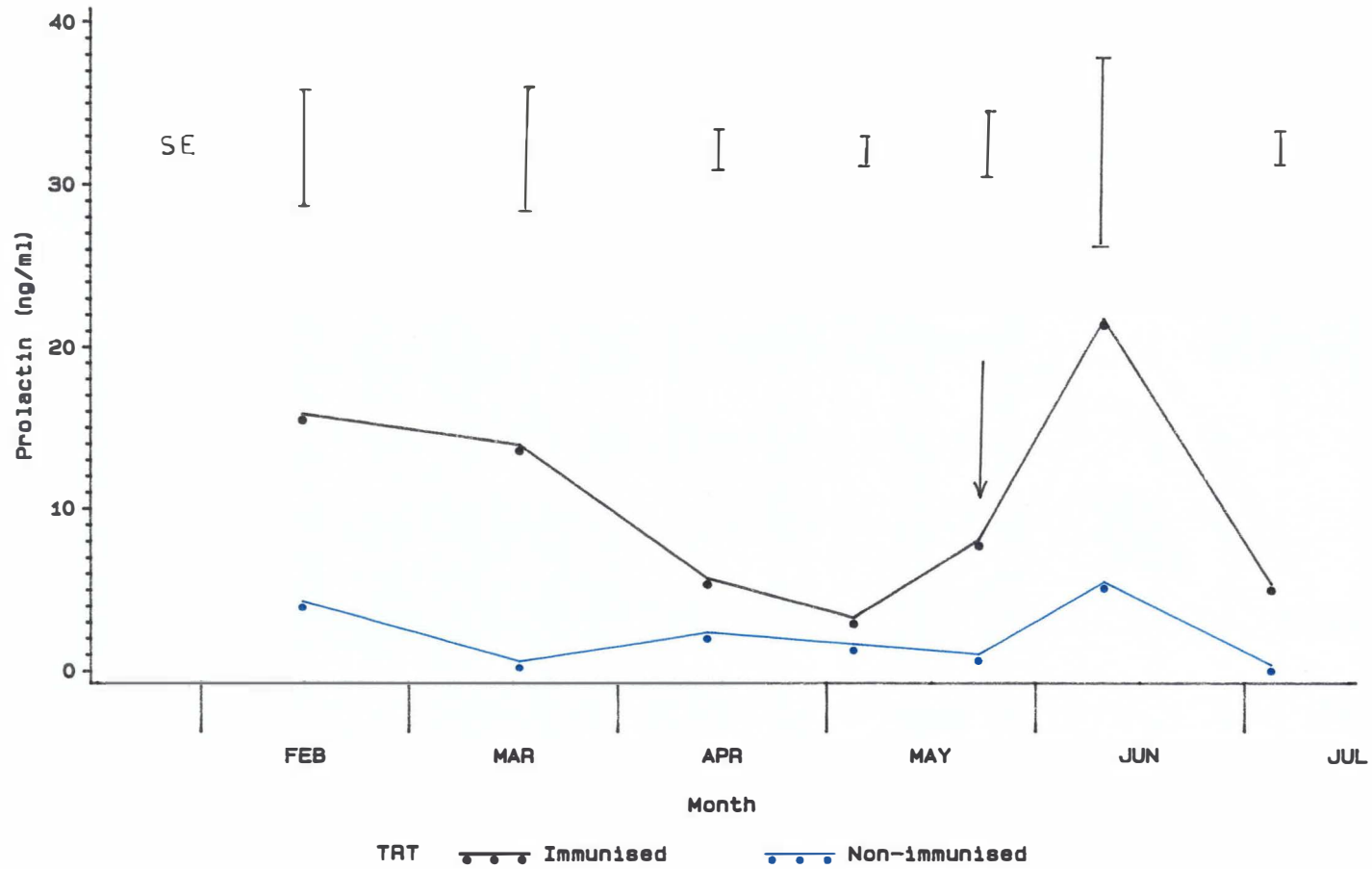


Figure 4.5c. Plasma concentrations of prolactin in immunised (n=6) and non-immunised (n=7) yearling red deer stags against melatonin. (↓) indicates booster.

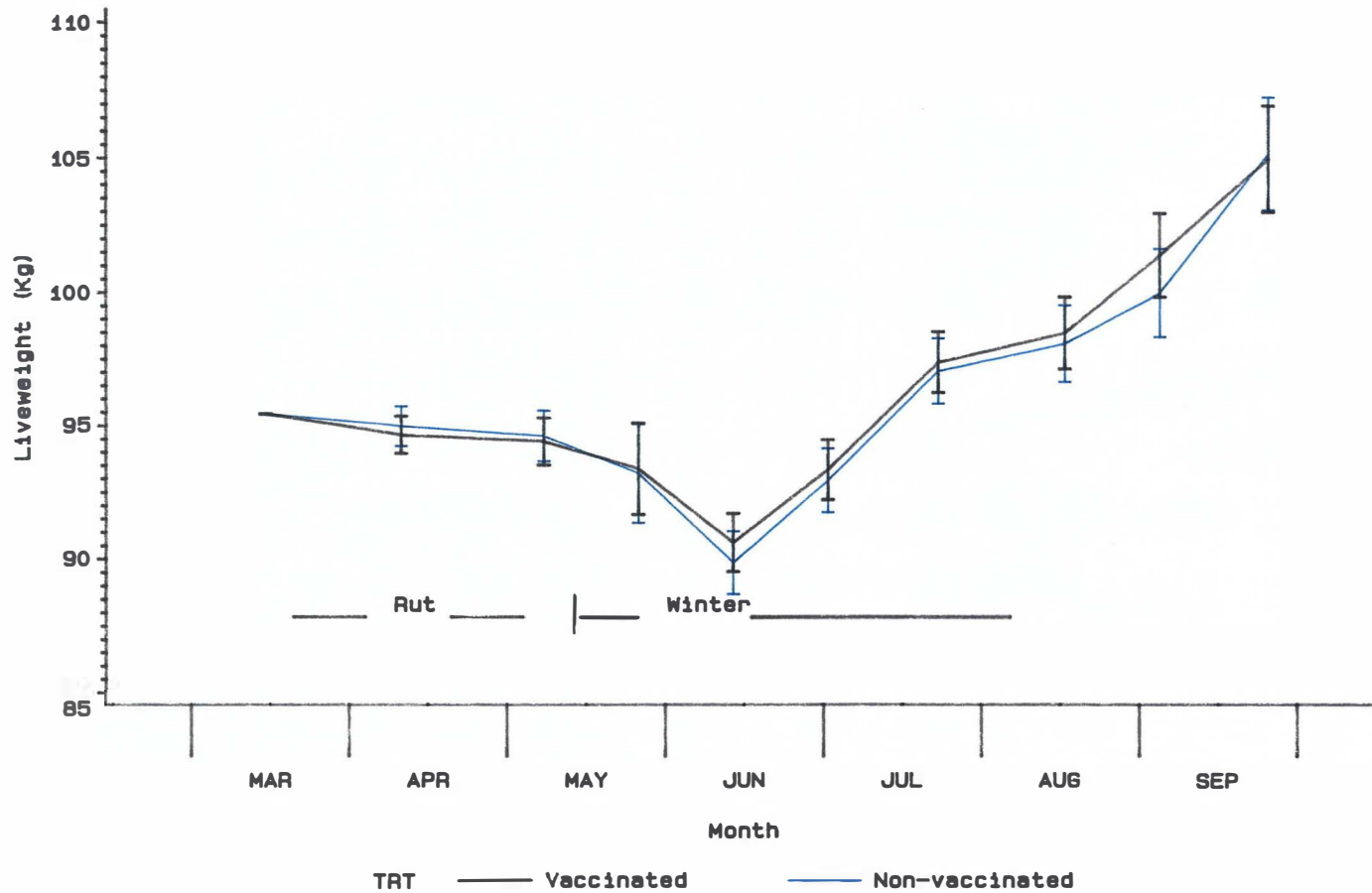


Figure 4.6a. Seasonal liveweight pattern of vaccinated (n=8) and non-vaccinated (n=7) yearling red deer stags against melatonin. (I) indicates SE.

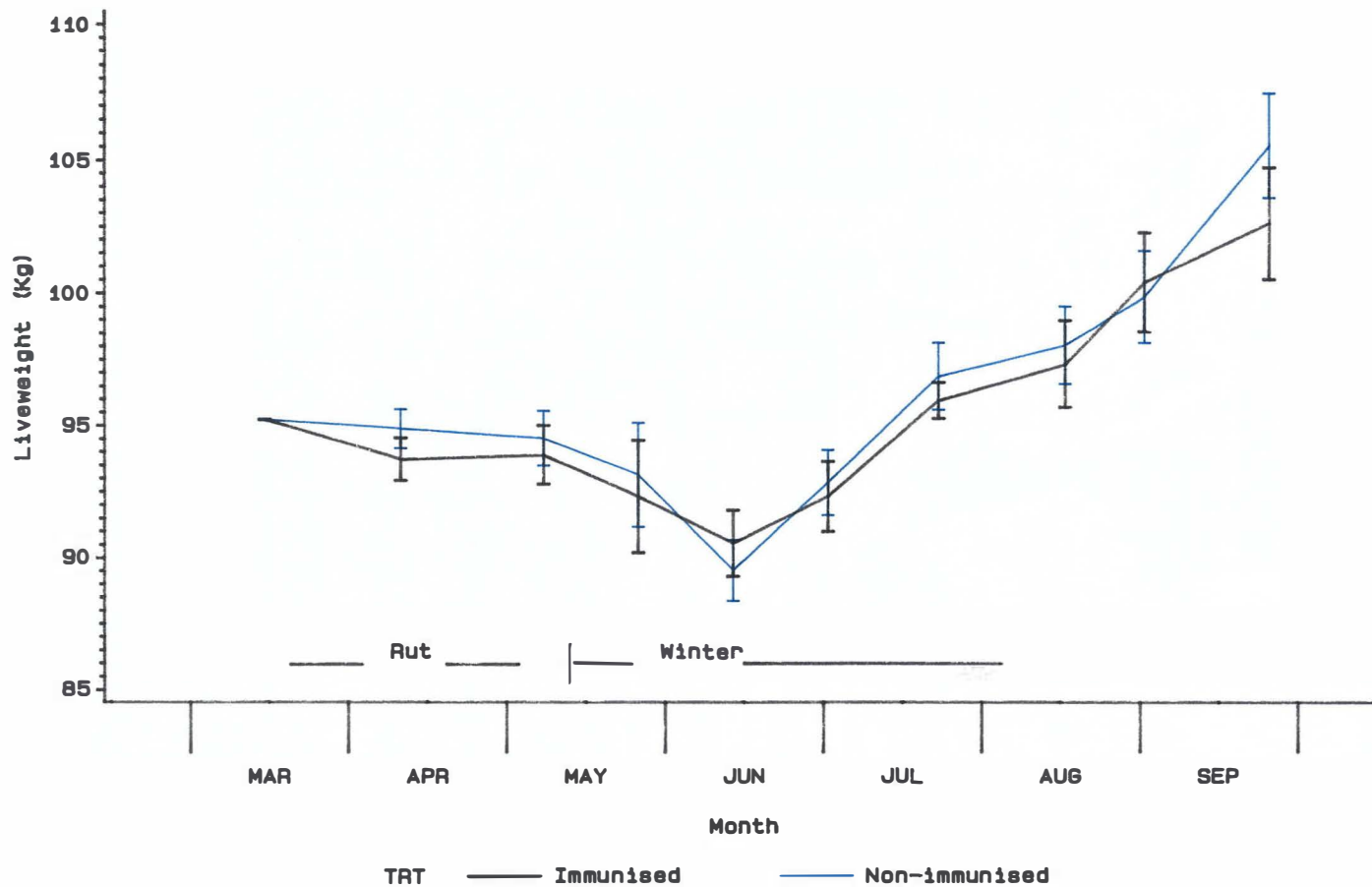


Figure 4.6b. Seasonal liveweight pattern of immunised (n=6) and non-immunised (n=7) yearling red deer stags against melatonin. (I) indicates SE.

4.3.2.4 LWG

Table 4.2 shows that there was no significant difference ($P > 0.10$) in the growth rates of both the vaccinated and the control groups during the two seasons. The vaccinated group and the control group lost an average of 32 and 34 g/day, respectively, during the rut season and gained 54 and 63 g/day respectively during winter. The LWG remained similar when responders to immunisation only ($n = 6$) were compared with the control group.

4.3.2.5 Carcass data

The values for the dressing-out percent, testes weight and GR for both the melatonin vaccinated and the control group were similar (Table 4.2; $P > 0.10$). The rump fat cover for the melatonin vaccinated ($n = 8$) and the responders ($n = 6$) were similar and were both lower ($P < 0.05$) than that for the control group.

Table 4.2 Liveweight gain (g/day) of anti-melatonin treated and control yearling red deer stags during the rut and during winter (1989) and carcass data.

	Control	Melatonin Vaccinated	S.E.
No. animals/group	7	8 (6)	
Initial weight (kg)	95.4	95.4 (95.2)	
LWG (g/day):			
Rut season	-34	-32 (-45)	26.51
Winter	63	54 (46)	16.01
Carcass data:			
Carcass weight (kg)	61.0	64.1 (63.9)	1.39
Dressing-out (%)	55.1	55.8 (55.9)	0.31
Rumpfat width (mm)	121.3	114.1* (113.4)*	1.87
Testes weight (g)	99.0	98.1 (97.7)	0.78
GR (mm)	6.2	6.6 (5.6)	0.59

* $P < 0.05$

($n = 6$) = responders to anti-melatonin vaccination (ie two non-responders deleted).
Rut and Winter LWG (g/day) was calculated using liveweight at the beginning of rut season (March 22) and Winter (May 25) as covariates, respectively.

Rump fat width, testes weight and GR were analysed using carcass weight as a covariate (mean 62.8 kg).

4.4 DISCUSSION

4.4.1 **Anti-LHRH trial**

4.4.1.1 **Anti-LHRH antibody titres**

The LHRH antibody titre values ranged between 1:173 - 1:1349 and had a mean value of $1:520 \pm 52$ after the peak in April. The antibody titre values recorded in the present experiment are, however, lower than the values measured on fallow deer in Australia using a similar antigen ($1:2580 \pm 452$; R.M. Hoskinson, pers. comm.). They are also much lower than the mean value of $1:10,867 \pm 7,224$ recorded for 3 red deer stags by Lincoln *et al* (1984), which was associated with a complete block of the seasonal reproductive development induced by treatment with melatonin implants. The antibody titre values for individual stags in the present experiment were not correlated with their rates of body growth.

4.4.1.2 **The timing of the LHRH primary vaccination**

The secretion of LHRH from the hypothalamus regulates the secretion of the gonadotrophic hormones, LH and FSH from the anterior pituitary gland. The seasonal changes in secretion of these hormones direct the seasonal changes in the reproductive physiology of the deer. When LHRH activity is blocked by active immunisation there is no breeding season in red deer (Lincoln 1985).

In the present experiment, the primary vaccination was given on January 17, at a time when the plasma concentration of LH in red deer stags was highest (7.5 ng/ml; Fennessy *et al* 1985). This suggested that the vaccination was given too late, and that the LHRH activity was not completely blocked. The anti-LHRH antibody titre response observed in the present trial showed that titres can be successfully raised against LHRH in the red deer, but to completely block LHRH activity and to ensure effective immunocastration of the stags the primary vaccination should probably be given a lot earlier (eg September-October), before the summer rise in LH secretion occurs and when the LHRH activity is presumably low. This should be considered for future experiments.

4.4.1.3 **Plasma hormone concentrations**

The mean plasma LH concentration recorded for the control group (0.81 ng/ml; Figure 4.2a) in April in the present experiment was higher than the value recorded by Fennessy *et al* (1985; 0.43 ng/ml) for red deer stags during the same month. The pattern of

plasma LH concentration follows a seasonal trend, with a decline from peak plasma concentrations between December and January to a low during winter (Fennessy *et al* 1985). Similar trends were followed in the present study, with the LH levels of the immunised group being lower than those of the control group, especially in late May ($P < 0.05$). This is an indication that there was a suppression of LH secretion in the immunised group, and the lack of complete blockade of LH secretion could be due to the fact that the vaccination programme was commenced too late. The plasma testosterone patterns (Figure 4.2b) also indicated some suppression of testosterone secretion in the immunised stags, which tended to have lower plasma levels compared with the control group, except in early May, when the mean plasma testosterone concentration of the immunised group was significantly ($P < 0.05$) higher than that of the control group.

4.4.1.4 Liveweight patterns and LWG

The weight loss shown by the control stags during the rut season in the present experiment (Fig. 4.1) is in agreement with reports published by several other workers (Lincoln 1971; Pollock 1975; Suttie and Simpson 1985). The weight loss occurred despite the fact that the stags were too young to exhibit elaborate rutting behaviour (Lincoln and Guinness 1973), and were not grazed in contact with hinds. The weight loss could be due to reduced VFI which was a result of seasonal changes in the physiology of the animals, and VFI needs to be measured in future experiments of this kind.

In the present experiment, immunocastration resulted in a small gain in liveweight over the rut, compared with a significant loss in liveweight in control animals. The present observation is in agreement with the report published by Ryg and Jacobsen (1982) on reindeer. They castrated six yearling male reindeer in spring and compared the weight gain and food intake with those of intact males. They observed that during late September and early October, coinciding with testosterone peaks, the intact animals lost weight, whereas the weights of the castrates were stable.

4.4.1.5 Carcass data

While the value for dressing-out percent was slightly lower ($P < 0.05$) for the vaccinated group than it was for the control group, the treatment had no significant effect ($P > 0.10$) on the rump fat width, testes weight or GR (Table 4.1), showing that active immunisation against LHRH to suppress the rut may not result in an increase in carcass fatness. Drew *et al* (1978) castrated red deer calves at 5 months of age and reared them with

entire animals of the same age. The stags were slaughtered at 16 and 27 months of age, and they observed that the castrate stags grew more slowly and had more fat than entire animals at equal carcass weight. The results reported in the present trial were different from that reported by Drew *et al* (1978) probably due to immunocastration being used for a short-term effect aimed at the rut period only.

Most intriguing, however, was the lack of vaccination effect on the weight of testes. In the roebuck, blood levels of LH and FSH increase in spring and summer before the rut and this is associated with an increase in the size and activity of the testes (Lincoln 1985). With active immunisation against LHRH in the present experiment, a negative testicular response to treatment had been anticipated. The fact that it was not observed could be due to two factors. Firstly, the testes may have been weighed too late (July), about 2 months after the end of rut, long enough to allow the blood levels of LH and FSH to decline and cause a rapid decrease in both the spermatogenic and androgenic functions of the testes of the control group, thereby eliminating any differences in testes size between the two groups. Secondly, immunocastration was only partially achieved in the vaccinated group, hence the testes of animals in both groups went through similar seasonal cycles.

4.4.2 Anti-Melatonin trial

4.4.2.1 Anti-melatonin antibody titres

Seventy-five percent of the stags vaccinated with the melatonin antigen gave an anti-melatonin antibody response. The antibody titre values range between 1:210 - 1:3167. The titre value at its peak in February was $1:1272 \pm 411$ (mean \pm s.e.) which was much lower than the peak value of $1:3479 \pm 1200$ recorded by McConnell *et al* (1987) in the Tammar Wallaby (*Macropus eugenii*) using a similar antigen. Within the vaccinated group, the antibody titres recorded for individual stags in the present experiment, were not correlated with their growth rates. The vaccinated animals did not grow faster than the control animals ($P > 0.10$; Table 4.2). Duckworth and Barrell (1989) reported that immunisation of red deer stags against melatonin can modify the seasonal pattern of liveweight changes during their first two years of growth. They observed that immunised stags were 7-10% heavier than their controls between 9 and 11 months of age and at 16 and 20 months of age. This observation was not repeated in the present trial. The Lincoln University workers, however, did not measure the antibody titres, and it would have provided a useful comparison with the values reported in the present trial, in order to determine if a high enough level of titre was raised

or not. The major difference between the Lincoln University experiment and the present trial was that they vaccinated the deer at birth, whilst in the present trial, the vaccination sequence commenced at weaning.

4.4.2.2 Plasma hormone concentrations

The patterns of mean plasma concentrations of LH were similar for both immunised and control groups and seemed to be seasonal, with high values during late February and low values in May (Figure 4.5a). There was no vaccination treatment effect on the plasma LH concentrations ($P > 0.10$). The mean plasma testosterone concentrations showed a similar seasonal pattern (Figure 4.5b) as the LH levels, with the mean testosterone levels for the immunised group being generally lower than those of the control group, though the difference did not attain significance ($P > 0.10$). The mean plasma prolactin concentrations of the control group in the present experiment showed a typical autumn/winter low levels after a decline from peak concentrations during mid summer as reported by Barrell *et al* (1985). The mean levels in the immunised group tended to be higher than those of the control group, although the difference did not attain significance ($P > 0.10$). The mean plasma testosterone and prolactin concentrations in the present experiment gave some indication of treatment effects. That the treatment effects were not significant could be a reflection of the low melatonin antibody titre recorded in the present experiment (Figure 4.4). In order to raise high melatonin antibody titre at an early time, it may be suggested for future experiments that the stags be vaccinated at birth rather than at weaning and that diethylaminoethyl dextran (DEAE-dextran) be used as an alternative adjuvant. Hibma and Griffin (1988) reported that DEAE-dextran acts as a very efficient adjuvant for antibody production in farmed deer. Raising high melatonin antibody titre in the immunised stags, may result in high plasma prolactin concentrations in the animals during autumn/winter. Because prolactin injections during winter have been shown to increase VFI and LWG in young male reindeer (Ryg and Jacobsen 1982) and in young male red deer (J.M. Suttie, pers. comm.), this could have a positive effect on the VFI and LWG of the immunised stags.

4.4.2.3 Liveweight patterns and LWG

The melatonin vaccinated and control groups showed similar liveweight patterns (Fig. 4.6a and b), with no significant difference between the two groups during both seasons. The vaccinated and the control groups lost an average of 32 and 34 g/day, respectively, during the rut season and gained an average of 54 and 63 g/day, respectively, during the winter (Table 4.2). The net weight gains for the respective groups for the period between March 22-August

18 (5 months) was 22 and 29 g/day. This, in terms of venison production, is very uneconomical and therefore a strong point in favour of venison production from young red deer stags by 12 months of age. During the first winter, the young stags have a low potential growth rate, but during the stag's second autumn, VFI is reduced to a greater extent because puberty has been reached. This, coupled with the poor growth during the second winter of life, leads to virtual growth stasis for about 5 months, which makes it uneconomical to rear stags for venison production beyond 12 months of age. Ataja *et al* (1989) reported that providing weaner red deer stags receive generous feed offer during winter and spring, a high proportion (75-79%) of them attained slaughter weight (92 kg LW) by 13 months of age.

4.4.2.4 Carcass data

The anti-melatonin treatment had no significant effect ($P > 0.10$) on the dressing-out percent, testes weight and GR. The melatonin vaccinated or the responders ($n = 6$) had lower rump fat width ($P < 0.05$) than the control group, suggesting that immunisation of young stags against melatonin did not result in greater fat deposition on that part of the carcass.

4.5 CONCLUSIONS AND FUTURE RESEARCH

1. Antibody titres were successfully raised against LHRH and melatonin antigens in yearling red deer stags.
2. The LHRH antigen vaccinated animals had a higher LWG ($P < 0.05$) than the control group during the rut. Plasma LH and testosterone concentrations tended to be lower than in control animals.
3. There was no melatonin vaccination effect on the growth rate of the stags during the rut or during winter. Plasma prolactin concentrations tended to be higher in the immunised than in control deer.
4. Immunocastration during the rut season may be more promising for increasing autumn growth of yearling red deer stags than immunisation against melatonin. However, further work involving larger numbers of animals and an earlier commencement of immunisation is needed.

5. The LHRH vaccinated stags had a lower dressing-out percent ($P < 0.05$) than the control group. The melatonin immunised animals had a lower rump fat width ($P < 0.05$) than the control group.

6. Measurements to consider for future experiments:
 - (a) The LHRH primary vaccination should be given earlier (eg September-October) to attempt to cause effective blockade of LHRH activity.
 - (b) Two or three booster vaccinations should be given to attempt to establish high antibody titre values.
 - (c) Vaccination of stags against melatonin should be commenced at birth using DEAE-dextran as alternative adjuvant.
 - (d) Measurement of testicular circumference should be made during the rut season.
 - (e) Measurement of dry matter VFI during the rut season using intra-ruminal chromium capsules should be considered.
 - (f) Chemical analysis to measure carcass fatness should be undertaken, to assess effects of the immunisation on carcass fatness.

CHAPTER 5

**STUDIES ON THE EFFECTS OF HIGH FEED ALLOWANCE,
THE INTRODUCTION OF MOATA ANNUAL RYEGRASS AND
IMMUNISATION AGAINST MELATONIN UPON VFI, DIET SELECTION
AND GROWTH RATE OF GRAZING RED DEER STAGS**

5.1 INTRODUCTION

The present experiment was the last in a series of three experiments designed to investigate treatments for improving growth of weaner red deer stags during winter and spring. Treatments evaluated were a high allowance of pastures based upon either perennial ryegrass or annual ryegrass, with the objective of getting them to a slaughter weight of 92 kg LW (> 50 kg carcass) within 12 months of age. Re-evaluation of the effectiveness of immunisation against melatonin as a means of increasing LWG during winter and early spring, which was investigated in previous trials (Chapters 2 and 3), was an integral part of this experiment. In previous experiments (Chapters 2 and 3), the anti-melatonin immunisation was commenced either in May or March. In the present experiment, the immunisation was commenced at birth.

The 1988 experiment (Chapter 3) showed that it was possible for weaner red deer stags grazing perennial ryegrass-based pastures to attain LWG of 153 and 234 g/day during winter and spring, respectively. Whilst those grazing annual ryegrass-based pastures attained 131 and 209 g/day during winter and spring, respectively, with the introduction of Moata having no effect.

The 1987 experiment (Chapter 2) showed that the annual ryegrass component of the Moata swards increased from 17 and 19% DM in winter to 36 and 27% DM in spring for high and medium allowances, respectively, under a rotational grazing system. In 1988, the second experiment (Chapter 3) using set stocking management revealed that the annual ryegrass component of the Moata swards declined from 33 and 46% DM in winter to 19 and 22% DM in spring for 10 and 5 cm swards, respectively, probably as a result of the sensitivity of the annual ryegrass to continuous defoliation through grazing. In the present experiment, in an attempt to establish a high annual ryegrass component in the Moata swards, a higher seed rate (24 kg seed/ha) was drilled into perennial ryegrass pastures. To maintain the high annual ryegrass component in the swards during winter and spring, a 5 and 3-weekly rotational grazing system was adopted during winter and spring, respectively, in an attempt to avoid continuous defoliation of Moata annual ryegrass by the stags.

The weaner stags were made to be of quiet temperament for the present experiment and were also trained to respect electric fences as described in Chapter 3.

The main objective of the present experiment which was to achieve a slaughter weight of 92 kg by 12 months of age, was the same as in the 1987 and 1988 experiments. The following factors were investigated:

1. The effect of inclusion of Moata annual ryegrass at a higher seed rate (24 kg seed/ha) on the winter and spring LWG and upon pasture composition.
2. Effect of commencing immunisation of stags against melatonin at birth upon the rate of LWG.
3. The patterns of anti-melatonin antibody titre development for Freund's and Dextran adjuvants. Previously only Freund's adjuvant had been used.
4. The effects of the pasture type and immunisation treatments upon voluntary VFI and diet selection, determined under grazing.

5.2 MATERIALS AND METHODS

5.2.1 **Experimental design**

Thirty-six weaner red deer stags were grazed under a rotational grazing system on either perennial ryegrass/white clover pasture (n = 18) or the same direct drilled with Moata annual ryegrass (n = 18). Balanced numbers of animals grazing each pasture type were given a vaccination treatment designed to immunise against melatonin, the objective being to increase animal growth rate during winter. The experiment was conducted on the Massey University deer research unit between May and November 1989.

5.2.2 **Animal temperament**

Eighteen weaner red deer stags purchased from a property at Fielding, Manawatu, were transported to Massey University on April 6, 1989, where they were joined with another group of 18 weaners raised on the University deer unit. The thirty-six weaner stags were run as a group during the pre-experimental period and were made to be of quiet temperament suitable for the present experiment as described in Chapter 3.

5.2.3 Animal allocation

Thirty-six weaner red deer stags weighing $52.9 \text{ kg} \pm 5.85$ (mean \pm SD) were assigned to two mixed pasture sward types (perennial ryegrass/white clover and the same direct drilled with Moata annual ryegrass) and were ear-tagged on May 15, 1989. All stags were drenched with "IVOMEK" (Ivermectin, Merck, Sharp and Dohme, N.Z.) at three weekly intervals from weaning to June 1989 and monthly thereafter until November 1989. The stags were also vaccinated against clostridial infections using "Convax 5" vaccine (Aluminium hydroxide adjuvant and 0.015% thiomersal; Coopers Animal Health, N.Z. Limited) on May 14 (dose rate = 2 ml/animal, s.c. on the side of the neck) and weighed and allocated to pasture treatment on May 15, 1989. Thereafter, the stags were weighed straight off pasture at three weekly intervals.

In order to estimate dry matter intake (DMI), all stags were orally dosed with sheep-type intraruminal chromium controlled release devices (CRD; Captec^R, 3.0 cm core, 65% Cr₂O₃ Matrix, 9.00 mm orifice diameter, QS Wing design), on June 14, and November 2, 1989. Group faecal samples (collected in the paddocks) and rectal faecal samples taken from individual animals between 8 and 20 days post-CRD dosing were collected to use for estimating winter and spring VFI of the grazing stags respectively.

The experiment was terminated on November 30, and animals that attained the target slaughter weight of 92 kg LW or over were sent for slaughter at the Feilding DSP of Venison New Zealand Limited, on December 7, 1989.

5.2.4 Oesophageal fistulated (OF) stags

Five 5 month-old, castrated, hand reared OF red deer stags weighing $50 \text{ kg} \pm 3.5$ (mean \pm SD) were randomly allocated between the two grazing groups (2 or 3 stags/group) for the purpose of diet selection studies.

Starting in June 1989, the OF stags were allowed to graze with their respective groups for four days, after which they were brought into the yard where they were kept to fast for 3 hours. After the fasting period, the stags were manually restrained and the oesophageal fistulae removed. They were then fitted with plastic sample collection bags around the necks and turned into pasture to graze for 40 minutes, after which they were brought into the yard

where the extrusa samples were collected in labelled aluminium foil containers. The OF stags were then sedated, using 10% "Rompun" (20 mg/stag, i.m.), the fistulae replaced. The stags were then given an injection of "Recervyl" (2 ml, i.v.) for the reversal of "Rompun" effect and were returned to their paddock. Extrusa samples were collected twice per month until November, with animals swapped between sward types during each sampling in order to remove any animal effects.

5.2.5 Rumen fistulated stags

Seven 4.5 year-old, castrated, hand reared rumen fistulated red deer stags weighing $115 \text{ kg} \pm 8.5$ (mean \pm SD) were randomly allocated between the two grazing groups (3 or 4 stags/group) for the purpose of rumen fluid sampling for VFA and NH_3 determination.

In September 1989, the fistulated stags were allowed to graze with their respective groups for 4-5 days. After the initial grazing period, the stags were brought into the yard where a metal probe encased in a polyester sac, which acted as a filter, with a pore size of $80 \mu\text{m}$ (Estal Mono; Swiss Screens Limited, Australia) was dropped into the rumen of each stag. The probes were attached to plastic tubes drilled through holes in rubber fistula-bungs for ease of rumen fluid sampling. The stags were turned back into the pastures to graze, and the next day, they were brought into the yard where rumen fluid samples were drawn from each animal through the plastic tubes using 20 ml syringes (Appendix III). The bungs with the probes were removed and replaced with normal fistulae bungs, the animals were cleaned and returned to their paddock. Rumen fluid samples were taken three times per month (September-November), with animals swapped between sward types each time in order to remove any animal effects.

5.2.6 Pasture management

The stags were grazed under a rotational grazing system, with 5 and 3 weeks period in between grazing during winter and spring respectively. This is described as infrequent grazing pressure. The in-between grazing periods of 5 and 3 weeks during winter and spring, respectively, were necessary to allow the Moata annual ryegrass to recover sufficiently in readiness for re-grazing (R.J.M. Hay, per. comm.). The animals grazed either perennial ryegrass/white clover swards (hence referred to as 'pasture') or pasture direct drilled with Moata annual ryegrass (hence referred to as 'Moata'), on levels of herbage DM mass of 2100-

1600 kg DM/ha (pre- and post-grazing herbage mass). The pasture swards were grazed from 10 cm (initial) to 8 cm (final) height during winter and spring, whilst the Moata swards were grazed from 16 cm to 12 cm during early winter, and as the tiller density of the sward increased, they were grazed from 12 to 10 cm from late winter through spring. The sward heights were based upon 6 weekly calibration curves produced from herbage cuts. The different initial heights were selected so that pasture and Moata swards of the same mass (2100 kg DM/ha) were offered.

Each sward type consisted of 2.5 ha areas divided into 5 plots (5 half ha plots) for weekly rotation. The Moata paddocks were direct drilled (blanket-sprayed with herbicide) using the cross-pass technique (Baker 1976) on March 23, 1989 at a rate of 24 kg seed/ha (12 kg seed/pass). Insecticide, "Thimet" 20G (200 g/kg phorate granules; ICI, N.Z. Limited, Wellington) was applied down the spout along with the seeds during drilling at 5 kg/ha, to kill slugs and other molluscs that might feed on the Moata seeds. Superphosphate fertiliser was applied to all paddocks on April 14, 1989 at a rate of 200-250 kg/ha. All Moata swards were grazed by the weaner stags in a group between April 28-May 14, in order to give the annual ryegrass a chance to tiller. The target sward heights (10 cm for pasture and 16 cm for Moata sward) were established on May 15, 1989, when the stags were sorted out into their respective groups and the experiment commenced on that day. All paddocks were top-dressed with Urea on May 23 and July 25 at a rate of 80 kg/ha (36.8 kg N/ha), respectively. The sward heights were monitored 3 times per week and maintained at the target heights as described in Chapter 3. During spring, animals in each group were restricted to grazing only 3 plots due to increase herbage production. Occasionally, non-experimental animals (deer from a different group that were not part of the experiment) were introduced into the paddocks to clean up post-grazing residues in order to ensure clean swards and to maintain target heights.

Five random herbage sample cuts (pooled) made just above soil level were taken from the plots being grazed by the stags once a month for laboratory *in vitro* digestibility analyses and for total nitrogen determination. Five sub-samples were taken monthly from each of these pooled herbage samples for botanical dissection into various components.

5.2.7 Vaccination procedures and blood sampling

The anti-melatonin vaccine was prepared in two different adjuvants; Freund's and diethylaminoethyl dextran (DEAE-dextran). Animals vaccinated with antigen in Freund's

5.2.9 Laboratory methods

All herbage and extrusa samples were stored at -20°C , freeze-dried and ground (1 mm diameter sieve) prior to laboratory analyses. *In vitro* digestibility was determined by the methods of Roughan and Holland (1977), and the total nitrogen (N) was determined by the Kjeldahl procedure as described in Chapter 2. The VFA determination was carried out by gas liquid chromatography as described by Domingue (1989). Faecal samples were stored at -20°C , and oven dried at 60°C for 48 hours to a constant weight. 1.0 g faeces DM/animal of the individual rectal samples were ashed overnight at 500°C . The group faecal samples were bulked across days (5 days/bulk) and ground (1 mm diameter sieve). The samples were thoroughly mixed and 1.0 g faecal sample in duplicate taken for each treatment were ashed overnight at 500°C . Chromium analysis was done as reported by Costigan and Ellis (1987).

Fresh herbage samples for botanical dissection were stored at 4°C , and the dissection was done as described in Chapter 2. The results were expressed as % DM.

Dissection of extrusa samples was done using a flotation technique (D.A. Clark, pers. comm.). The samples were dissected into perennial ryegrass (PRG) + other species (OS), Moata annual ryegrass (MAR), white clover (WC) and dead materials (Dm) components. Results were expressed as proportion (% contact).

The anti-melatonin antibody titre was determined by the method of Abraham (1974) as described in Chapter 2. The lowest titre measured (detectable antibody) was 1:100. The plasma LH concentrations were determined using the procedure described for sheep plasma by Scaramuzzi *et al* (1970) and validated for fallow deer plasma by Asher *et al* (1986). Plasma testosterone concentrations were determined using the procedures described by Peterson *et al* (1978), and plasma prolactin concentrations were determined using the method of van Landeghem and van de Weil (1978), as described in detail in Chapter 4.

5.2.10 Statistical analyses and calculation of data

The experimental data was analysed using GLM, as a 2 x 3 factorial design, with two swards types (Pasture and Moata) and three types of vaccination (none, Freund's and DEAE-dextran). LSM was used to test the differences between treatments.

The winter LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at August 28} - \text{Liveweight (kg) at May 15}}{104 \text{ days}} \times 1000$$

using the initial liveweight at April 10, as a covariate.

The spring LWG (g/d) was calculated as:

$$\frac{\text{Liveweight (kg) at November 30} - \text{Liveweight (kg) at August 28}}{94 \text{ days}} \times 1000$$

using the liveweight at the start of spring (August 28) as a covariate.

Pasture M/D values (MJ metabolisable energy/kg DM) were calculated as

$$\frac{\text{DOMD} \times 16.3}{100}$$

As there were no interactions between effects of pasture types and immunisation ($P > 0.10$), main effects only are presented in the results.

Plasma prolactin concentrations were analysed using GLM, and LSM was used to test the differences between treatments. Least Squares Means are presented.

5.3 RESULTS

5.3.1 **Feed on offer**

Levels of feed on offer and residue (kg DM/ha) during winter and spring for stags grazing pasture and Moata swards, respectively, are shown in Table 5.1. The two sward types were grazed at different heights but had similar herbage mass before (2012-2235 kg DM/ha) and after (1576-1665 kg DM/ha) grazing, during both seasons.

Table 5.1 Level of feed on offer (kg DM/ha) during winter (June-August) and spring (September-November) 1989.

		Pasture	Moata
WINTER			
Height (cm)	Before grazing	10	16
	After grazing	8	12
Herbage mass (kg DM/ha)	Before grazing	2105	2012
	After grazing	1600	1587
SPRING			
Height (cm)	Before grazing	10	12
	After grazing	8	10
Herbage mass (kg DM/ha)	Before grazing	2235	2190
	After grazing	1576	1665

5.3.2 Seasonal patterns of sward components

The seasonal patterns of various sward components are shown in Figures 5.1a-e. The Moata annual ryegrass component of the Moata swards was highest (87%) in June (Figure 5.1a) and remained stable at about 80% throughout winter, but started declining during September. The lowest value (43%) was recorded in late spring. The perennial ryegrass component of the Moata swards was low (< 18%) during winter and early spring and rose to 26% during late spring (Figure 5.1b). The perennial ryegrass component of the pasture swards was 82-94% during winter and early spring (Figure 5.1b), and declined to about 67% in late spring. The dead matter component of both swards showed a seasonal pattern (Figure 5.1c), being low during winter and increasing during spring. The other species and white clover components of both sward types also showed seasonal patterns (Figures 5.1d and e). They were low during winter and tended to increase during spring. The Moata swards contained very little white clover (< 1%) during winter.

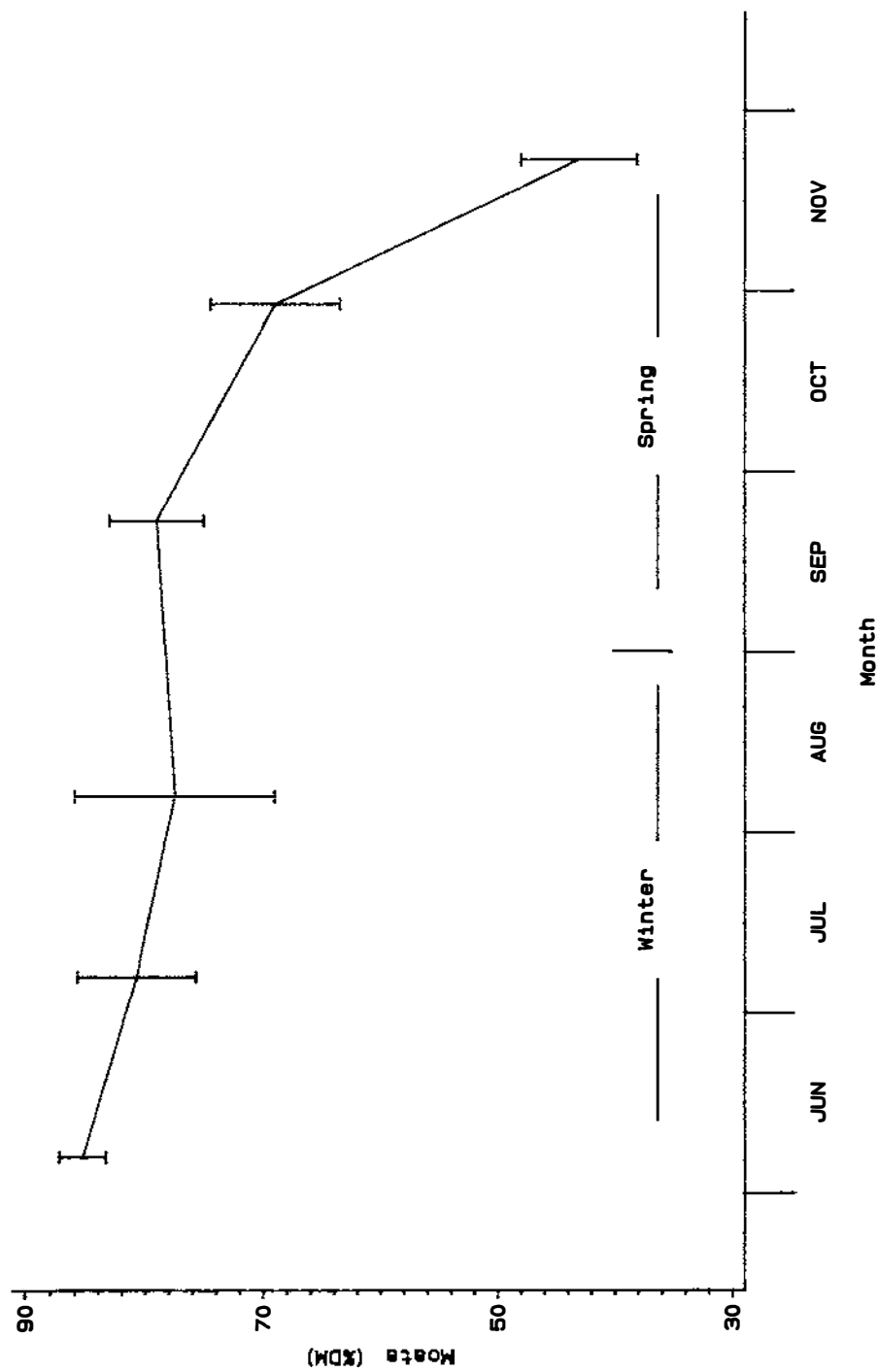


Figure 5.1a. The proportion of moata annual ryegrass on offer in the grazed pastures. (I) indicates SD.

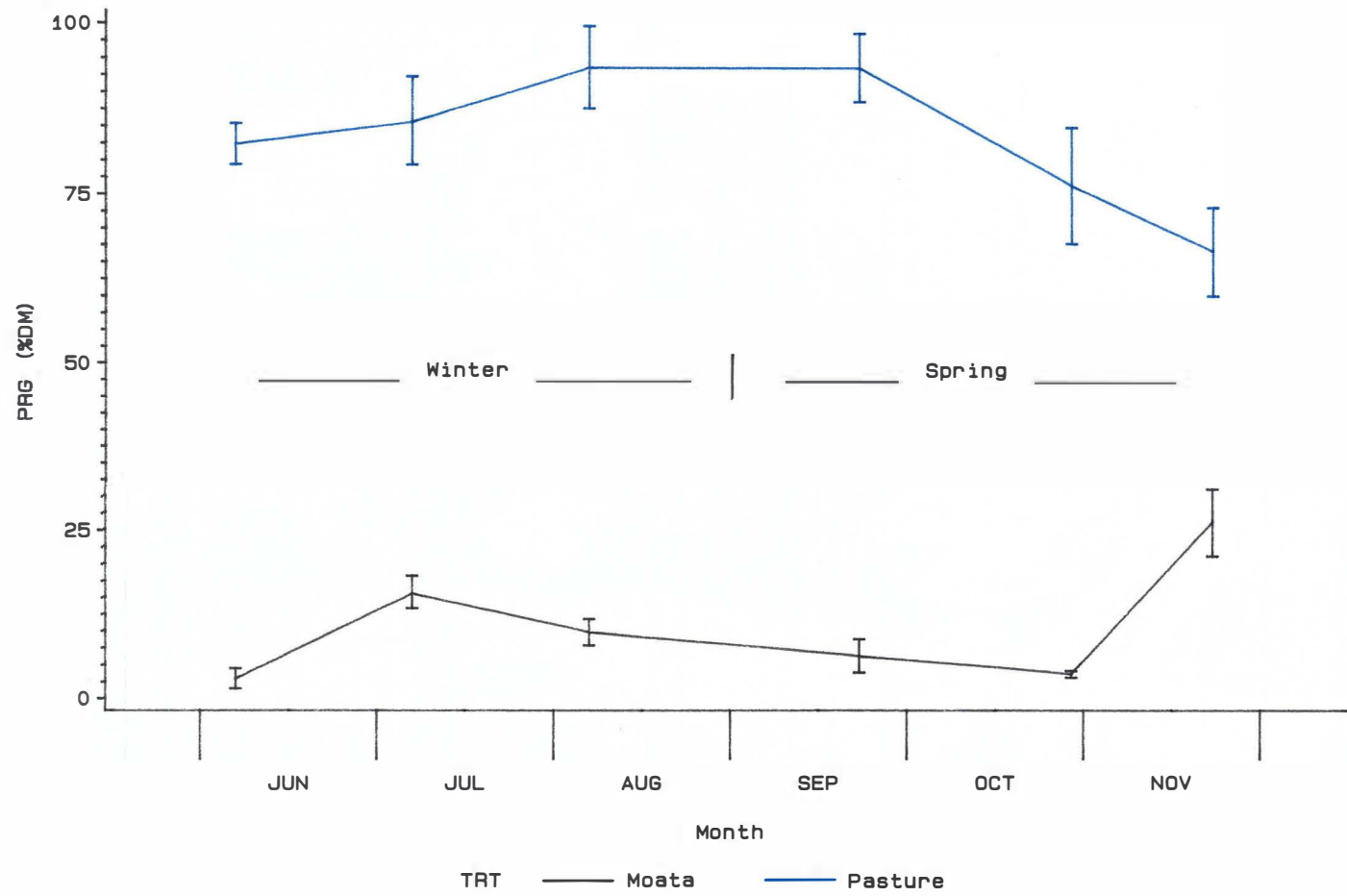


Figure 5.1b. *The proportion of perennial ryegrass on offer in the grazed pastures. (I) indicates SD.*

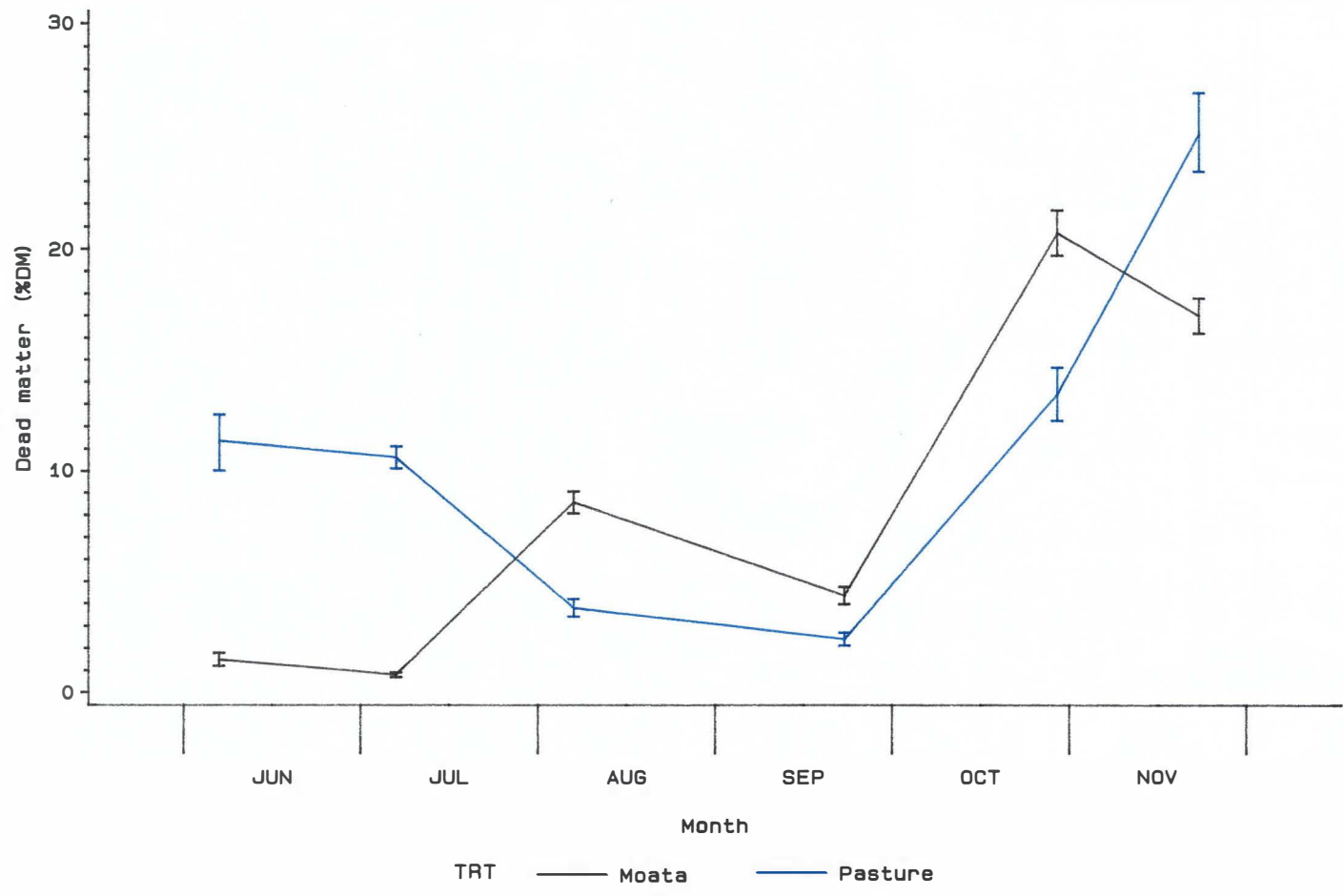


Figure 5.1c. *The proportion of dead matter in the grazed pastures. (I) indicates SD.*

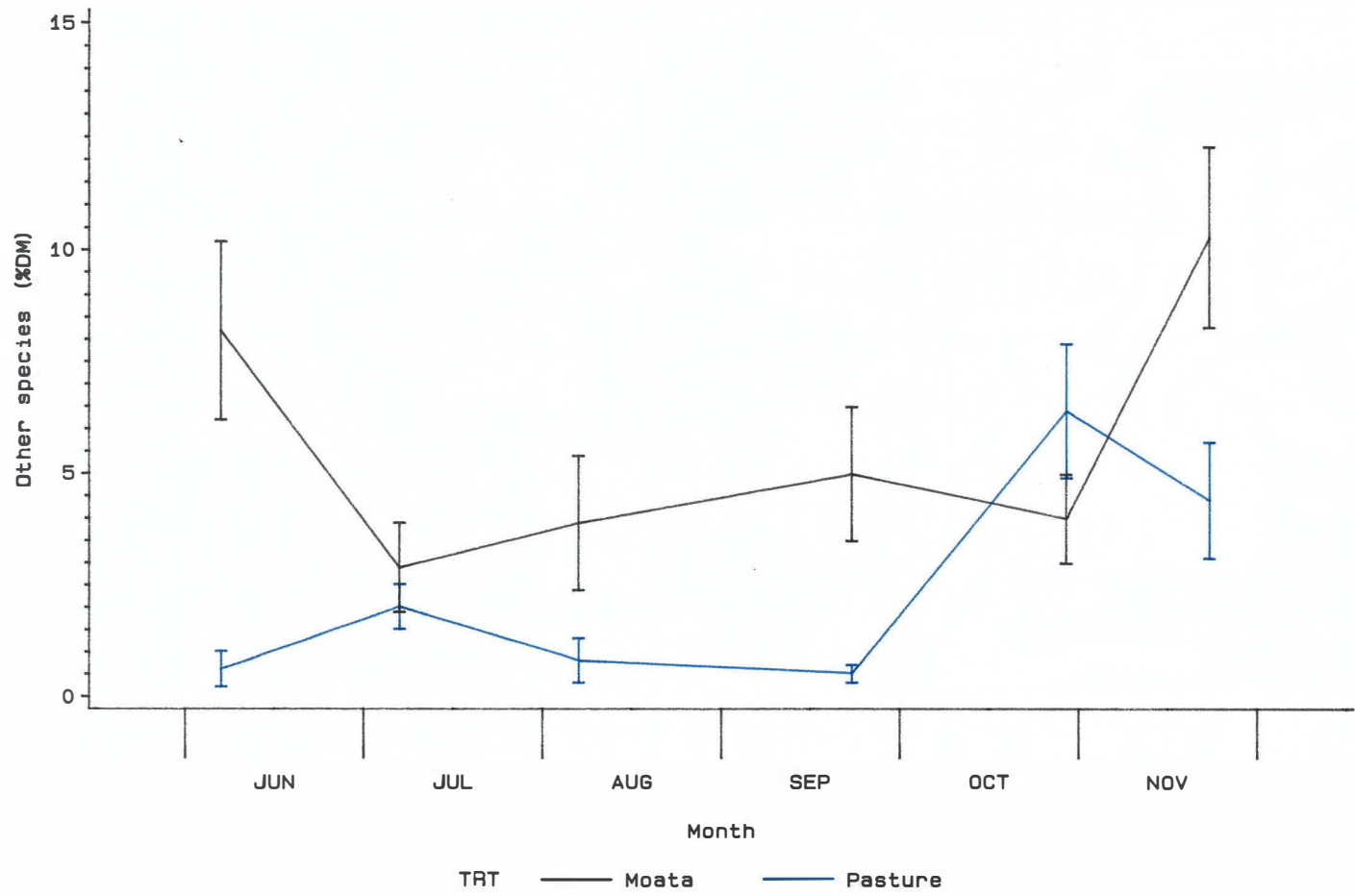


Figure 5.1d. *The proportion of other species in the grazed pastures. (I) indicates SD.*

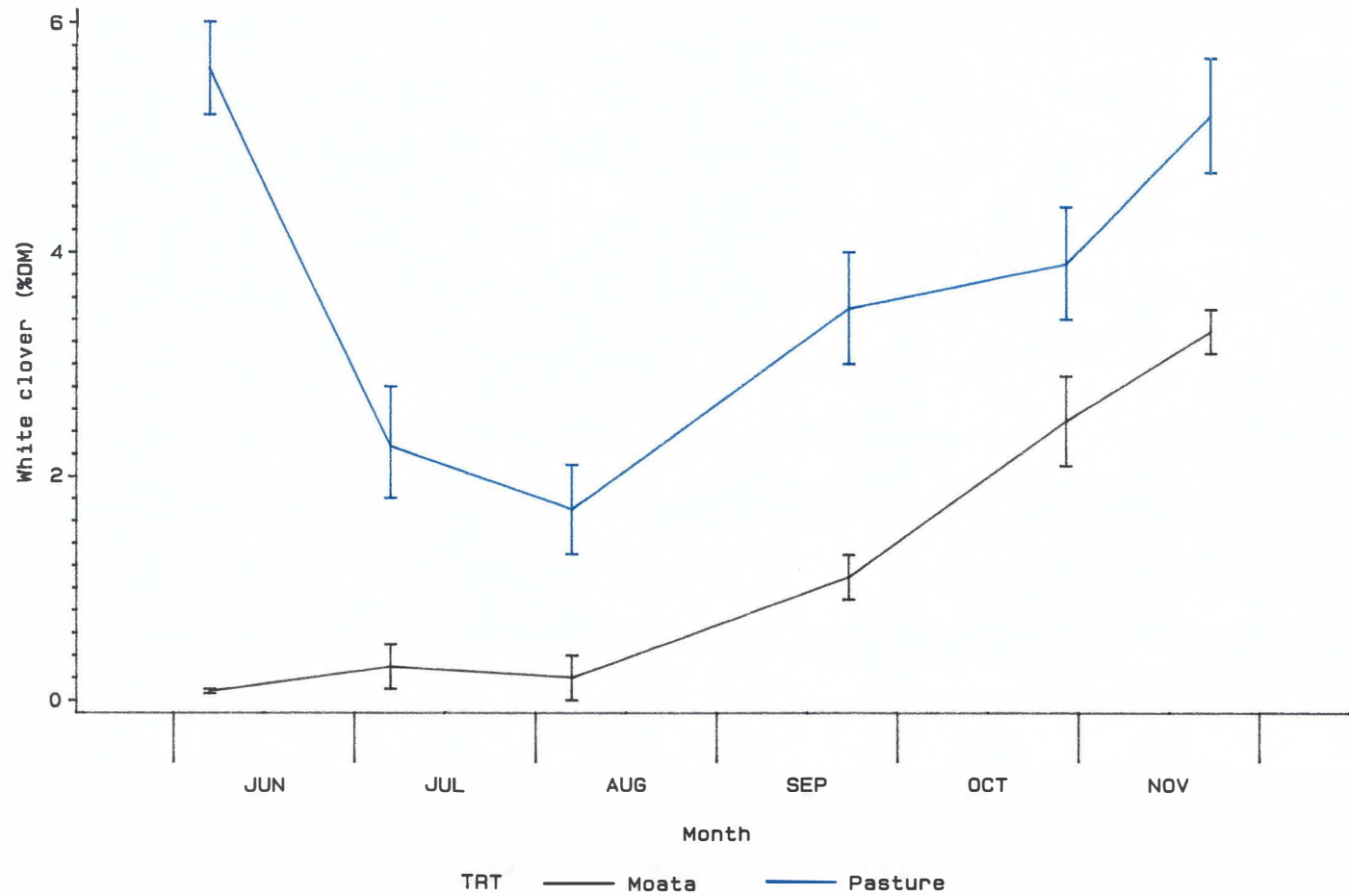


Figure 5.1e. The proportion of white clover on offer in the grazed pastures. (I) indicates SD.

5.3.3 Botanical composition of swards

The percentage botanical composition of the two sward types averaged over the winter and spring seasons, is shown in Table 5.2. Moata swards contained less perennial ryegrass than the pasture swards during both seasons. Moata annual ryegrass content of the Moata swards was very high during winter (Mean = 82%) and declined to 65% during spring. Moata swards contained lower amounts of white clover than the pasture swards during both seasons, with the difference being largest during winter (0.2 vs 3.2%). The other species and dead matter components of both swards increased during spring.

Table 5.2 Botanical composition (% DM) of the swards during winter and spring 1989.

Sward type		Perennial ryegrass	Moata annual ryegrass	White clover	Other species	Dead matter
WINTER						
Pasture	Mean	87.0	-	3.2	1.1	8.6
	SD	(5.87)		(2.12)	(0.76)	(4.21)
Moata	Mean	9.3	81.9	0.2	5.0	3.6
	SD	(6.17)	(4.94)	(0.11)	(2.82)	(4.32)
SPRING						
Pasture	Mean	78.9	-	4.2	3.8	13.1
	SD	(13.58)		(0.89)	(3.00)	(10.55)
Moata	Mean	12.0	65.1	2.3	6.4	14.1
	SD	(12.34)	(20.34)	(1.11)	(3.39)	(8.60)

Number of samples per season = 15

5.3.4 Botanical composition of feed and extrusa

Table 5.3 shows the composition of feed on offer (% DM) and of oesophageal extrusa (% contact) of grazing red deer stags during winter and spring. There was consistently a

larger proportion of (PRG + OS) and (PRG + MAR + OS) in the extrusa than in the swards on offer during both seasons, whilst the WC and Dm proportions in the extrusa were consistently smaller than those in the swards during winter and spring.

Table 5.3 Botanical composition of feed (% DM) and oesophageal extrusa (% contact) of grazing stags during winter and spring 1989.

Type		Perennial ryegrass and other species (PRG + OS)	Perennial ryegrass, Moata annual ryegrass and other species (PRG + MAR + OS)	White clover (WC)	Dead matter (Dm)
WINTER					
Herbage	Pasture	88.1	-	3.2	8.6
	Moata	-	96.2	0.2	3.6
Extrusa	Pasture	95.6	-	1.4	3.0
	Moata	-	99.2	0.1	0.7
SPRING					
Herbage	Pasture	82.7	-	4.2	13.1
	Moata	-	83.5	2.3	14.1
Extrusa	Pasture	98.0	-	1.5	0.5
	Moata	-	97.8	1.2	1.0

No. of samples per season: Herbage = 15
 Extrusa (winter) pasture = 19, Moata = 25
 Extrusa (spring) pasture = 5, Moata = 14

5.3.5 Nutritive values of feed and extrusa

The OMD, OM, total N and M/D values for the feed on offer were generally high during winter (Table 5.4a). The Moata swards had greater OMD and M/D values ($P < 0.05$) than the pasture swards over this period. OMD and M/D values for the extrusa were higher ($P < 0.01$) than those for the feed on offer, and OM values were lower for the extrusa ($P < 0.01$) than for the feed on offer.

There was a slight decline in OMD and total N contents of the feed on offer during spring (Table 5.4b), with both feed types having similar nutritive values ($P > 0.10$). OMD and M/D values for the extrusa were higher than those for feed on offer ($P < 0.05$). While the total N for the extrusa was higher than that for the feed on offer ($P < 0.01$), the OM value was lower for extrusa than for feed on offer ($P < 0.05$).

5.3.6 Carrying capacity (animals/ha)

The number of animals/ha/day for the two sward types during winter and spring are shown in Table 5.5. During winter, both Moata and pasture swards supported a similar number of animals/ha/day (8.8 vs 8.7). The number of animals/ha increased for both swards in spring, with Moata swards having lower carrying capacity than the pasture swards (16.6 vs 23.0).

Table 5.4a Organic matter digestibility (OMD), organic matter (OM), total nitrogen concentration (N) and calculated concentrations of metabolisable energy (M/D values) of feed on offer and oesophageal extrusa of grazing stags during winter (June-August) 1989.

Herbage type	Sward type		OMD (%)	OM (%)	Total N (% DM)	M/D (MJ ME/kg DM)
Feed	Pasture	Mean (SD)	80.3 (1.08)	84.0 (2.51)	3.95 (0.48)	11.0 (0.48)
	Moata	Mean (SD)	86.1 (2.06)	86.7 (0.49)	4.40 (0.45)	12.2 (0.36)
Extrusa	Pasture	Mean (SD)	89.2 (1.25)	61.9 (12.36)	4.03 (0.38)	12.4 (0.17)
	Moata	Mean (SD)	89.6 (0.44)	73.0 (7.09)	4.12 (0.39)	12.7 (0.06)

No. of feed samples = 3/feed type

No. of extrusa samples = 9/extrusa type

Table 5.4b Organic matter digestibility (OMD), organic matter (OM), total nitrogen concentration (N) and calculated concentrations of metabolisable energy (M/D values) of feed on offer and oesophageal extrusa of grazing stags during spring (September-November) 1989.

Herbage type	Sward type		OMD (%)	OM (%)	Total N (% DM)	M/D (MJ ME/kg DM)
Feed	Pasture	Mean (SD)	78.9 (4.65)	86.1 (0.85)	2.83 (1.06)	11.1 (0.73)
	Moata	Mean (SD)	80.4 (3.68)	86.6 (2.45)	2.70 (0.55)	11.3 (0.81)
Extrusa	Pasture	Mean (SD)	88.0 (0.90)	77.0 (4.60)	4.09 (0.48)	12.2 (0.13)
	Moata	Mean (SD)	88.9 (1.20)	69.1 (12.38)	3.65 (0.46)	12.6 (0.17)

No. of feed samples = 3/feed type

No. of extrusa samples = 9/extrusa type

Table 5.5 Carrying capacity (animals/ha/day) during winter and spring 1989.

Animals	Pasture	Moata
WINTER		
Experimental	6.8	6.0
Experimental + non-experimental	8.7	8.8
SPRING		
Experimental	6.8	6.0
Experimental + non-experimental	23.0	16.6

5.3.7 Growth patterns and LWG

The seasonal nature of growth in the young red deer is shown in Figures 5.2, 5.5 and 5.6. There are two phases in the growth curves; slow growth during winter and faster growth during spring. Animals in all groups showed similar growth patterns.

The winter and spring LWG (g/day), VFI (g DM/day) and the percentage of stags attaining slaughter weight by end of November for the pasture and Moata groups are shown in Table 5.6. The winter LWG ($P < 0.05$) and VFI ($P < 0.001$) of the Moata group was significantly greater than that of the pasture group (165 vs 140 g/day; 1615 vs 1185 g DM/day). Spring LWG and VFI were higher than those recorded in winter and were similar for both groups ($P > 0.10$). During late August and late November, deer grazing Moata swards were significantly heavier ($P < 0.01$; Figure 5.2) than those grazing pasture swards. A larger proportion (60%) of animals grazing the Moata swards reached the target liveweight (92 kg LW) by November 30, whilst 41% of those grazing the pasture sward attained the target liveweight by this date.

Table 5.6 Liveweight gain (g/d), voluntary food intake (g DM/d) and percentage of stags attaining slaughter weight (92 kg) by November 30, 1989.

	Pasture	Moata	SE
No of animals/group	17	15	
Liveweight gain:			
Winter	140	165	6.6*
Spring	226	235	5.4
Voluntary food intake:			
Winter (group samples)	1185	1615	100.00***
Spring (individual samples)	1762	1719	50.00
Spring (group samples)	2318	2570	107.00
Stags to slaughter (% of total)	41	60	

*** $P < 0.001$; * $P < 0.05$

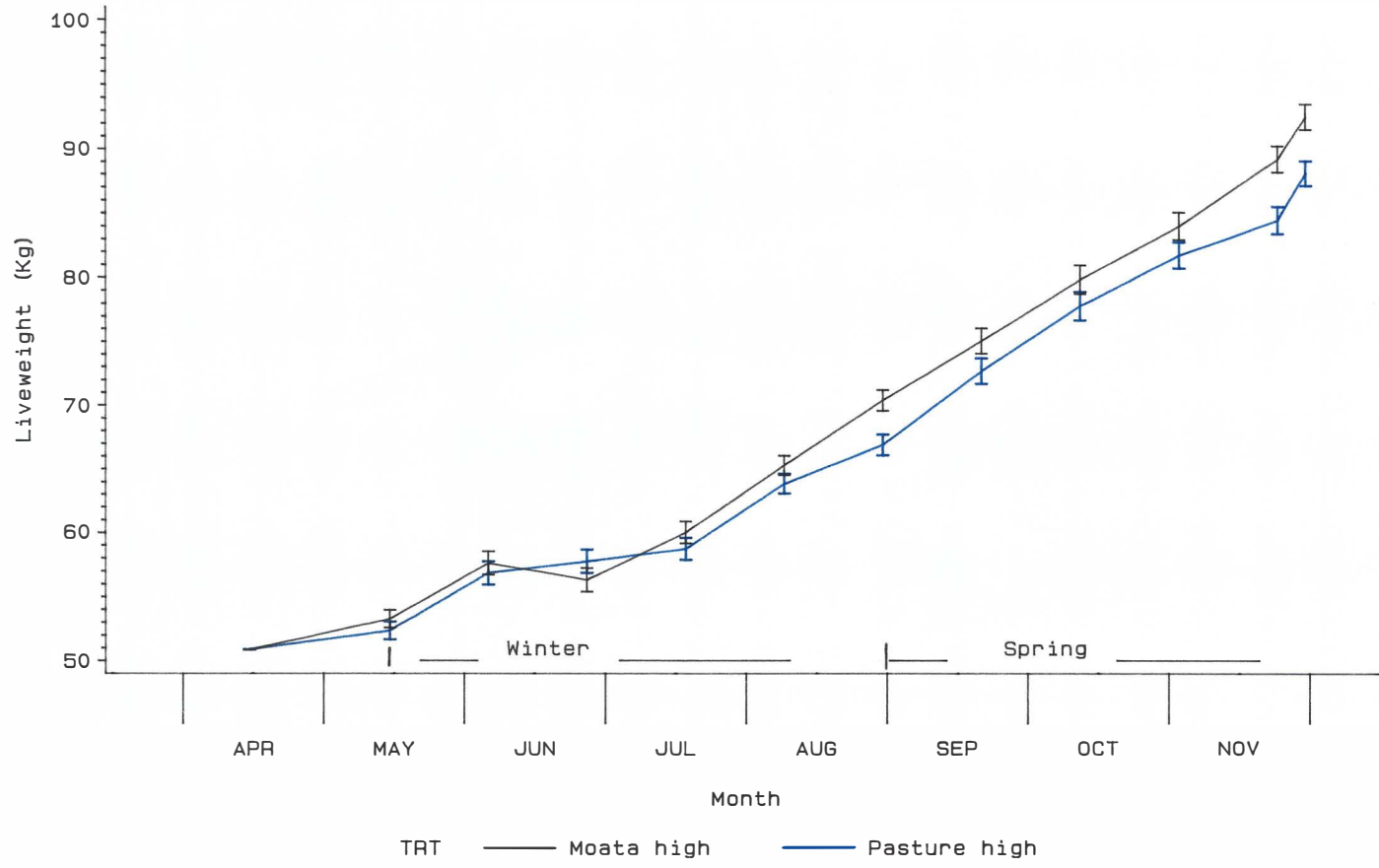


Figure 5.2. Seasonal liveweight patterns of weaner red deer stags grazing Moata and perennial ryegrass/white clover swards at high DM allowance. (I) indicates SE.

5.3.8 Rumen VFA and NH₃ concentrations

There was no significant difference ($P > 0.10$) in the concentration of total VFA (m mols/l) in the rumen fluid of stags grazing Moata or pasture swards, though the Moata group appeared to have higher concentrations of total VFA than the pasture groups (Table 5.7).

The molar proportion of acetate was lower ($P = 0.08$) in animals grazing Moata than those grazing pasture. However, the molar proportion of n-butyrate was higher ($P < 0.01$) in the Moata group than the pasture group. The molar proportions of propionate, iso-butyrate, n-valerate and iso-valerate were, however, similar ($P > 0.10$) in both groups.

There was no difference in acetate/propionate ratio between the two groups. Ammonia concentration was lower ($P < 0.001$) in the Moata group than the pasture group.

Table 5.7 Total VFA (m mole/l), the molar proportions of acetate, propionate, butyrate, and valerate and ammonia concentrations in the rumen fluid of red deer stags grazing pasture or Moata swards, during spring.

	Pasture	Moata	SE
Total VFA (m mole/l)	89.2	94.7	0.37
Acetate (m moles %)	66.8	65.3	0.64(*)
Propionate (m moles %)	18.2	18.6	0.38
n-butyrate (m moles %)	11.1	12.4	0.24**
iso-butyrate (m moles %)	1.7	1.4	0.11
n-valerate (m moles %)	0.8	0.8	0.08
iso-valerate (m moles %)	1.7	1.5	0.09
Ratio: Acetate/Propionate	3.70	3.56	0.089
Ammonia (mg N/l)	188.0	133.8	4.95***

*** $P < 0.001$; ** $P < 0.01$; (*) $P < 0.10$.

5.3.9 Plasma anti-melatonin antibody titre

The patterns of melatonin antibody development in both vaccinated groups (Freund's vs DEAE-dextran adjuvant) are shown in Figure 5.3. Seventy-five percent (15/20) of the vaccinated animals gave an antibody titre response. The antibody titres of the Freund's group (mean \pm SE) were much higher (1:3,545 \pm 1,059 to 1: 15,215 \pm 5,551) than those of DEAE-dextran group (1:48 \pm 31 to 1:1,941 \pm 423), and peaked in October, about 11 months after the primary vaccination. The titre level of the DEAE-dextran group peaked in May at 1:1,941 \pm 423, about 6 months after the primary vaccination, and rapidly declined to undetectable levels by September. The antibody titre level of the Freund's group rose above 1:5,000 shortly after the second booster injection in May, and remained high until the end of the experiment in November.

5.3.10 Plasma hormone concentrations

Table 5.8 shows the plasma concentrations of LH and testosterone for control and immunised groups during spring. The LH and testosterone values for both groups were similar during each month ($P > 0.10$), and October values were generally higher than the November values. Plasma prolactin concentrations in the control group were slightly above the baseline level during winter period (0.34 - 1.40 ng/ml; Figure 5.4), with an inclination to increase during spring. Plasma prolactin levels of the immunised groups followed a similar pattern, but were higher during winter, and the spring rise in concentration occurred earlier and was of larger magnitude than in the control group. The DEAE-dextran group had greater plasma prolactin concentrations than the control group in mid May and early November ($P < 0.05$; $P = 0.07$), respectively.

5.3.11 Effect of vaccination on weaning weight and LWG

Stags vaccinated at birth with Freund's adjuvant had lighter weaning weight (47.7 kg \pm 1.25) compared with control animals (51.8 kg \pm 2.12; $P < 0.05$) or those vaccinated with dextran adjuvant (52.2 kg \pm 1.38; $P < 0.05$), and the depressed growth rate continued until end of autumn (Figure 5.5). Thereafter, animals in all treatment groups grew at a similar rate during winter and spring. There was some indication that stags vaccinated using dextran adjuvant grew faster in spring (Figure 5.5), but the difference did not attain significance ($P > 0.10$). Figure 5.6 shows the seasonal liveweight changes of immunised stags (responders

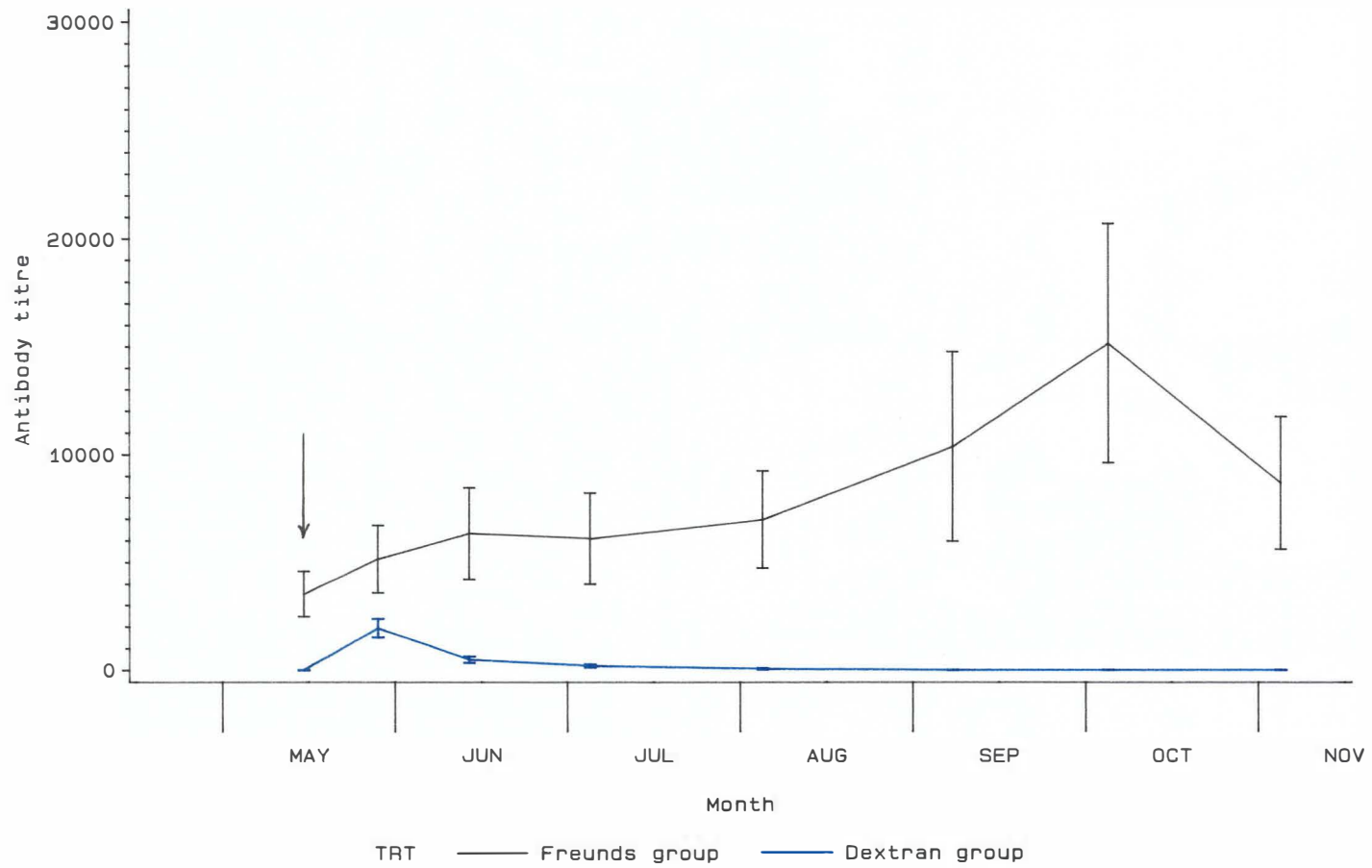


Figure 5.3. Patterns of anti-melatonin antibody titre development in red deer stags. (↓) indicates booster, (I) indicates SE.

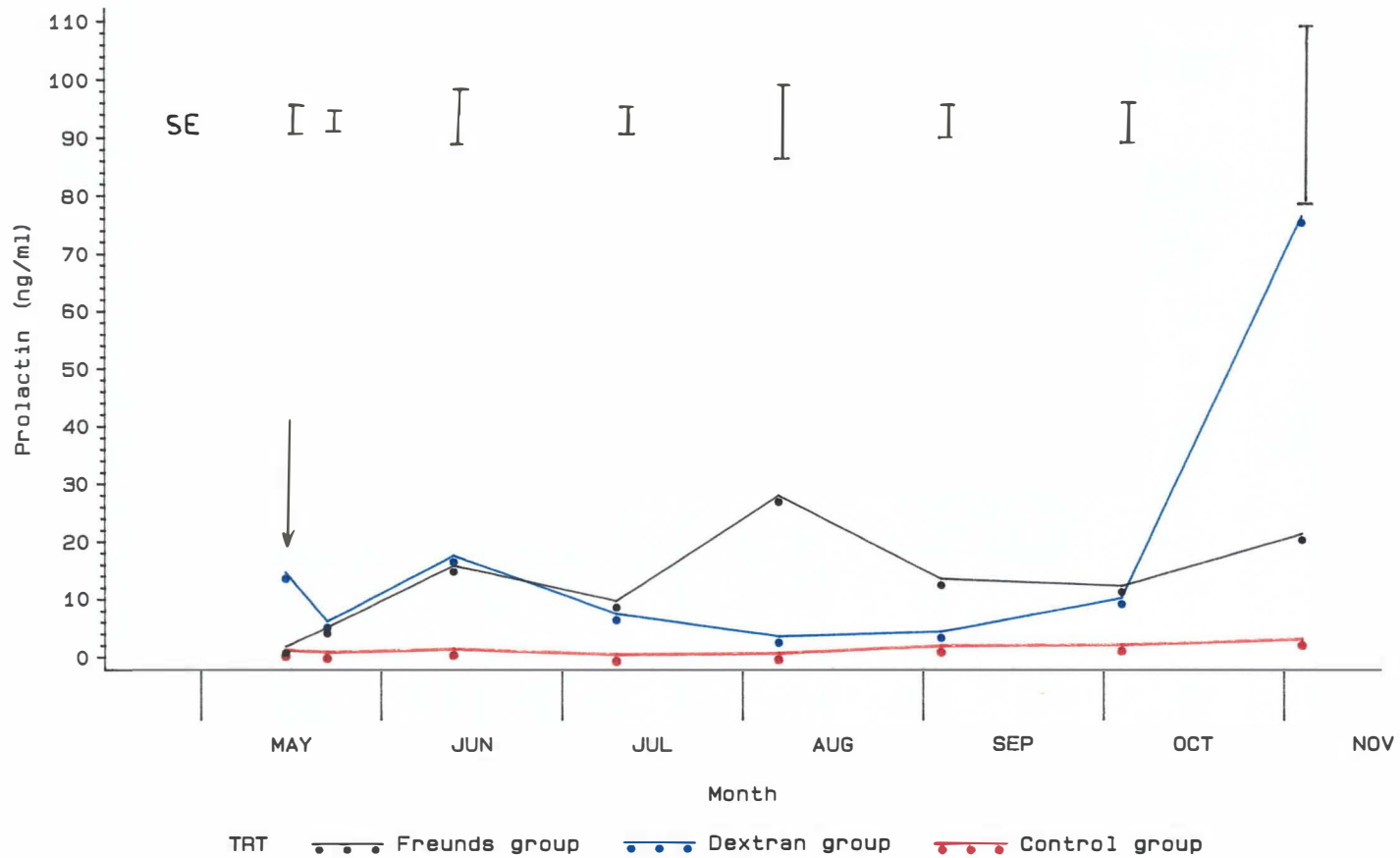


Figure 5.4. Plasma prolactin concentrations of weaner red deer stags immunised and non-immunised (control) against melatonin. (↓) indicates booster.

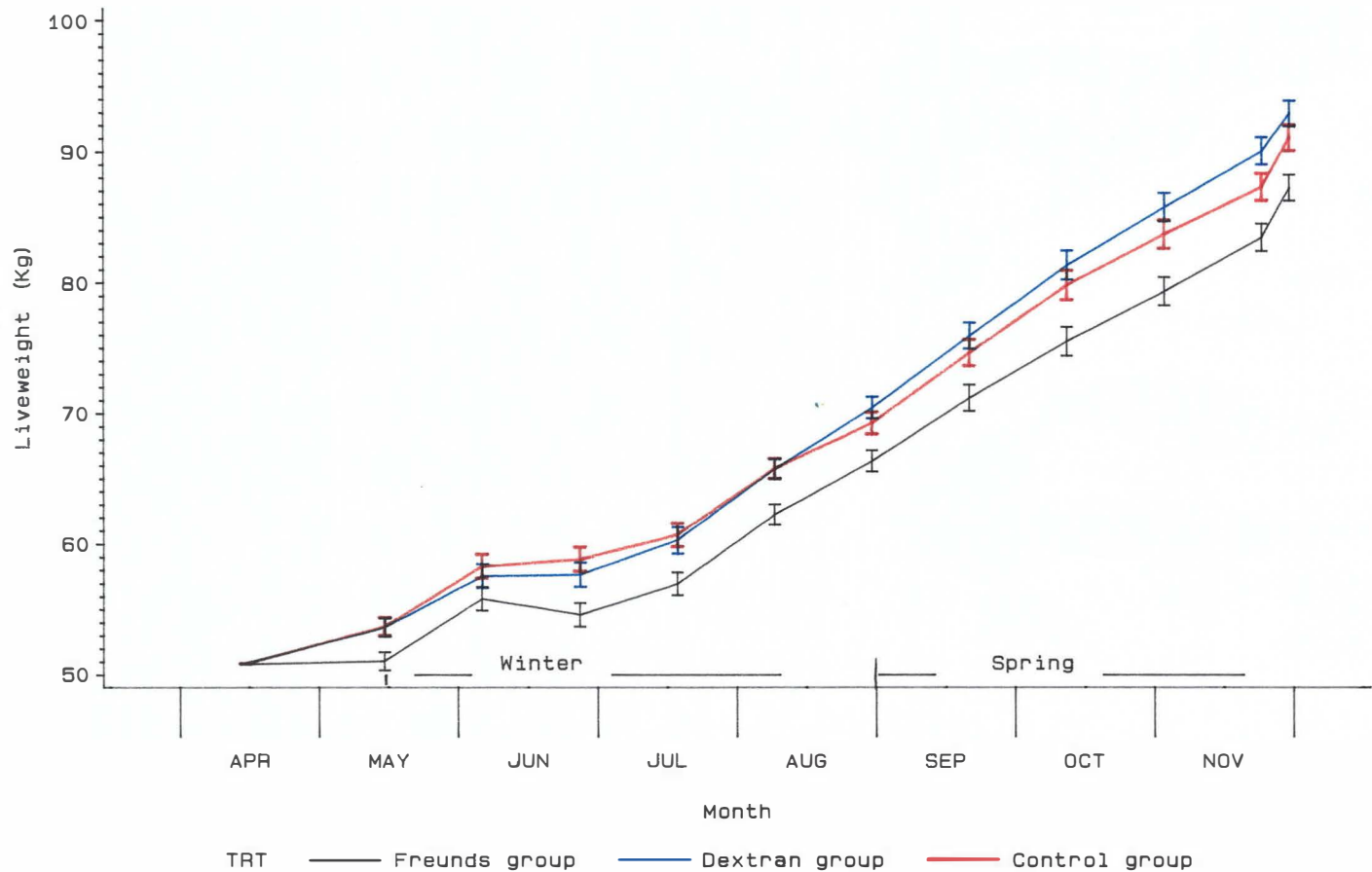


Figure 5.5. Seasonal liveweight patterns of weaner red deer stags vaccinated with melatonin antigen. (I) indicates SE.

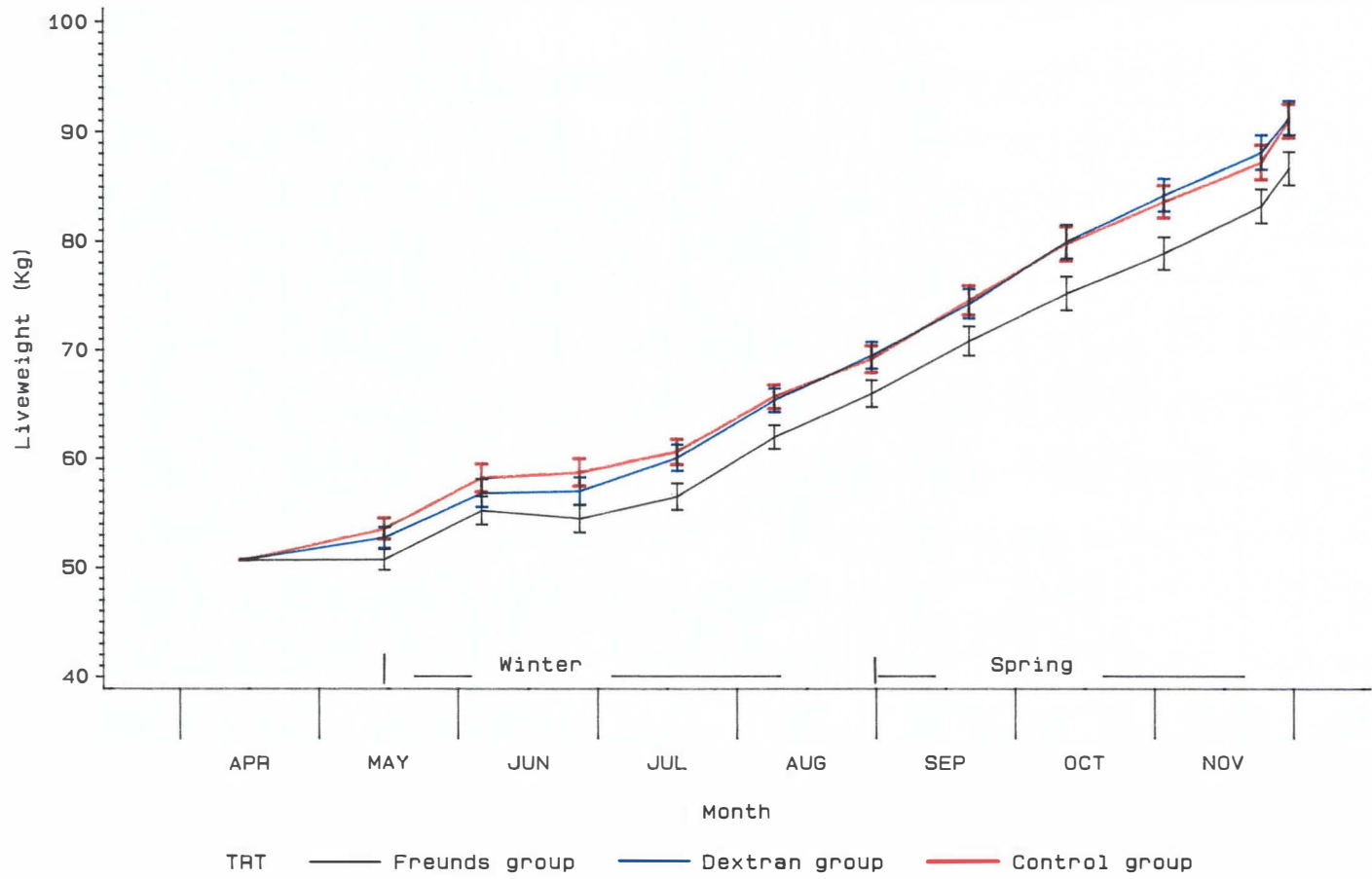


Figure 5.6. Seasonal liveweight patterns of weaner red deer stags immunised against melatonin (Responders to anti-melatonin vaccinations only). (I) indicates SE.

Table 5.8 Plasma concentrations of LH and testosterone in red deer stags during October and November 1989.

Date	Control	Vaccinated	SE
	(LH; ng/ml)		
October 2	0.55	0.54	0.02
November 2	0.49	0.45	0.02
	(Testosterone; ng/ml)		
October 2	2.28	2.25	0.04
November 2	1.54	1.44	0.10

to melatonin vaccination only, i.e. non-responders deleted). It indicates that the dextran and the control groups were of similar liveweight and were heavier ($P < 0.05$; 0.10) than the Freund's group between July and November, except during late August and September. Table 5.10 shows that all treatment groups grew at similar rates during winter and spring ($P > 0.10$). Whilst 73% of calves vaccinated with dextran and 67% of control group attained the target slaughter weight (92 kg LW) by the end of November, no animals from the Freund's group attained the target weight at this date.

Table 5.9 Effect of vaccination on stag weaning weight.

	Control	Vaccinated		SE
		Dextran	Freund's	
Animals/group	12	11	9	
Weaning weight (kg)*	51.8	52.5	47.7	1.80

* Recorded on April 10, 1989

5.3.12 Carcass data

The dressing-out percent, rump fat width and GR were similar for all treatment groups ($P > 0.10$; Table 5.10). The Freund's immunised group had heavier testes than the control group ($P = 0.08$). There was no difference in carcass characteristics between Moata and pasture groups.

Table 5.10 Liveweight gain (g/day) of yearling red deer stags during winter and spring (1989) and carcass data.

	Control	Freund's	DEAE-dextran	Freund's + DEAE-dextran	SE
Animals/group	12	9	11	20 (15)	
Initial weight (kg)	50.9	50.9	50.9	50.9 (50.7)	
LWG (g/day):					
Winter	149	142	163	154 (153)	
(SE)	(8.38)	(9.68)	(8.76)	(6.63)	
Spring	230	222	229	231 (225)	
(SE)	(6.06)	(7.00)	(6.33)	(4.88)	
VFI (g/day):					
Spring	1792	1672	1745		74.22
Carcass data:					
Animals/group	9	3	8		
Dressing-out %	53.5	53.2	53.2	53.4 (53.7)	0.38
Rumpfat width (mm)	114.7	107.1	117.3	114.7 (112.0)	1.66
Testes wt (g)	43.4	55.8	47.2	49.5 (51.1)(*)	2.06
GR (mm)	3.1	4.2	3.3	3.4 (3.3)	0.31

(*) $P < 0.10$

(n = 15) = responders to anti-melatonin vaccination (ie 5 non-responders deleted).

Winter LWG (g/day) was calculated using initial liveweight (April 10) as a covariate.

Spring LWG (g/day) was calculated using liveweight at the start of spring (August 28) as a covariate.

Rump fat width, Testes wt and GR were analysed using carcass wt as a covariate (mean = 52.6 kg).

5.4 DISCUSSION

The present experiment being the last in a series of four experiments and based on the findings from the previous experiments (Chapters 3 and 4), the following changes were made in its design in an attempt to arrive at more conclusive results.

1. The weaner red deer stags were given the primary anti-melatonin vaccination at birth (November/December 1988).
2. Freund's and DEAE-dextran adjuvants were used to compare their efficacy in antibody production in immunised deer.
3. The Moata paddocks were direct drilled at a higher rate of 24 kg seed/ha, and blanket spraying with herbicide used to further reduce competition from other pasture species.
4. A 5 and 3-weekly rotational grazing practice was adopted during winter and spring, respectively, in order to allow MAR to recover in between grazing.
5. All animals were grazed at a high feed allowance; 2100 kg DM/ha pre-grazing herbage mass and 1600 kg DM/ha post-grazing herbage mass.
6. Oesophageal fistulated stags were used to collect extrusa samples for the purpose of diet selection studies.
7. The stags were orally dosed with intra-ruminal chromium capsules in order to estimate VFI under grazing conditions.
8. Rumen fluid samples were taken for laboratory analysis to measure VFA and NH_3 concentrations.

In the present experiment, 60% of the animals grazing the Moata swards and 41% of those grazing the pasture swards attained the target weight (92 kg LW) by the end of November.

5.4.1 Seasonal patterns of sward components and carrying capacity

The Moata annual ryegrass component of the Moata swards was about 82% during winter, supporting a similar number of stags/ha/day as did the pasture swards (Table 5.5). The number of animals/ha/day increased during spring for both swards, due to increased spring pasture production, with the Moata swards supporting fewer animals than the pasture swards (16.6 vs 23.0 animals/ha). This observation is consistent with that recorded during the previous experiment (Chapter 3). This can be attributed to Moata annual ryegrass dying off in spring resulting in a decline of its component in the Moata swards during late spring. In the present experiment, the Moata annual ryegrass component of the swards declined to an average of 65% during spring, creating swards with an open structure and reduced tiller density resulting in increased invasion by weeds (Figures 5.1a and d).

5.4.2 Diet selection by grazing deer

The deer consumed mainly green plant material and rejected dead matter. This is in agreement with the results published by L'Huillier *et al* (1984) on diet selection by sheep, and by Hughes *et al* (1984) on diet selection by kids, lambs and calves during late spring. Dietary (extrusa) and swards white clover contents in the present experiment were low (0.1-1.5% in the diet and 0.2-4.2% in the sward) and no selection for this component was evident. The pasture and Moata diets eaten had high components of PRG + OS and PRG + MAR + OS, respectively, and were consistently greater than the proportions found in the swards during both seasons. This is consistent with the results recorded in Chapter 3, and indicated that the stags consumed high proportions of these components. Diet selection in the present experiment may be masked, considering the fact that the animals were grazing high quality swards (Tables 5.4a and b). Therefore, selecting for a particular component of the swards became unnecessary and they ate all components in proportion to their presence in the swards. There was, however, evidence that the animals ate a diet high in OMD and ME (Tables 5.4a and b) which can be explained by the fact that they selected against dead material.

5.4.3 Nutritive value of Moata and PRG

The high nutritive values for both feed types (Tables 5.4a and b) indicate that the pastures were kept in the vegetative state and of high nutritive quality during both seasons.

Generally, the OMD and ME values of the diet selected were greater than those of the feed on offer, indicating the animals' ability to select a more nutritive diet. The OM values of the diet were, however, lower than that of the feed on offer during both seasons, due to saliva contamination of the extrusa samples.

5.4.4 VFI of deer under grazing conditions

The stags grazing Moata swards had greater VFI than those grazing pasture swards during winter ($P < 0.001$; 1615 vs 1185 g/day; Table 5.6), corresponding to 2.8 and 2.0% LW and 20.5 and 14.7 MJ ME/head/day respectively. The Moata group has ME intakes which were similar to that required to meet their needs for maintenance and growth as estimated from the values derived by Fennessy and Milligan (1987). The pasture group had lower ME intakes than would be required to meet their needs for maintenance and growth estimated in a similar way. This could be due to the CRD technique used to determine the VFI. Further experiments are needed to verify the use of this technique to estimate VFI in red deer. During spring the VFI determined using individual faecal samples was lower than that determined using group faecal samples. There was no difference in the VFI of animals grazing either Moata or pasture swards during spring ($P > 0.10$; 1719 vs 1762 or 2570 v 2378) determined using either individual rectal or group faecal samples (Table 5.11), which is reflected in similar growth rates for both Moata and pasture groups ($P > 0.10$; 235 vs 226 g/day) during this time. While the energy intake determined using individual rectal faecal samples (21.7 and 21.5 MJ ME/head/day) for Moata and pasture groups, respectively, were lower than the estimated daily requirement (27 MJ ME; Fennessy and Milligan 1987), the MEI calculated using the group faecal samples were higher (32.4 and 28.3 MJ ME), respectively. Generally, the MEI determined for grazing deer in these experiments (Chapters 2 and 5) were lower than the estimates published by Fennessy and Milligan (1987).

Both methods of sampling, ie individual rectal and group faecal samples from the swards should be further compared in future experiments, to determine which method is more appropriate.

5.4.5 Seasonal growth patterns and LWG

The young red deer stags in the present experiment showed the normal seasonal pattern in body weight growth (Moore *et al* 1988; Ataja *et al* 1989; Barry *et al* 1990), with lower growth rates during winter (152 g/day) and higher growth rates during spring (231

Table 5.11 VFI (g DM/day) of grazing red deer stags during winter and spring of 1987 and 1989.

	Pasture	Moata	SE
1987:			
Winter	1697	1680	98.00
Spring	2109 ¹	2222	103.00
1989:			
Winter (group samples)	1185	1615	100.00
Spring (individual samples)	1762	1719	50.00
Spring (group samples)	2318	2570	107.00

¹ Pasture high feed allowance only

g/day). The winter growth rate of 140 g/day obtained from the pasture diet in the present experiment corresponds with the upper limit of winter liveweight gain for weaner deer suggested by Fennessy and Milligan (1987). With an average liveweight of 52.3 kg at the end of autumn (May 15), consistent winter LWG of 140 g/day, combined with high spring LWG of 226 g/day resulted in 41% of the animals grazing pasture attaining the target slaughter weight at 12 months of age.

Animals grazing the Moata swards grew at the rate of 165 g/day during winter (Table 5.6), significantly greater ($P < 0.05$) than that recorded for animals grazing pasture swards. This resulted in 60% of them attaining the slaughter weight by November 30. This is consistent with superior LWG of sheep grazing annual ryegrass varieties compared with perennial ryegrass varieties (Rae *et al* 1964; Ulyatt 1971). This could be due to greater VFI of animals grazing the Moata swards than those grazing the pasture swards ($P < 0.001$), which could be as a result of a high proportion (82%) of Moata annual ryegrass being present in the Moata swards during winter.

5.4.6 Rumen VFA and NH₃ concentrations

The molar proportion of acetate in the rumen fluid of stags grazing Moata swards was lower ($P = 0.08$) than those grazing pasture swards. Experiments with sheep have shown that acetic acid was poorly utilised for fattening (McDonald *et al* 1981). Higher acetate/

propionate ratios are associated with lower efficiency for weight gain (Waghorn and Barry 1987). The acetate/propionate ratios of 3.56 and 3.70 reported in the present experiment for Moata and pasture groups, respectively, were higher than 2.55 reported for spring ryegrass by Waghorn and Barry (1987). However, there was no difference ($P > 0.10$) in acetate/propionate ratio between Moata and pasture groups and during spring there was no difference in LWG (235 v 226 g/day).

The lower rumen ammonia concentration for deer grazing Moata could be a reflection of the total N (% DM) content of diet eaten (extrusa), which appeared to be lower in Moata than pasture (3.65 v 4.09% DM). It could also represent more efficient microbial protein synthesis from ammonia, as found for sheep fed short rotation ryegrass (Ulyatt *et al* 1975), but this would need to be measured in future experiments.

5.4.7 Anti-melatonin titre and its effect on LWG

The present experiment has shown that commencing active immunisation against melatonin at birth produced higher antibody titres than when immunisation was commenced at 3 or 6 months of age (Ataja *et al* 1989; Chapters 2 and 3). Immunising stags using Freund's adjuvant produced higher titres of antibody which persisted for a long period (6 months; Figure 5.3). The Freund's group experienced reduced growth until autumn (6 months of age; Figure 5.5) which could be due to adverse effect of Freund's complete adjuvant (FCA) used in the primary vaccination at birth. Ataja *et al* (1989) showed that Freund's adjuvant itself (ie vehicle only) did not influence stags' growth when immunisation was commenced at 6 months of age. During late winter/spring, the DEAE-dextran group showed evidence of superior growth (Figure 5.5), which was similar to the effect reported by Duckworth and Barrell (1989), but in the present experiment the response did not attain significance ($P > 0.10$) and furthermore was not apparent when non-responders to the immunisation were deleted. Comparing the immunised stags only (Figure 5.6), the DEAE-dextran group were heavier in most months than the Freund's group ($P < 0.10$) during spring, demonstrating the initial apparent adverse effect of vaccination on the Freund's group. Further studies are needed to investigate the use of Freund's incomplete adjuvant (FIA) in the vaccination programme in order to eliminate the apparent adverse adjuvant effect on growth rate, or in formulating a DEAE-dextran-based anti-melatonin vaccine that produces high antibody titres over a longer period of time.

5.4.8 Plasma hormone concentrations

Active immunisation against melatonin tended to result in higher plasma prolactin concentrations during winter and earlier onset of the spring rise in prolactin. Ryg and Jacobsen (1982) reported that injections of prolactin to yearling male reindeer during winter were associated with increases in VFI and LWG. It might therefore be expected that immunisation against melatonin, with its associated elevation of plasma prolactin concentrations, should have increased winter LWG. This was not observed in the present experiment, probably due to lack of any clear significant difference between the plasma prolactin concentrations of the immunised and the control groups. Re-formulated vaccines and more animals are needed to investigate this aspect further.

5.4.9 Carcass data

The vaccination treatment had no significant effect ($P > 0.10$) on the dressing-out percent, rump fat width and the GR, in agreement with the result of vaccination effect on LWG. The vaccinated groups appeared to have heavier testes than the control group. In order to realistically compare the testes size between the two groups, it is suggested for future experiments that testes size be determined during the rut season when activity of the testes is highest rather than in November when the testes are just starting to get active in preparation for the rut season.

5.5 CONCLUSIONS

1. The Moata swards direct drilled on March 23, 1989 with Moata annual ryegrass contained 82% DM as Moata during winter and decreased to 65% DM as Moata during spring. The Moata swards contained lower proportions of perennial ryegrass and white clover, and high proportions of other species, the drilling having no effect on the proportions of dead matter especially during spring. White clover made up very low proportions of the feed on offer during both seasons in the Moata swards
2. The Moata swards supported fewer animals/ha/day than the pasture swards during spring (16.6 vs 23), but similar numbers during winter (8.8 vs 8.7).

3. The stags ate more green plant material with a higher OMD and ME content than was on offer and rejected dead matter.
4. The Moata feed on offer had greater OMD and M/D values ($P < 0.05$) than the pasture feed on offer during winter. The diet eaten had higher OMD and M/D values ($P < 0.01$), than the feed on offer during both seasons. The diet eaten had a very low white clover content.
5. The pattern of body weight change was similar for all animals during both seasons, with slow growth during winter and faster growth occurring during spring.
6. Animals grazing the Moata swards had greater winter LWG (165 g/day; $P < 0.05$) than those grazing the pasture swards (140 g/day).
7. The VFI determined for the grazing stags were generally low, with those grazing the Moata swards having higher VFI (1615 g/day; $P < 0.001$) than those grazing pasture swards (1185 g/day) during winter. There were no differences in VFI ($P > 0.10$) between both groups during spring.
8. There was no significant difference ($P > 0.10$) in the concentration of total VFA (m moles/l) and acetate/propionate ratio in the rumen fluid of stags grazing Moata or pasture swards. Ammonia concentration was lower ($P < 0.001$) in the Moata group than the pasture group.
9. Sixty percent of animals grazing the Moata swards attained the slaughter weight by November 30, while only 41% of those grazing the pasture swards attained the slaughter weight at this time.
10. The management system adopted was very suitable for both animal husbandry and pasture management.
11. Seventy-five percent (15/20) of the vaccinated stags developed melatonin antibody titres, with the Freund's group having higher mean antibody titre that persisted for 6 months. There was no vaccination effect on animal growth rate.

12. The plasma prolactin concentrations showed a seasonal pattern, being low during winter and increasing during spring, with the immunised group tended to having higher levels than the control group.
13. The vaccination treatment generally had no effect on the carcass data, but the vaccinated stags had heavier testes ($P = 0.08$) than the control group.

The OMD of feed on offer appeared to be higher for Moata than pasture during winter (86.1 v 80.3%) and spring (80.4 v 78.9%), but was similar for feed eaten by the stags during winter (89.6 v 89.2%) and spring (88.9 v 88.0%). The acetate/propionate ratio in rumen fluid in the Moata group during spring was similar to the pasture group (3.56 v 3.70; $P > 0.10$), and may also be similar during winter, suggesting that the pastures did not differ in efficiency of utilisation of ME for weight gain. However, the VFI was greater for the Moata group than the pasture during winter (1615 v 1185 g/day; $P < 0.001$) but was not different during spring. The greater LWG for the Moata group during winter (165 v 140 g/day; $P < 0.05$), may therefore be due to greater VFI recorded for this group. Hence, differences in VFI are probably the major reason for differences in LWG observed in this study for red deer stags grazing either Moata or perennial ryegrass pastures.

14. Points to consider for future experiments are as follows:
 - (a) Increase the white clover proportions of the swards (up to 15% DM) by sowing white clover into pastures in spring prior to the next trial.
 - (b) Further investigation of methods of faecal sample collection for VFI determination, to ascertain which method of faecal sampling gives more consistent and reasonable results, ie group or individual rectal samples.
 - (c) Experiment should include a group injected with FCA only, to confirm the apparent adverse effect of adjuvant on the LW of the stags.
 - (d) Investigate the use of FIA in the primary vaccine in an attempt to eliminate the adverse adjuvant effect on growth rate. Also, further studies in formulating a DEAE-dextran-based anti-melatonin vaccine that produces high antibody titre

over a longer period of time is needed, or giving an extra booster injection by the end of June should be considered.

- (e) To realistically determine the effect of vaccination treatment on the status of testes, the testes size should be measured during the rut season.

CHAPTER 6

GENERAL DISCUSSION

6.1 Deer temperament

Apart from 2 m high boundary fences, captive deer in New Zealand (NZ) are farmed under similar grazing conditions as sheep and cattle. Farming of deer became legal in NZ only about 20 years ago, whilst sheep have been domesticated by man for the past 6,000 years. Deer, compared with sheep, have a nervous disposition, and the 1987 experiment (Chapter 2) showed that untrained deer did not adapt to being part of a grazing experiment in the same manner as is normally found for sheep.

It is imperative, therefore, that prior to commencement of grazing and management experiments with deer, they should be handled carefully and be introduced to the experimental conditions. This includes transporting the animals to the site of the experiment about 2 months prior to the start of the experiment, in order to give them enough time to settle down in the new environment. During the pre-experimental period, the animals should be fed 100-300 g of grain (eg barley) daily for about 6 weeks, to get them used to regular human contact. They should be herded into the handling yards and introduced to routine procedures such as going through the crush and getting on the weighing scale, about twice/week. They should also be trained to respect electric fences at an early age, preferably before weaning. Adopting this strategy during the 1988 and 1989 experiments resulted in weaner stags sufficiently tamed for the experiments, and is therefore recommended for future grazing experiments with deer.

6.2 LWG of deer grazing PRG/WC pasture

Feeding a highly digestible pelleted diet (11 MJ ME/kg DM) to weaner red deer stags ad libitum resulted in high LWG during winter and spring (Table 6.1; Suttie et al 1989), thus approaching as closely as possible their genetic potential for growth in a natural daytime environment. This treatment produced a winter/spring growth ratio (W/S) of 0.75. Early attempts at deer farming (grazing pastures) fell well short of achieving their genetic potential in growth, especially during winter (Table 6.1; W/S = 0.02-0.52, Moore et al 1988). In the present experiments (Ataja et al 1990; Table 6.1) weaner red deer stags grazing PRG/WC pasture at high feed allowance showed higher winter LWG, resulting in W/S ratios of 0.62-0.65. The W/S growth ratio recorded for grazing red deer closer to the equator are much higher (0.82; Table 6.1; Woodford et al 1990). This may be because red deer are native to temperate zones and their body growth is entrained by changes in photoperiod (Kay 1979;

Table 6.1 Liveweight gain (g/day) of weaner red deer stags over winter and spring.

Author	Year of birth	Diet	No/group	Liveweight gain (g/d)			Location and Latitude
				Winter (W)	Spring/Summer (S)	W/S	
Moore <u>et al</u> (1988)	1974	Perennial	10	6	250	0.02	Invermay, Mosgiel (N.Z.) 45.5 S
	1975	ryegrass/	26	41	251	0.16	
	1976	white clover	13	41	243	0.17	
	1977	pasture	6	122	236	0.52	
	1978		38	102	239	0.43	
	1979		18	103	256	0.40	
	1982		33	60	218	0.28	
				Winter	Spring		
Ataja <u>et al</u> (1990)	1987	Perennial	12	103	184	0.56	Palmerston North (N.Z.) 40.2 S
	1988	ryegrass/	12	153	234	0.65	
	1989	white clover pasture	17	140	226	0.62	
Woodford <u>et al</u> (1990)	1985/88	Sub-tropical pasture with grain supplement	32	179	219	0.82	Brisbane (Aust.) 27.4 S
Suttie <u>et al</u> (1989)	1981	Pelleted concentrate diet	6	180	240	0.75	Invermay, Mosgiel (N.Z.) 45.5 S

Suttie and Simpson 1985), being slow during winter, a period of short daylight length and faster during spring/summer when the days are longer. The seasonal changes in body growth may be less marked at lower latitude, due to reduced changes in photoperiod, with body growth rate during winter being almost as high as during spring. Thus it is possible that the genetic potential of weaner red deer stags for growth during winter may be high at lower latitudes.

Increased knowledge of nutrition of the deer over the years has resulted in management strategies that have improved their rate of growth, especially during winter, but does not abolish its seasonality. Thus daylight length could be manipulated to increase the body growth rate during winter in deer farmed at higher latitude (Suttie *et al* 1984; Vigh-Larsen, pers. comm.).

6.3 Proportion of stags attaining slaughter weight by 12 months

The 1988 and 1989 experiments have consistently shown that 41-42% of weaner red deer stags grazing the perennial ryegrass/white clover swards at high allowance (10 cm) attained slaughter LW (92 kg) by 12 months of age (Table 6.2). The average liveweight of the stags at the start of the experiments were 56.9 and 52.4 kg, respectively. The number of weaner stags attaining slaughter LW within one year of age could be increased by using well grown animals as starting material in experiments of this kind (eg stags of 50 kg LW by March 1, or 64 kg LW by May 30; Judge 1989). In commercial herds, the usual weight of red deer stags at March 1, would be 42-45 kg (P.R. Wilson, pers. comm.).

The heavier the young stags at the beginning of the experiment, the easier it will be to achieve the objective of attaining 50 kg CW within one year of age. This reinforces the need to examine growth from birth, not only in winter (see section 6.6). Application of results reported in these experiments to commercial deer farms will increase the proportion of young red deer stags reaching optimum slaughter weight, both within the spring period and by one year of age.

Table 6.2 Percent of red deer stags grazing perennial ryegrass/white clover pasture at high DM allowance that attained slaughter weight by 12 months of age (November 30).

	1987	1988	1989
Liveweight (kg) at the start of experiments	55.0	56.9	52.3
Stags attaining 92 kg LW by end of November (% total)	0	42	41 (64)

Source: Ataja *et al* (1989; 1990); () % of total excluding Freund's group

6.4 Effect of introduction of Moata annual ryegrass

The LWG of the red deer stags grazing the Moata swards showed a seasonal pattern, being slow during winter and faster during spring (Table 6.3), similar to that reported for stags grazing the perennial ryegrass/white clover swards (Table 6.1). Best responses to the inclusion of Moata ryegrass were obtained in 1989 when animals grazing the Moata swards grew at the rate of 165 g/day during winter (Table 6.3), significantly greater ($P < 0.05$) than that recorded for animals grazing the perennial ryegrass/white clover (Table 6.1). As the W/S ratio was increased from 0.62 to 0.70, it seems that these deer were growing close to their genetic potential in a paddock environment at that latitude. The higher growth rate of animals grazing the Moata swards in winter agrees with reports that sheep grazing annual ryegrass varieties had greater LWG than those grazing perennial ryegrass varieties (Rae *et al* 1964; Ulyatt 1971). This could be attributed to 82% of the Moata swards being Moata annual ryegrass during winter, and also that the animal grazing the Moata sward had greater VFI ($P < 0.001$) than those grazing the perennial ryegrass/white clover swards during winter. In the series of experiments since 1987, the 82% proportion of Moata annual ryegrass in the Moata swards during winter of 1989 was the highest recorded for a direct drilled paddock, and produced the best responses in winter LWG. This indicates that Moata annual ryegrass can improve animal growth rate but only when present in high proportions in the swards. The percent of stags grazing the Moata swards that attained slaughter weight by 12 months of age (Table 6.3) tended to be slightly greater than that of those grazing perennial ryegrass/white clover swards (Table 6.2).

Table 6.3 Liveweight gain (g/day) and percentage of stags attaining slaughter LW (92 kg) at 12 months of age for red deer stags grazing Moata annual ryegrass swards 1987-89.

	1987	1988	1989
Animals/group	12	14	15
Liveweight gain			
Winter (W)	110	131	165
Spring (S)	222	209	235
Ratio W/S	0.50	0.63	0.70
Stags to slaughter (% of total)	25	50	60 (75)

Source: Ataja *et al* (1989; 1990); () % of total excluding Freund's group

6.5 Carrying capacity of Moata swards to achieve maximum growth

The 1989 experiment gave higher winter LWG than the 1988 experiment (165 v 131 g/day), probably due to a higher proportion of Moata annual ryegrass in the swards (82%) compared with 33% present in swards in 1988. The carrying capacity in winter during the 1989 experiment was however reduced (8.8 deer/ha; Table 6.4) compared with 13.1 deer/ha in 1988, probably due to the blanket-spray method used for herbicide application, which severely suppressed growth of white clover and other species, creating swards with open structure and low density. In order to ensure high winter LWG and carrying capacity in future experiments, it is suggested that the cross-pass method of direct drilling be used at a seed rate of 30 kg/ha, with herbicide applied using the band-spray method. This should ensure a high Moata annual ryegrass proportion in the swards and avoid severe suppression of white clover and retain reasonable amounts of other grass species to improve sward density.

Moata swards had lower carrying capacity in the spring of both 1988 and 1989 than the perennial ryegrass/white clover swards (Table 6.4), due to Moata annual ryegrass dying off in late spring, resulting in reduced tiller density and the number of stags/ha the swards could support.

Table 6.4 Direct drilling methods of Moata swards and the carrying capacity (animals/ha/day) on high Moata and PRG allowances during 1987, 1988 and 1989.

	1987	1988	1989
Drilling method	Single-pass, 15 kg seed/ha and band-sprayed with herbicide	Cross-pass, 20 kg seed/ha and band-sprayed with herbicide	Cross-pass, 24 kg seed/ha and blanket-sprayed with herbicide
Carrying capacity			
Winter PRG	12	10.5	8.7
Moata	12	13.1	8.8
Spring PRG	12	12.4	23.0
Moata	12	9.4	16.6

6.6 Feeding deer calves during summer and autumn

Grassland farming in NZ is most suitable for sheep and both dairy and beef cattle operations with mating timed to produce offspring in late winter/early spring, resulting in good alignment of animal feed requirements with the seasonal forage supply. However, in many parts of NZ this does not apply to deer farming, as deer are late calvers; calves are born in late spring/early summer, at a time when both pasture production and nutritive value are declining. Consequently, this may lead to low milk production from the dams, and to deer calves not achieving their genetic potential for growth from birth to weaning. Hunt and Hay (1989) reported that red deer hinds selected legumes in preference to grasses in summer, and that red clover was their most highly preferred legume. Red clover has a high nutritive value (Waghorn and Barry 1987) and has maximum DM production during the summer period. Therefore, red clover should be evaluated as an alternative to perennial ryegrass/white clover pasture for deer grazing during this period. An initial experiment by the Massey University deer research group (Niezen *et al* 1990), summarised in Table 6.5, has indeed shown that grazing hind/calf pairs on pure red clover during lactation increased weaning weight, compared to control hind/calf pairs grazing PRG/WC pasture. The LWG of deer calves grazing red clover was also greater than that reported for deer calves grazing PRG/WC pasture (384 g/day; Moore *et al* 1988).

Table 6.5 The LWG (g/day), feed on offer and weaning weight of red deer calves grazing perennial ryegrass/white clover or pure red clover swards during summer (December 1989 - February 1990; 61 days) at Massey University deer research unit.

Treatment (DM allowance)	DM offered (kg/head/d)	Calf growth (g/d)	Weaning Weight (kg; 28 Feb)	Hind growth (g/d)
High red clover	16.4	461	51.3	53
Medium red clover	10.8	433	49.5	58
Low red clover	5.4	380	46.7	5
Perennial ryegrass/white clover	9.9	333	42.8	-52

Source: Niezen *et al* (1990); Animals/group = 8 hind/calf pairs

In another experiment conducted by the Massey University deer research group during the subsequent autumn (March-May, 1990; Semiadi *et al* unpublished data), 10 weaner hinds and 10 weaner stags were grazed on either PRG/WC or a pure red clover sward. Young deer grazing red clover grew better than those grazing PRG/WC (Table 6.6), with the stags grazing pure red clover attaining an average LW of 63.7 kg by termination of the trial; May 16. In the present experiment (1989; Chapter 5), LW was 52.3 kg (May 15), 11.4 kg lower than that reported for stags grazing red clover swards. This suggests that red clover could be used as alternative pasture species for grazing red deer during summer and autumn, to produce stags of heavier weight, as starting material for an early venison production programme.

Chicory ('Grasslands Puna') is another herbage species that has high DM yields (Hare *et al* 1987; Clark *et al* 1990), and should be evaluated for deer grazing during summer and autumn. Experiments with sheep and cattle (Hare *et al* 1987; Clark *et al* 1990) showed that grazing chicory swards resulted in high LWG during summer. Hunt and Hay (1989) showed that red deer stags preferred chicory to other herbage species. The combination of high DM yields and nutritive value suggests it has the potential to become a valuable summer-autumn herbage for grazing red deer, it is therefore suggested that this possibility be investigated in future experiments.

Table 6.6 The LWG, feed on offer and final LW of weaner red deer stags grazing perennial ryegrass/white clover or red clover swards during autumn at Massey University deer research unit.

	Pasture		Red Clover	
	Stags	Hinds	Stags	Hinds
Initial weight (kg) (March 7)	44.5	47.3	44.6	47.9
Final weight (kg) (May 16)	58.4	59.9	63.7	62.5
Liveweight gain (g/d)	193	173	262	200
Herbage (before grazing) mass (after grazing) (kg DM/ha)	2780		3318	2901

Source: Semiadi *et al* (unpublished data)

6.7 Estimation of VFI of grazing red deer using intraruminal chromium controlled release devices

Animal production is dependent on adequate levels of voluntary intake being attained, especially in the case of ruminants, which can utilise poor forages and by-products which are of no direct nutritional value to man (Forbes 1986). Since provision of feed is a major input cost on the farm, knowledge of feed requirements is necessary for the efficient farming of livestock. The use of chromium sesquioxide (Cr_2O_3) is widely accepted as a marker for the measurement of total faecal output (FO) and VFI in animal nutrition studies. Intraruminal chromium controlled release devices (CRD) designed to deliver chromic oxide to the rumen at a constant rate, allow measurement of FO and thereby estimation of pasture intakes (Ellis *et al* 1982). This technique has made possible studies of VFI with ruminants under grazing conditions. Measurement of FO in grazing sheep (Laby *et al* 1984; Ellis and Rodden 1987), fallow deer (Kelly *et al* 1985) and VFI in red deer stags (Parker and Ataja 1990) using CRD have been reported.

FO is calculated as:

$$\text{FO} = \frac{\text{Cr release rate (mg/day)}}{\text{Cr conc. in faeces (mg/kg DM)}}$$

and VFI is calculated from FO according to the formula:

$$\text{VFI} = \frac{\text{FO}}{(1 - \text{Digestibility})}$$

Since chromium release in the rumen is constant, diurnal variations in faecal chromium concentration caused by variation in eating pattern may affect the estimation of FO and VFI. In order to avoid the effect of diurnal variation of chromium concentration in faeces, group faecal sampling from the sward may be a more preferred method of sampling, since the sample is over 24 hours; however, as a group mean sample is taken, it prevents appropriate factorial statistical analysis of the data.

In the present experiment (1989; Chapter 5) two methods of faecal sampling were used during spring; sward group sampling of faeces (Raymond and Minson 1955) and individual rectal sampling of faeces. The VFI of red deer stags determined using group faecal samples were greater than that determined using individual faecal samples (2444 v 1740 g DM/head/day; Table 6.7). This difference in the VFI could be due to diurnal variation of chromium concentrations in faeces, or to frequent yarding and handling depressing VFI. Red deer have 6-9 feeding cycles daily with peaks at dawn and dusk (Kay and Staines 1981) which could result in variable concentrations of chromium in the faeces at certain times of the day. Table 6.7 shows similar values (2250 v 2444 g DM/head/day) for calculated VFI (Fennessy and Milligan 1987) and determined VFI of red deer stags using group faecal samples. Parker *et al* (1990) in an experiment with sheep concluded that CRD are well suited to the estimation of mean intake in groups of animals, but did not permit accurate estimation of individual intakes for selection purposes. There is a need for more experiments to be conducted to determine the relevance of each method for deer, especially using CRD designed for use in deer.

6.8 Feed selection

In the surgical operation to fit oesophageal fistula in the deer, attention must be paid to the positioning of the fistula. It is crucial that the fistula is located at the appropriate place

to enable representative sample collection. It has been observed at Massey University that the location of oesophageal fistula in the deer should be different to the position normally used for sheep. Oesophageal fistulae located about 1/3 the length of the neck from the body and slightly to the left side gave more consistent and representative extrusa samples, and was also in a position where the deer could not pull out the cannula.

Table 6.7 Seasonal ME requirement and VFI of young (3-15 months) red deer stags (Source: Fennessy and Milligan 1987; Ulyatt *et al* 1980).

	Autumn	Winter	Spring	Summer
Estimated daily ME requirement (MJ/head/day) ¹	16.0	20.9	27.0	26.5
Approximate M/D values for PRG/WC dominant poastures (MJ ME/kg DM) ²	10.5	11.2 ^s	12.0 ^s	10.3 ^l
Calculated VFI (g DM/head/day)	1524	1866	2250	2573
Determined VFI from present 1989 experiment (g DM/head/day)				
Group faecal samples	-	-	2444	-
Individual faecal samples	-	-	1740	-

s = short pasture; l = leafy pasture

¹ Fennessy and Milligan (1987)

² Ulyatt *et al* (1980)

The results of the 1989 experiment (Table 6.8) shows that deer selected green grass material high in OM digestibility and rejected dead matter. There was no evidence that they grazed white clover in preference to other pasture species. Hughes *et al* (1984; Table 6.9) reported that on similar swards, the diet of the lamb contained a greater proportion of clover and smaller proportion of grass and dead matter than the diet of the bovine calf, whilst the diet of the kid was intermediate. While older goats consumed a diet similar in composition to the kids, older sheep ate slightly more dead matter than the lambs. Their experiment also shows that like the deer, goats, sheep and cattle all selected a highly digestible diet leaving ungrazed herbage mass high in dead matter (33%; OMD estimate not likely to exceed 60%).

Table 6.8 Mean proportion of sward components of feed on offer (% DM) and oesophageal extrusa (% contact) and digestibility of OM for grazing red deer stags over winter and spring (1989).

	Pasture		Moata	
	Feed on offer	Extrusa	Feed on offer	Extrusa
Grass	85.4	96.8	89.9	98.5
White clover	3.7	1.5	1.3	0.7
Dead matter	10.9	1.8	8.9	0.9
OMD (%)	79.6	88.6	83.3	89.3

Table 6.9 Mean proportion (DM) of sward components and digestibility of OM in oesophageal extrusa from goats, sheep and calves grazing similar ryegrass white clover swards (Source: Hughes *et al* 1984).

	Mean ungrazed herbage masses	Kid	Goat	Lamb	Sheep	Calf
Grass	0.41	0.64ab	0.79a	0.56b	0.59ab	0.76a
Clover	0.26	0.35ab	0.20b	0.42a	0.36ab	0.19b
Dead matter	0.33	0.01b	0.01b	0.02b	0.05a	0.05a
OM digestibility (%)		81ab	83a	77ab	76ab	76b

Note: Subscripts a, b and ab were not defined in the original publication.

6.9 Immunisation against LHRH

The LHRH immunisation experiment conducted in 1989 (Chapter 4) showed that the immunised stags grew better than the non-immunised stags ($P < 0.05$) during the rut when they were 16-17 months old. The results also showed low anti-LHRH antibody titre (1:173-1:1349), slight indications of treatment effect on plasma hormone concentrations and no treatment effect on the weight of testes. The lack of immunisation effects on the plasma hormone levels could be due to late commencement in the vaccination programme (January 17, 1989). It is suggested for future experiments that primary vaccination be given earlier, eg September/October of the previous year, to ensure high anti-LHRH antibody titre development to effect a more complete blockade of LHRH activity.

The hypothesis that early vaccination may be more successful, was based on reports that peak plasma concentration of LH in the red deer occurs during December/January and lowest during July/October (Fennessy *et al* 1985). Studies with sheep showed that the release of LHRH is phasic, and there is a close relationship between the episodic peaks in the concentration of LHRH in the hypothalamic-pituitary portal blood and the episodic peaks in the level of LH in the peripheral blood (Clarke and Cummins 1982; Levine *et al* 1982). It is thought that the control mechanism is the same in the red deer, and therefore, that the LHRH activity would be lowest during winter/early spring and highest during early summer. In order to stimulate the production of antibodies which will bind endogenous LHRH being released in summer, it was thought appropriate to start the vaccination programme during September/October. As the lag phase between commencement of anti-LHRH immunisation and the development of antibody titre in the present experiment was about 2 months, it seems that the immunisation should commence in spring in order to reduce LH production during summer and testosterone production in autumn.

In 1989/90, another LHRH immunisation experiment was conducted by the Massey University deer research group using yearling red deer stags to test the above hypothesis (Freundenberger *et al* unpublished). The primary vaccination was given to stags in group 1 (GP1) on October 9, 1989, followed by 5 booster vaccinations given on October 26, November 13, December 12, 1989 and March 8 and 29, 1990, respectively. The stags in group 2 (GP2) received 4 booster vaccinations, as above; but none on October 26, 1989, and stags in group 3 (GP3) received injections of the adjuvant only (control group). The LW pattern (Figure 6.1) showed that GP1 were heavier than GP3 all the time, with effects first attaining significance ($P < 0.10$) in October and significant at $P < 0.05$ or $P < 0.01$, from February to July. The early treatment effect on liveweight observed in this experiment supports the early vaccination hypothesis. Assays for anti-LHRH antibody titre and plasma hormone concentrations are in progress.

In 1989 LHRH immunisation experiment (Chapter 4), there was no treatment effect on testes weight, which could either be due to the fact that:

1. The testes were weighed 2 months after the rut (July), which was long enough to allow the testes of the control group to regress in size following peak activity during the rut, thereby attaining similar weight as the testes of the immunised group, or

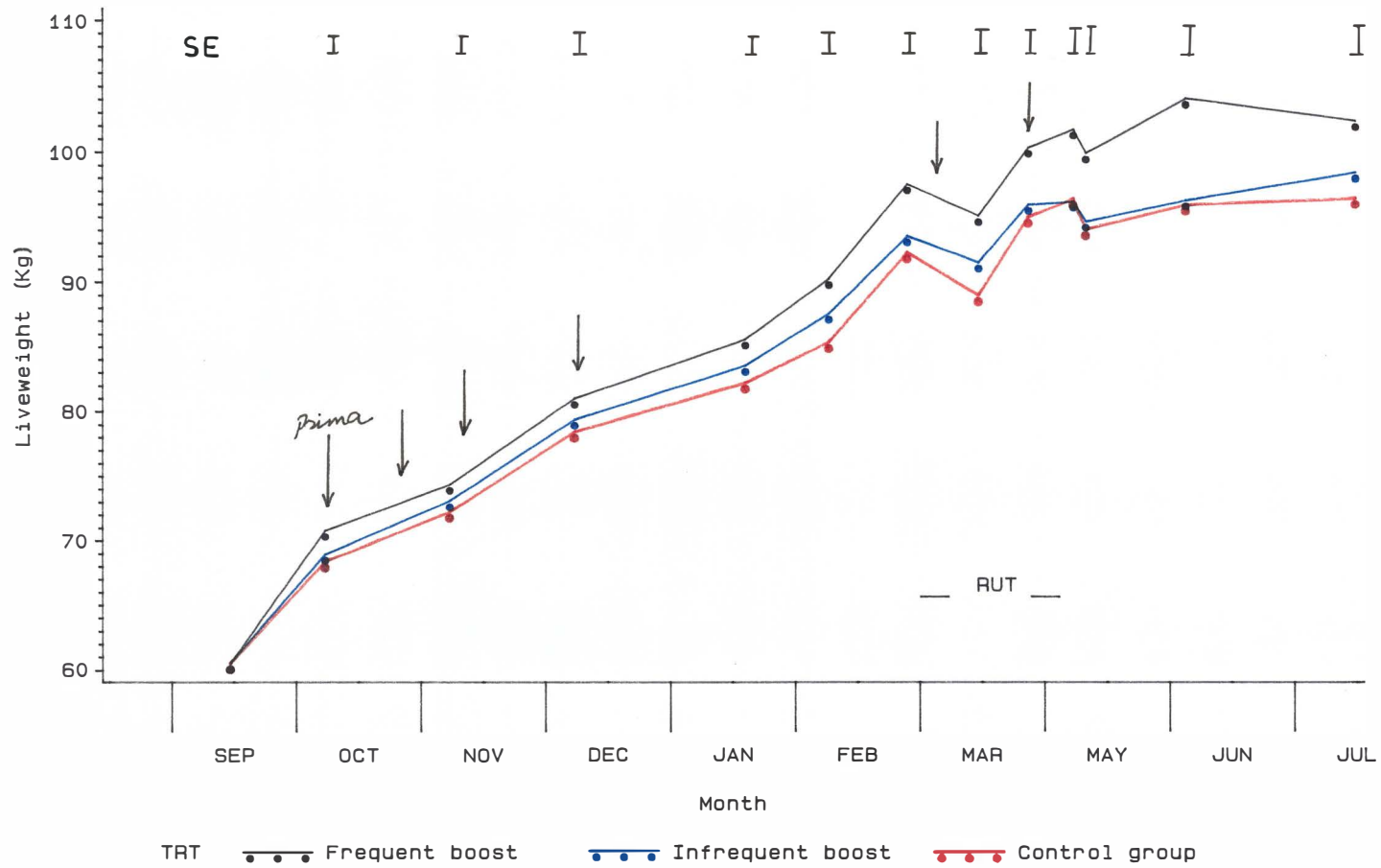


Figure 6.1. Seasonal liveweight patterns of yearling red deer stags vaccinated with LHRH antigen. (↓) indicates booster vaccinations.

2. Due to late commencement in the vaccination programme, LHRH activity was only partially blocked and did not prevent the testes of the immunised stags from going through similar physiological changes as did the testes of the control group. This is the more likely event given that testicular changes commenced as early as December of the previous year.

In future experiments of this kind, the testes size should be recorded as the experiment progresses.

Plasma concentrations of GH and IGF-1 are positively correlated with LWG in the red deer (Suttie *et al* 1989), and prolactin injections during winter resulted in increased VFI and LWG in young male red deer (J.M. Suttie pers. comm.) and in young male reindeer (Ryg and Jacobsen 1982). Because of the difference in LWG recorded between the immunised and control stags during rut in the 1989 experiment (Chapter 4) and in the experiment of Freudenberger *et al* (unpublished), assay of plasma samples for GH, IGF-1 and prolactin levels, should also be done in future experiments.

6.10 **Anti-melatonin antibody titre**

The main aim of immunising stags against melatonin was to create the physiological state not influenced by exogenous lighting patterns, by generating antibodies to bind plasma melatonin. The objective was to test the hypothesis that creating a free-running endogenous rhythm may reduce the seasonality in the physiology of the deer, thereby allowing the animals to increase VFI and increase their potential for growth during autumn/winter.

The present experiments (Chapters 2-5), showed that it was feasible to raise anti-melatonin antibody titres in the red deer, and that commencing the vaccination programme at birth produced the highest antibody titres (Table 6.10). The proportion of the vaccinated stags that gave detectable immune response in the 1989 experiment (89%; Table 6.10), is slightly higher than 79% responders recorded by Duckworth and Barrell (1989), but similar to 90% recorded by Roberts and Reeves (1989) in ewes immunised against LH. The results also showed that despite the various dates of primary vaccination, immunisation using Freund's adjuvant consistently yielded highest antibody titres during spring (October/November; Table 6.10). Red deer show very marked seasonal cycles in VFI and

liveweight change (Blaxter *et al* 1974; Suttie *et al* 1989), testicular activity, hormonal profiles and reproduction (Lincoln and Kay 1979; Lincoln 1985; Barrell *et al* 1985), casting and regrowth of the antlers (Wislocki *et al* 1947; Suttie *et al* 1984) and moulting of the hair coat (Lincoln 1983). The highest mean values of anti-melatonin antibody titres consistently recorded during spring in the present experiments may indicate a further seasonal rhythm in the red deer, involving antibody production.

Table 6.10 Age of stags at primary vaccination against melatonin hormone and anti-melatonin antibody titres raised.

	1987	1988	1989 ^P	
Age at primary immunisation (months)	6	3	At birth	
Adjuvants	Freund's	Freund's	Freund's	DEAE-dextran
Highest mean titre values (SE) and date attained	1:1571 (583) November	1:613 (256) November	1:15,215 (5551) October	1:1941 (423) May
Responders (% vaccinated)	56	73	89	64

^P peak titre values

In the 1989 experiment (Chapter 5), the DEAE-dextran group tended to grow faster than the control group ($P > 0.10$) during spring, coinciding with increase in the plasma concentration of prolactin. This tended to agree with the effect of prolactin on LWG as reported for young male reindeer (Ryg and Jacobsen 1982) and young male red deer (J.M. Suttie, pers. comm.).

The lack of significant immunisation effect ($P > 0.10$) on the LWG in the 1989 experiment could be due to the adverse effect of Freund's adjuvant (FCA) on the animals' LW from birth to the end of autumn, and also to lack of persistence of the anti-melatonin antibody titre in the DEAE-dextran group.

In future experiments of this kind, there is a need for

1. Further studies in the use of FIA in the vaccine in order to eliminate the adverse effect of FCA on the weaning weight of the stags;
2. The use of placebo (adjuvant only) in the control group to determine the effects of the adjuvant;
3. Further studies in formulating DEAE-dextran-based anti-melatonin vaccine that produces higher antibody titres over a longer period of time;
4. For the experiment to be repeated using more animals (20 animals/group for main effect) over a 2 year period. Since it has consistently been shown that immunising stags using Freund's adjuvant-based vaccine produced highest antibody titre during October/November, booster vaccinations should be given in January and March of the second year, to determine what effect sustaining high anti-melatonin antibody titre may have on LWG during autumn/winter, and
5. Plasma samples to be taken every 30 min over a 26-hour period on some occasions, in order to monitor the diurnal patterns in plasma concentrations of free melatonin in immunised stags. This would provide additional information on the amount of free melatonin in circulation in the immunised red deer.

6.11 Effect of immunisation on carcass components

The present experiments (Chapters 2-5) did not show any detrimental effect of immunisation of stags against either melatonin or LHRH upon carcass composition. Successful immunisation of stags against LHRH should result in immuno-castration. Drew *et al* (1978) reported that castrate stags grew more slowly and contained more fat than entire animals at equal carcass weight. A similar effect was not observed in the present experiments, either due to a general lack of anti-melatonin immunisation effects on animal growth or because immuno-castration, being a temporary physiological state, did not produce the same effect as permanent castration.

Stags immunised against LHRH had a lower dressing-out percentage than the control group ($P < 0.10$; Chapter 4). This may be attributed to gut-fill effects. The LW of the immunised stags was greater than that of the control group during the rut, probably because the immunised group had higher VFI. At slaughter, the immunised stags may therefore have had higher non-carcass gut contents than the control group, which could result in a lower dressing-out percent for the immunised group.

In future experiments of this kind, the following should be considered:

1. Measurement of VFI of animals during the rut.
2. Immunisation against LHRH should start earlier (eg September), using more animals (15 per group) and running for 12 months to allow collection of more data.
3. Immunisation against melatonin should start at birth and the experiment be conducted over a period of 2 years as suggested earlier.

Carcass components should then be re-examined to determine effects of immunisation on carcass composition. It is possible that effects upon carcass composition could become more evident, when the vaccination regimes against LHRH and melatonin in deer have been better defined.

**APPENDIX I VALIDATION OF PROLACTIN
RADIO-IMMUNOASSAY FOR USE WITH DEER PLASMA**

Plasma prolactin was determined using the double-antibody radioimmunoassay based on the method of van Landeghem and van de Weil (1978), as modified by Peterson *et al* (unpublished). This assay utilised lyophilized ovine prolactin (NIADDK-oPRL-1-2 (AFP-7150B) from NIADDK, NIH, Bethesda, Md, U.S.A. and supplied through NHPP University of Maryland School of Medicine, Baltimore, Md, U.S.A.) for the tracer. The first antibody was NIADDK-anti-oPRL-1 (AFP-973269) rabbit serum, donated by NHPP, University of Maryland School of Medicine, Baltimore, Maryland, U.S.A. The second antibody was Donkey anti-rabbit precipitating serum (IDS Gamma-B precipitating anti-serum for radioimmunoassay, Code APPT1, Lot # 11656, IDS, Washington, Tyne and Wear, England).

Serial volumes of red deer plasma samples 25, 50, 70, 100, 150, 200 μ l were made up to 350 μ l with assay buffer and were used with 50 μ l each of first antibody, tracer, and second antibody to produce binding % curves (Appendix Figure 1). These were parallel to the standard ovine reference curve, thus validating the assay for use with cervine plasma. The assay had a linear range of 1-1000 ng/ml of ovine reference standard.

The internal recovery (IR) was calculated from preparing five samples as follows:

- (a) Mean expected concentration of 50/50 deer plasma sample/standard ovine mix (E) ng/ml, and
- (b) observed concentration of 50/50 deer plasma sample/standard ovine mix (O) ng/ml;

$$\text{IR} = \frac{\text{O}}{\text{E}} \times 100 = 120.7\%$$

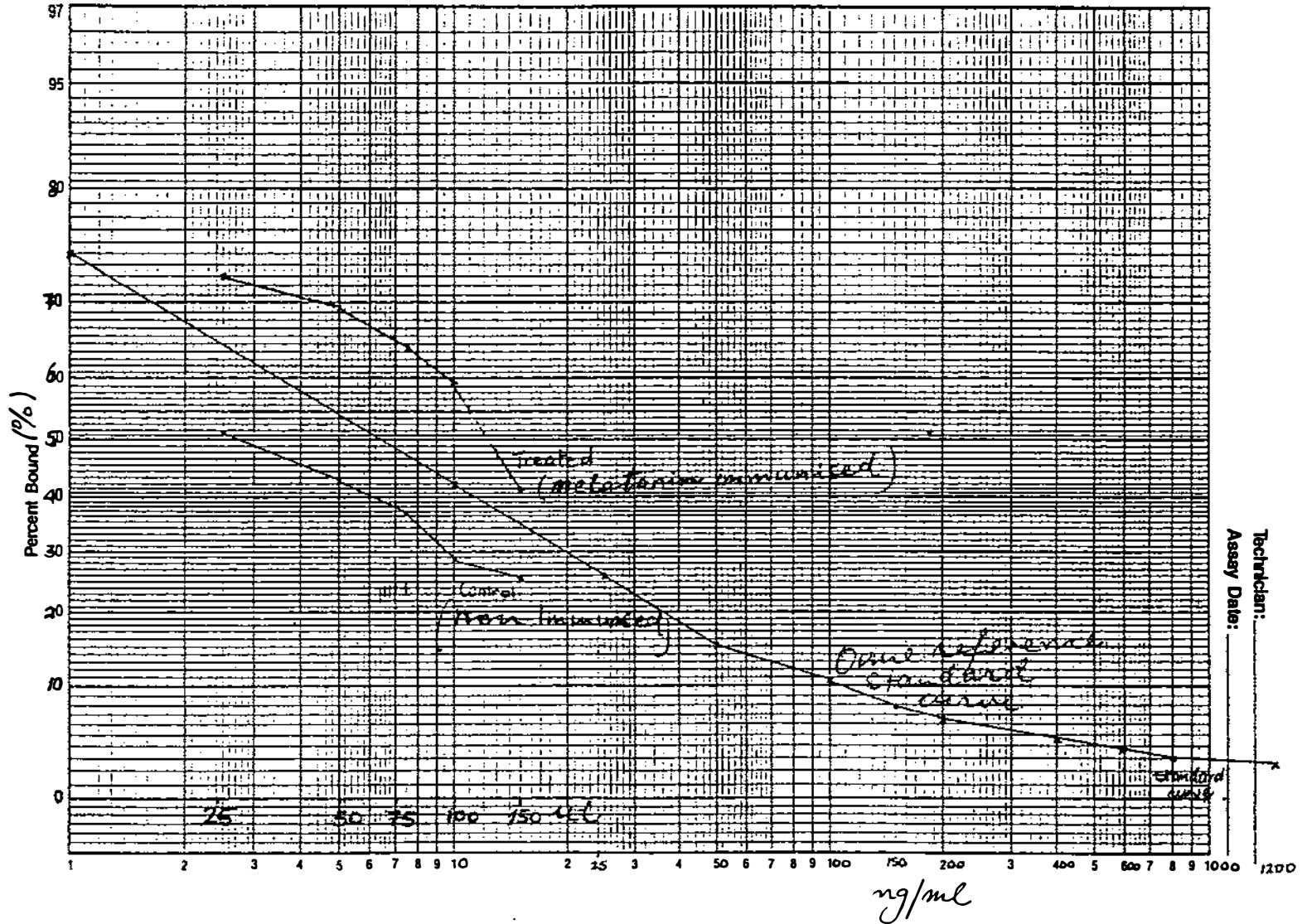
The inter-assay coefficient of variation (c.v.) = 11%; n = 5.

Based upon these criteria, the radioimmunoassay procedure was considered validated for the analysis of prolactin in cervine blood plasma.

Calibrator Levels: PRL #33

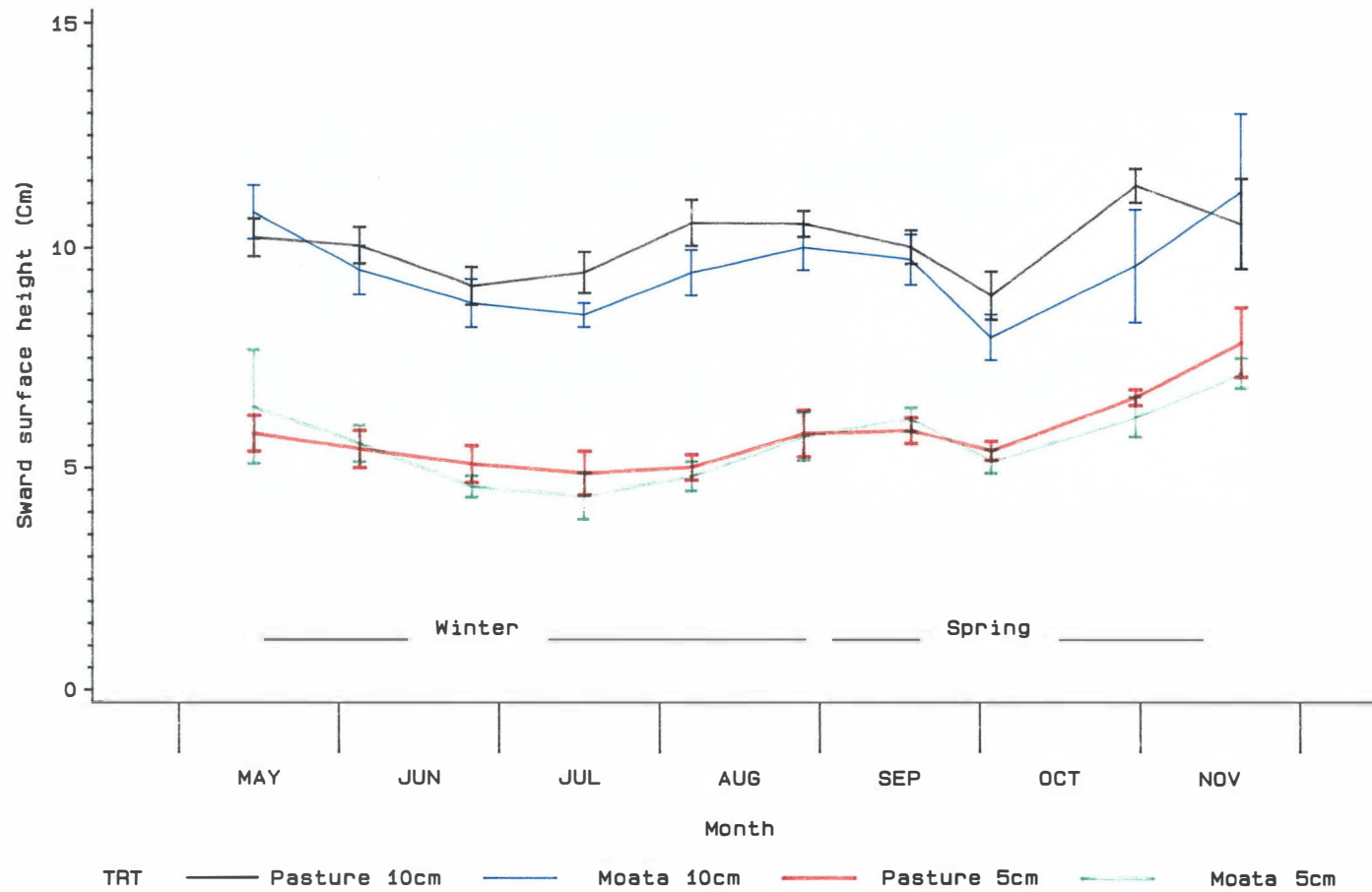
2/9/89 Units: ng/ml

DPC



Technician:
Assay Date:

Appendix Figure 1. Curves for parallelism test between cervine plasma and ovine reference standard for the validation of prolactin assay for use with red deer plasma.



Appendix Figure 2. Mean sward surface heights grazed by weaner red deer stags during the 1988 season. (I) indicates SD.

APPENDIX II FEED ON OFFER

Appendix Table 1 shows the level of feed on offer (kg DM/ha) for the two sward types at 5 cm and 10 cm, during winter and spring, respectively. At a similar sward height, the pasture swards appeared to have greater herbage mass (kg DM) than the Moata swards, and the herbage mass was lower in winter than spring.

Appendix Table 1. Level of feed on offer (kg DM/ha) during winter (June-August) and spring (September-November) 1988.

	10 cm sward		5 cm sward	
	Pasture	Moata	Pasture	Moata
<u>WINTER</u>				
Herbage Mass (SD)	1840 (247.1)	1694 (107.9)	1236 (278.7)	1148 (31.4)
<u>SPRING</u>				
Herbage Mass (SD)	2251 (177.6)	2022 (127.6)	1731 (283.3)	1690 (171.6)

APPENDIX III RUMEN FLUID SAMPLING

Ammonia in rumen fluid

Duplicate samples (10 ml) were added to 2.5 ml of deproteinising reagent (1 M H₂SO₄, saturated with magnesium sulphate), centrifuged at 1985 g for 15 mins and stored at -20 °C until analysed.

VFA in rumen fluid

Duplicate samples (5 ml) were added to 1 ml of protein precipitant (metaphosphoric acid/formic acid: 18.75% w/v/25% v/v). One ml of the internal standard (isocaproic acid; 0.52% v/v) was added to one sample (internal standard sample), and 1 ml of distilled water added to the other sample (control sample). Both samples were centrifuged at 1895 g for 15 mins and stored at -20 °C until analysed.

REFERENCES

- Abraham, G.E. (1974). Radioimmunoassay of steroids in biological materials. *Acta Endocrinologica* 183 (Supplement):7-42.
- Adam, C.L. and Atkinson, T. (1984). Effect of feeding melatonin to red deer (*Cervus elaphus*) on the onset of the breeding season. *Journal of Reproduction and Fertility* 72: 463-466.
- Adam, C.L., Moir, C.E. and Atkinson, T. (1986). Induction of early breeding in red deer (*Cervus elaphus*) by melatonin. *Journal of Reproduction and Fertility* 76: 569-573.
- Adam, J.L. (1984). Growth and venison production of farmed red deer stags in the northern region. *IX Annual Conference of the New Zealand Deer Farmers Association*. Pp.72-79. Hamilton, New Zealand.
- Adam, J.L. and Asher, G.W. (1986). Growth and venison production: Red and fallow deer. In: *Proceedings Ruakura Farmers' Conference, 38th Conference Hamilton, New Zealand*. Pp.5-9.
- Adam, J.L. (1988). Pasture for deer production. *Proceedings of the New Zealand Grassland Association* 49: 37-40.
- Allain, D., Martinet, L. and Rougeot, J. (1981). Effect of melatonin implants on changes in the coat, plasma prolactin and testis cycle in the mink (*Mustela vison*). In: *Photoperiodism and Reproduction in Vertebrates*. Ed. R. Ortavant, J. Pelletier and J-P Ravault. Pp.263-271. I.N.R.A. Service des Publications, France.
- Anfinson, M.S., Davis, S.L., Christian, E. and Everson, D.O. (1975). Episodic secretion of growth hormone in bulls and steers: An analysis of frequency and magnitude of secretory spikes occurring in a 24-hour period. *Proceedings of the Western Section American Society of Animal Science* 26: 175-177.
- Arendt, J., Symons, A.M. and Laud, C.A. (1981a). Pineal function in the sheep: evidence for a possible mechanism mediating seasonal reproductive activity. *Experientia* 37: 584-586.

- Arendt, J. (1986). Role of the pineal gland and melatonin in seasonal reproductive function in mammals. *In: Oxford Reviews of Reproductive Biology* 8: 266-320.
- Armstrong, C.S. (1981). 'Grasslands Moata' tetraploid Italian ryegrass (*Lolium multiflorum* Lam.). *New Zealand Journal of Experimental Agriculture* 9: 337-341.
- Arnold, G.W. (1964). Some principles in the investigation of selective grazing. *Proceedings of Australian Society of Animal Production* 5: 258-271.
- Asher, G.W. and Adam, J.L. (1985). Reproduction of farmed red and fallow deer in northern New Zealand. *In: Biology of Deer Production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 217-224. The Royal Society of New Zealand Bulletin 22.
- Asher, G.W., Barrell, G.K. and Peterson, A.J. (1986). Hormonal changes around oestrus of farmed fallow deer, *Dama dama*. *Journal of Reproduction and Fertility* 78: 487-496.
- Asher, G.W., Barrell, G.K., Adam, G.L. and Staples, L.D. (1988). Effects of subcutaneous melatonin implants on reproductive seasonality of farmed fallow deer (*Dama dama*). *Journal of Reproduction and Fertility* 84: 679-691.
- Asher, G.W., Peterson, A.J. and Bass, J.J. (1989). Seasonal pattern of LH and testosterone secretion in adult male fallow deer, (*Dama dama*). *Journal of Reproduction and Fertility* 85: 657-665.
- Asher, G.W., Fisher, M.W. and Fennessy, P.F. (1989). Manipulating seasonal breeding patterns of red and fallow deer. *Proceedings of the Ruakura Deer Industry Conference, Ruakura*. Pp.51-59.
- Ataja, A.M., Wilson, P.R., Purchas, R.W., Hodgson, J., Barry, T.N. and Hay, R.J.M. (1989). A study of early venison production from grazing red deer (*Cervus elaphus*). *Proceedings of the New Zealand Society of Animal Production* 49: 25-27.

- Ataja, A.M., Wilson, P.R., Purchas, R.W., Hodgson, J., Varela-Alvarez, H. and Barry, T.N. (1990). Venison production from grazing young red deer stags. *In: Biology of Deer Production*. (In press).
- Bahnak, B.R., Holland, J.C., Verme, L.J. and Ozoga, J.J. (1981). Seasonal and nutritional influences on growth hormone and thyroid activity in white-tailed deer. *Journal of Wildlife Management* 45: 140-147.
- Baker, C.J. (1976). Experiments relating to techniques for direct drilling of seeds into untilled dead turf. *Journal of Agricultural Engineering Research* 21: 133-144.
- Barrell, G.K. and Lapwood, K.R. (1979). Seasonality of semen production and luteinizing hormone, testosterone, and prolactin levels in Romney, Merino and Polled Dorset rams. *Animal Reproduction Science* 1: 213-228.
- Barrell, G.K., Muir, P.D. and Sykes, A.R. (1985). Seasonal profiles of plasma testosterone, prolactin, and growth hormone in red deer stags. *In: Biology of Deer Production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 185-190. The Royal Society of New Zealand Bulletin 22.
- Barry, T.N., Suttie, J.M., Milne, J.A. and Kay, R.N.B. (1990). Control of food intake in domesticated deer. *In: Proceedings of the VII International Symposium on Ruminant Physiology*. Sendai, Japan. (In press).
- Barry, T.N. and Wilson, P.R. (1990). The New Zealand deer industry: development and progress. *In: Proceedings of Deer Physiology and Production . VII International Satellite Symposium of Ruminant Physiology*. Sendai, Japan. (In press).
- Baumgardt, B.R., Taylor, M.W., and Cason, J.L. (1962). Evaluation of forages in the laboratory. II. Simplified artificial rumen procedure for obtaining repeatable estimates of forage nutritive value. *Journal of Dairy Science* 45: 62-68.
- Berg, R.T. and Butterfield, R.M. (1976). *In: New Concepts of Cattle Growth*. Halsted Press, John Wiley and Sons, New York.

- Bircham, J.S. and Korte, C.J. (1984). Principles of herbage production. *New Zealand Agricultural Science* **18**: 123-126.
- Bittman, E.L., Dempsey, R.J. and Karsch, F.J. (1983). Pineal melatonin secretion drives the reproductive response to daylength in the ewes. *Endocrinology* **113**: 2276-2283.
- Blaxter, K.L., Kay, R.N.B., Sherman, G.A.M., Cunningham, J.M.M. and Hamilton, W.J. (1974). Farming the red deer. *Her Majesty's Stationery Office, Edinburgh*.
- Blaxter, Sir Kenneth, Kay, R.N.B., Sharman, G.A.M., Cunningham, J.M.M., Eadie, J. and Hamilton, W.J. (1988). Farming the red deer. *Her Majesty's Stationery Office, Edinburgh*.
- Bolt, D.J. (1971). Changes in the concentration of luteinizing hormone in plasma of rams following administration of oestradiol, progesterone or testosterone. *Journal of Reproduction and Fertility* **24**: 435-438.
- Bramley, P.S. (1970). Territoriality and reproductive behaviour of roe deer. *Journal of Reproduction and Fertility* **11** (*Supplement*): 43-70.
- Breier, B.H., Bass, J.J., Butler, J.H. and Gluckman, P.D. (1986). The somatotrophic axis in young steers: influence of nutritional status on pulsatile release of growth hormone and circulating concentrations of insulin-like growth factor I. *Journal of Endocrinology* **111**: 209-215.
- Brown, R.D., Cowan, R.L. and Kavanaugh, J.F. (1978). Effect of pinealectomy on seasonal androgen titre, antler growth and feed intake in white-tailed deer. *Journal of Animal Science* **47**: 435-440.
- Brown, W.B., Forbes, J.M., Goodall, E.D., Kay, R.N.B. and Simpson, A.M. (1979). Effects of photoperiod on food intake, sexual condition and hormone concentrations in stags and rams. *Journal of Physiology* **296**: 58-59 P.
- Bubenik, G.A., Bubenik, A.B., Brown, G.M. and Wilson, D. (1975). The role of sex hormones in the growth of antler bone tissue. Part 1. Endocrine and metabolic effects of antiandrogen therapy. *Journal of Experimental Zoology* **194**: 348-358.

- Clark, D.A., Anderson, C.B. and Hongwen, G. (1990). Liveweight gain and intake of Friesian bulls grazing 'Grasslands Puna' chicory (*Cichorium intybus L.*) or pasture. *New Zealand Journal of Agricultural Research* **33**: 219-224.
- Clarke, I.J., Fraser, H.M. and McNeilly, A.S. (1978). Active immunization of ewes against luteinizing hormone releasing hormone, and its effects on ovulation and gonadotrophin, prolactin and ovarian steroid secretion. *Journal of Endocrinology* **78**: 39-47.
- Clarke, I.J. and Cummins, J.T. (1982). The temporal relationship between gonadotrophin releasing hormone (GnRH) and luteinizing hormone (LH) secretion in ovariectomized ewes. *Endocrinology* **III**: 1737-1739.
- Costigan, P. and Ellis, K.J. (1987). Analysis of faecal chromium derived from controlled release marker devices. *New Zealand Journal of Technology* **3**: 89-92
- Cowan, R.L. and Long, T.A. (1962). Studies on antler growth and nutrition of white-tailed deer. *Paper 107, Pennsylvania Cooperative Wildlife Research Unit, University Park, Pennsylvania.*
- Cruickshank, G.J., Poppi, D.P. and Sykes, A.R. (1985). Intake and duodenal protein flow in early weaned lambs grazing white clover, lucerne, ryegrass and prairie grass. *Proceedings of the New Zealand Society of Animal Production* **45**: 113-116.
- Curlewis, J.D., Loudon, A.S.I., Milne, J.A. and McNeilly, A.S. (1988). Effects of chronic long-acting bromocryptine treatment on liveweight, voluntary feed intake, coat growth and breeding season in non-pregnant red deer hinds. *Journal of Endocrinology* **119**: 413-420.
- Daughaday, W.H., Hall, K., Raben, M.S., Salmon, M.D., Van den Brande, J.L. and Van Wyk, J.J. (1972). Somatomedin: Proposed designation for sulphation factor. *Nature* **235**: 107.
- Davis, S.L., Ohlson, D.L., Klindt, J. and Anfinson, M.S. (1977). Episodic growth hormone secretory patterns in sheep: relationship to gonadal steroid hormones. *American Journal of Physiology* **233**: E519-E523.

- Djura, P. and Hoskinson, R.M. (1986). Radioiodination of somatostatin analogues employing Sep-Pak rapid sample purification and label assessment by high-performance liquid chromatography. *Journal of Chromatography* **363**: 424-427.
- Domingue, B.M-F. (1989). A comparative study of voluntary intake and rumen digestion in goats, sheep and deer. Ph.D. Thesis, Massey University, New Zealand.
- Drew, K.R. (1976). The Farming of Red Deer in New Zealand. *World Review of Animal Production* **12**: 49-60.
- Drew, K.R. (1985). Meat production from farmed deer. *In: Biology of Deer Production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 285-290. The Royal Society of New Zealand Bulletin **22**.
- Drew, K.R., Fennessy, P.F. and Greer, G.J. (1978). The growth and carcass characteristics of entire and castrate red stags. *Proceedings of the New Zealand Society of Animal Production* **38**: 142-144.
- Drew, K.R. and Greer, G.J. (1977). Venison production and carcass composition of red deer. *New Zealand Agricultural Science* **11**: 187-189.
- Drew, K.R. and Hogg, B.W. (1990). Comparative carcass production from red, wapiti and fallow deer. *Proceedings of the Australian Association of Animal Breeding and Genetics* **8**: 491-496.
- Drozdz, A., Weiner, J., Gebczynska, Z. and Krasinska, M. (1975). Some bioenergetic parameters of wild ruminants. *Polish Ecological Studies* **1**: 85-101.
- Duckworth, J.A. and Barrell, G.K. (1989). Effect of melatonin immunisation on the liveweight gain of red deer. *Proceedings of the New Zealand Society of Animal Production* **49**: 29-34.
- Eisemann, J.H., Bauman, D.E., Hogue, D.E. and Travis, H.F. (1984). Evaluation of a role for prolactin in growth and the photoperiod-induced growth response in sheep. *Journal of Animal Science* **59**: 86-94.

- Ellis, K.J., Laby, R.H., Costigan, P., Zirkler, K. and Choice, P.G. (1982). Continuous administration of chromic oxide to grazing animals. *Proceedings of the Nutrition Society of Australia* **7**: 177.
- Ellis, K.J. and Rodden, B. (1987). Measuring faecal output of grazing ruminants using the Captec chromic oxide controlled release capsule. *Proceedings of the IV AAAP Animal Science Congress*. Pp. 54. Hamilton, New Zealand.
- English, J.E, Poulton, A.L., Symons, A.M. and Arendt, J. (1985a). Episodic release of melatonin in the sheep. *Society for the Study of Fertility: Aberdeen*. Abstract.
- Evans, P.S. (1964). A study of leaf strength in four ryegrass varieties. *New Zealand Journal of Agricultural Research* **7**: 508-513.
- Evans, P.S. (1967). Leaf strength studies of pasture grasses - Apparatus, techniques and some factors affecting leaf strength. *Journal of Agricultural Science (Cambridge)* **69**: 171-174.
- Fennessy, P.F. (1981). Nutrition of Red Deer. *In: Proceedings of a Deer Seminar for Veterinarians*. Pp. 8-15.
- Fennessy, P.F., Moore, G.H. and Corson, I.D. (1981). Energy requirements of red deer. *Proceedings of the New Zealand Society of Animal Production* **41**: 167-173.
- Fennessy, P.F., Moore, G.H. and Muir, P.D. (1981). Artificial rearing of red deer calves. *New Zealand Journal of Experimental Agriculture* **9**: 17-21.
- Fennessy, P.F., Greer, G.J. and Bass, J.J. (1982). Progeny test of selected lean and fat rams. *Proceedings of the New Zealand Society of Animal Production* **42**: 137-140.
- Fennessy, P.F., Suttie, J.M. and Fisher, M.W. (1985). Reproductive physiology of male red deer. *In: Proceedings of a Deer Course for Veterinarians*. Pp. 101-106. Deer Branch Course # 2.

- Fennessy, P.F. and Milligan, K.E. (1987). Grazing management of red deer. *In: Livestock Feeding on Pasture*. Ed. A.M. Nicol. Pp. 111-118. The New Zealand Society of Animal Production. Occasional Publication 10:
- Fennessy, P.F. and Pearse, A.J. (1990). The relative performance of Canadian wapiti and their hybrids. *Proceedings of the Australian Association of Animal Breeding and Genetics* 8: 497-500.
- Fisher, M.W., Fennessy, P.F. and Milne, J.D. (1988). Effects of melatonin on seasonal physiology of red deer. *Proceedings of the New Zealand Society of Animal Production* 48: 113-116.
- Fletcher, J. (1974). The timing of reproduction in red deer, (*Cervus elaphus*), in relation to latitude. *Journal of Zoology* 172: 363-367.
- Forbes, J.M., Driver, P.M., Brown, W.B., Scanes, C.G. and Hart, I. (1979). The effect of day length on the growth of lambs 2. Blood concentrations of growth hormone, prolactin, insulin and thyroxine and the effect of feeding. *Animal Production* 29: 43-51.
- Forbes, J.M. (1986). *In: The Voluntary Food Intake of Farm Animals*. Butterworth and Company (Publishers) Limited.
- Gasaway, W.C. and Coady, J.W. (1974). Review of energy requirements and rumen fermentation in moose and other ruminants. *Naturaliste Canadien* 101: 227-262.
- Goss, R.J. (1968). Inhibition of growth and shedding of antlers by sex hormones. *Nature, London* 204: 798-799.
- Goss, R.J. (1983b). Control of deer antler cycles by the photoperiod. *In: Antler Development in Cervidae*. Ed. R.D.Brown. Ceasar Kleberg Wildlife Research Institute, Kingsville, Texas.
- Grimes, R.C., Watkin, B.R. and Gallagher, J.R. (1967). The growth of lambs grazing on perennial ryegrass, tall fescue and cocksfoot, with and without white clover, as related to the botanical and chemical composition of the pasture and pattern of fermentation in the rumen. *Journal of Agricultural Science (Cambridge)* 68: 11-21.

- Hare, M.D., Rolston, M.P., Crush, J.R. and Fraser, T.J. (1987). Puna chicory - A perennial herb for New Zealand pastures. *Proceedings of Agronomy Society of New Zealand* 17: 45-49.
- Herbert, J. (1981). The pineal gland and photoperiodic control of the ferrets' reproductive cycle. *In: Biological Clocks in Seasonal Reproductive Cycle*. Ed. B.K. Follett and D.E. Wright. Pp. 261. Wright, Bristol.
- Hight, G.K. and Sinclair, D.P. (1965). The autumn growth of hoggets on different pasture types. *New Zealand Journal of Agricultural Research* 8: 1079-1086.
- Hibma, M. and Griffin, J.F.T. (1988). Optimisation of antibody production and immunisation schedules in farmed deer. *In: Proceedings of a Deer Course for Veterinarians* 5: 105-110.
- Hochereau-de Rivers, M.T. and Lincoln, G.A. (1978). Seasonal variation in testicular histology of the red deer stag, (*Cervus elaphus*). *Journal of Reproduction and Fertility* 54: 209-213.
- Hodgson, J., Mackie, C.K. and Parker, J.W.G. (1986). Sward surface heights for effective grazing. *Grass Farmer*. A British Grassland Society Publication 24: 5-10.
- Hughes, T.P., Sykes, A.R. and Poppi, D.P. (1984). Diet selection of young ruminants in late spring. *Proceedings of the New Zealand Society of Animal Production* 44: 109-112.
- Hunt, W.F. and Hay, R.J.M. (1989). Alternative pasture species for deer production in the Waikato. *In: Proceedings of the Ruakura Deer Industry Conference*. Ed. G. Asher and J. Squire. Pp. 31-33.
- Inoue, T., John, A., Brookes, I.M. and Barry, T.N. (1989). Digestibility and rumen outflow of high and low shear strength Nui ryegrass fed to sheep. *Proceedings of the New Zealand Society of Animal Production* 49: 221-224.
- Judge, M. (1989). Target and standards for high liveweight gains. *Proceedings of the Ruakura Deer Industry Conference*. Ed. G. Asher and J. Squire. Pp. 5.

- Katongole, C.B., Naftolin, F. and Short, R.V. (1974). Seasonal variations in blood luteinizing hormone and testosterone levels in rams. *Journal of Endocrinology* **60**: 101-106.
- Kay, R.N.B. (1979). Seasonal changes of appetite in deer and sheep. *ARC Research Review* **5**: 13-15.
- Kay, R.N.B. and Staines, B.W. (1981). The Nutrition of the Red Deer. *Nutrition Abstracts and Reviews - Series B* **51**: 601-622.
- Kay, R.N.B. (1985). Body size, patterns of growth, and efficiency of production in red deer. *In: Biology of Deer production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 7-20. The Royal Society of New Zealand Bulletin **22**.
- Kelly, T.J., Thompson, J.M., Ellis, K.J. and Rowe, M.D. (1985). Faecal output and grazing pattern in fallow deer and sheep. *Proceedings of the ANZAAS Deer Farming Seminar*. Ed. R.P. Couchman. Pp. 34-40. Auckland, New Zealand.
- Kennaway, D.J., Gilmore, T.A. and Seamark, R.F. (1982). Effect of melatonin feeding on serum prolactin and gonadotrophic levels and the onset of seasonal estrous cyclicity in sheep. *Endocrinology* **110**: 1766-1772.
- Kennaway, D.J., Dunstan, E.A., Gilmore, T.A. and Seamark, R.F. (1984b). Melatonin feeding increases ovulation rate in ewes. *In: Abstracts of VII International Congress of Endocrinology*. Quebec, Canada. Abstract 1021.
- Korte, C.J., Chu, A.C.P. and Field, T.R.O. (1987). Pasture production. *In: Livestock Feeding on Pasture*. Ed. A.M. Nicol. Pp. 7-20. The New Zealand Society of Animal Production. Occasional publication **10**.
- Laby, R.H., Graham, C.A., Edwards, S.R. and Kautzner, B. (1984). A controlled release intraruminal device for the administration of fecal dry-matter markers to the grazing ruminants. *Canadian Journal of Animal Science* **64** (Supplement): 337-338.

- Leader-Williams, N. (1979). Age-related changes in the testicular and antler cycles of reindeer, (*Rangifer tarandus*). *Journal of Reproduction and Fertility* **57**: 117-126.
- Levine, J.E., Pau, K-Y.F., Ramirez, V.D., and Jackson, G.L. (1982). Simultaneous measurement of luteinizing hormone releasing hormone and luteinizing hormone release in unanaesthetized ovariectomized sheep. *Endocrinology* **III**: 1449-1455.
- L'Huillier, P.J., Poppi, D.P. and Fraser, T.J. (1984). Influence of green leaf distribution on diet selection by sheep and the implications for animal performance. *Proceedings of the New Zealand Society of Animal Production* **44**: 105-107.
- Lincoln, G.A., Youngson, R.W. and Short, R.V. (1970). The social and sexual behaviour of the red deer stag. *Journal of Reproduction and Fertility* **11 (Supplement)**: 71-103.
- Lincoln, G.A. (1971). The seasonal reproductive changes in the red deer stag (*Cervus elaphus*). *Journal of Zoology* **163**: 105-123.
- Lincoln, G.A., Guinness, F.E. and Short, R.V. (1972). The way in which testosterone controls the social and sexual behaviour of the red deer stag (*Cervus elaphus*). *Hormones and Behaviour* **3**: 375-396.
- Lincoln, G.A. and Davidson, W. (1977). The relationship between sexual and aggressive behaviour, and the pituitary and testicular activity during the seasonal sexual cycle of rams, and the influence of photoperiod. *Journal of Reproduction and Fertility* **49**: 267-276.
- Lincoln, G.A. and Guinness, F. (1973). The sexual significance of the rut in red deer. *Journal of Reproduction and Fertility* **19(Supplement)**: 475-589.
- Lincoln, G.A. (1979). Photoperiodic control of seasonal breeding in the ram: participation of the cranial sympathetic nervous system. *Journal of Endocrinology* **82**: 135-147.

- Lincoln, G.A. and Kay, R.N.B. (1979). Effect of season on the secretion of LH and testosterone in intact and castrated red deer stags (*Cervus elaphus*). *Journal of Reproduction and Fertility* **55**: 75-80.
- Lincoln, G.A. and Short, R.V. (1980). Seasonal breeding: Nature's contraceptive. *Recent Progress in Hormone Research* **36**: 1-52.
- Lincoln, G.A. and Almeida, O.F.X. (1981). Melatonin and the seasonal photoperiodic response in sheep. In: *Photoperiodism and Reproduction*. Ed. R.Ortavant, J.Pelletier and J.P.Ravault. Pp.231-251. INRA, France.
- Lincoln, G.A, Almeida, O.F.X. and Arendt, J. (1981). Role of melatonin and circadian rhythms in the seasonal reproduction in rams. *Journal of Reproduction and Fertility* **30** (Supplement): 23-31.
- Lincoln, G.A., Fraser, H.M. and Fletcher, T.J. (1982). Antler growth in male red deer (*Cervus elaphus*) after active immunization against LHRH. *Journal of Reproduction and Fertility* **66**: 703-708.
- Lincoln, G.A. (1983). Melatonin as a seasonal time-cue: a commercial story. *Nature, London*. **302**: 755.
- Lincoln, G.A. and Forbes, J.M. (1984). Seasonal physiology in pinealectomised rams. *Society for the Study of Fertility*. Reading, Abstract 33.
- Lincoln, G.A., Fraser, H.M. and Fletcher, T.J. (1984). Induction of early rutting in male red deer (*Cervus elaphus*) by melatonin and it's dependence on LHRH. *Journal of Reproduction and Fertility* **72**: 339-343.
- Lincoln, G.A. (1985). Seasonal breeding in Deer. In: *Biology of Deer Production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 165-179. The Royal Society of New Zealand Bulletin **22**.
- Lincoln, G.A. and Ebling, F.V.P. (1985). Effect of constant-release implants of melatonin on seasonal cycles of reproduction, prolactin secretion and moulting in rams. *Journal of Reproduction and Fertility* **73**: 241-253.

- Loudon, A.S.I., Milne, J.A., Curlewis, J.D. and McNeilly, A.S. (1986). Reproduction, prolactin and the appetite cycle in red deer. *Society for the Study of Fertility*: Pp. 80.
- Loudon, A.S.I., Milne, J.A., Curlewis, J.D. and McNeilly, A.S. (1989). A comparison of the seasonal hormone changes and patterns of growth, voluntary food intake and reproduction in juvenile and adult red deer (*Cervus elaphus*) and Pere David's deer (*Elaphurus davidianus*) hinds. *Journal of Endocrinology* **122**: 733-745.
- Mackinnon, B.W., Easton, H.S., Barry, T.N. and Sedcole, J.R. (1988). The effect of reduced leaf shear strength on the nutritive value of perennial ryegrass. *Journal of Agricultural Science (Cambridge)* **111**: 469-474.
- Marshall, F.H.A. (1937). On the change over in the oestrous cycle in animals after transference across the equator, with further observations on the incidence of the breeding seasons and the factor controlling periodicity. *Proceedings of the Royal Society of London*. **B122**: 413-428.
- McConnell, S.J. and Hinds, L.A. (1985). Effect of pinealectomy on plasma melatonin, prolactin and progesterone concentrations during seasonal reproductive quiescence in the tammar, (*Macropus eugenii*). *Journal of Reproduction and Fertility* **75**: 433-440.
- McConnell, S.J., Newman, R.E., Hoskinson, R.M., Colgan, L. and Robinson, E. (1987). Effect of active immunization against melatonin on seasonal reproduction in the tammar, (*Macropus eugenii*). *Proceedings of the Australian Society for Reproductive Biology* **19**: 72.
- McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. (1981). Evaluation of foods. In: *Animal Nutrition*. Longman Group Limited, Longman House, Burnt Mill, Harlow, Essex.
- McMillin, J., Seal, U.S., Kennlyne, K.D., Erickson, A.W. and Jones, J.E. (1974). Annual testosterone rhythm in the adult white-tailed deer (*Odocoileus virginianus borealus*). *Endocrinology* **94**: 1034-1040.

- Milne, J.A., Macrae, J.C., Spence, A.M. and Wilson, S. (1978). A comparison of the voluntary intake and digestion of a range of forages at different times of the year by the sheep and the red deer (*Cervus elaphus*). *British Journal of Nutrition* **40**: 347-357.
- Milne, J.A., Hodgson, J., Thompson, R., Souter, W.G. and Barthram, G.T. (1982). The diet ingested by sheep grazing swards differing in white clover and perennial ryegrass content. *Grass and Forage Science* **36**: 209-218.
- Milne, J.A., Sibbald, A.M., McCormack, H.A. and Loudon, A.S.I. (1987). The influences of nutrition and management on the growth of red deer calves from weaning to 16 months of age. *Animal Production* **45**: 511-522.
- Milne, J.A., Loudon, A.S.I., Sibbald, A.M., Curlewis, J.D. and McNeilly, A.S. (1990). Effects of melatonin and a dopamine agonist and antagonist on seasonal changes in voluntary intake, reproductive activity and plasma concentrations of prolactin and tri-iodothyronine in red deer hinds. *Journal of Endocrinology* **125**: 241-249.
- Mirarchi, R.E., Scanlon, P.F., Kirkpatrick, R.L. and Schreck, C.B. (1975). Variation in androgen levels in white-tailed deer in relation to the antler cycle and breeding season. *Journal of Animal Science* **40**: 185.
- Mirarchi, R.E., Howland, B.E., Scanlon, P.F., Kirkpatrick, R.L. and Sanford, L.M. (1978). Seasonal variation in plasma LH, FSH, prolactin and testosterone concentrations in adult male white-tailed deer. *Canadian Journal of Zoology* **56**: 121-127.
- Moore, G.H. and Brown, C.G. (1977). Growth performance in farmed red deer. *New Zealand Journal of Agricultural Science* **11**: 175-178.
- Moore, G.H., Littlejohn, R.P. and Cowie, G.M. (1988). Liveweights, growth rates, and mortality of farmed red deer at Invermay. *New Zealand Journal of Agricultural Research* **31**: 293-300.
- Moore, G.H., Littlejohn, R.P. and Cowie, G.M. (1988). Factors affecting liveweight gain in red deer calves from birth to weaning. *New Zealand Journal of Agricultural Research* **31**: 279-283.

- Moxham, R.W. and Brownlie, L.E. (1976). Sheep carcass grading and classification in Australia. *Proceedings of the Carcass Classification Symposium*. Adelaide, Australia, May 1976. Sydney, Australia: Australian Meat Board, Paper S4, Pp. 1-15.
- Niezen, J.H., Wilson, P.R., Holmes, C.W., Hodgson, J. and Barry, T.N. (1990). Lactation performance of red deer hinds grazing red clover and perennial ryegrass/white clover pastures. *Journal of Agricultural Science (Cambridge)* (In press).
- Nowak, R. and Rodway, R.G. (1984). Effect of intravaginal implants of melatonin on the onset of ovarian activity in adult and prepubertal ewes. *Journal of Reproduction and Fertility* **74**: 287-293.
- Palsson, H. (1939). Meat qualities in the sheep with special reference to Scottish breeds and crosses. *Journal of Agricultural Science (Cambridge)* **29**: 544-626.
- Parker, W.J. and Ataja, A.M. (1990). Evaluation of intraruminal chromium controlled release capsules for measuring herbage intakes in deer. *Proceedings of the V Asian-Australasian Association of Animal Production Societies Animal Science Congress*. Pp. 123. Taipei, Taiwan.
- Parker, W.J., McCutcheon, S.N. and Garrick, D.J. (1990). The suitability of chromium controlled release capsules for estimating herbage intakes of grazing ruminants. *Proceedings of the Australian Association of Animal Breeding and Genetics* **8**: 151-154.
- Peterson, A.J., Fairclough, R.J. and Smith, J.F. (1978). Radioimmunoassay of androstenedione and testosterone in cow plasma at the time of luteolysis and oestrus. *Journal of Reproduction and Fertility* **52**: 127-129.
- Plotka, E.D., Seal, U.S., Letellier, M.A., Verme, L.J. and Ozaga, J.J. (1981). Effect of pinealectomy on seasonal phenotypic changes in white-tailed deer (*Odocoileus virginianus borealis*). *In: Pineal Function*. Ed. C.D. Matthews and R.F. Seamark. Pp.45-56. Elsevier/North Holland Amsterdam.

- Pollock, A.M. (1975). Seasonal changes in appetite and sexual condition in red deer stags maintained on a six-month photoperiod. *Journal of Physiology (London)* **244**: 95-96P.
- Radcliffe, J.E. (1974). Seasonal distribution of pasture production in New Zealand. II. Southland plains. *New Zealand Journal of Experimental Agriculture* **2**: 341-348.
- Radcliffe, J.E. (1975). Seasonal distribution of pasture production in New Zealand. VII. Masterton (Wairarapa) and Maraekakaho (Hawke's Bay). *New Zealand Journal of Experimental Agriculture* **3**: 259-265.
- Rae, A.L., Brougham, R.W. and Barton, R.A. (1964). A note on liveweight gains of sheep grazing different ryegrass pastures. *New Zealand Journal of Agricultural Research* **7**: 491-495.
- Ralph, C.L., Binkley, S., MacBridge, S.E. and Klein, D.G. (1975). Regulation of pineal rhythms in chickens: Effect of blinding constant light, constant dark, and superior cervical ganglionectomy. *Endocrinology* **97**: 1373-1378.
- Rattray, P.V. and Joyce, J.P. (1974). Nutritive value of white clover and perennial ryegrass. IV. Utilisation of dietary energy. *New Zealand Journal of Agricultural Research* **17**: 401-406.
- Raymond, W.F. and Minson, D.J. (1955). The use of chromic oxide for estimating the faecal production of grazing animals. *Journal of the British Grassland Society* **10**: 282-296.
- Ringberg, T., Jacobsen, E., Ryg, M. and Krog, J. (1978). Seasonal changes in levels of growth hormone, somatomedin and thyroxine in free ranging, semidomesticated reindeer (*Rangifer tarandus tarandus* (L.)). *Comparative Biochemistry and Physiology A*, **60**: 123-126.
- Roberts, A.J. and Reeves, J.J. (1989). Reproductive and endocrine changes in ewes actively immunised against luteinizing hormone. *Journal of Reproductive Immunology* **16**: 302-305.

- Rollag, M.D., O'Callaghan, P.L. and Niswender, G.D. (1978). Serum melatonin during different stages of the annual reproductive cycle in ewes. *Biology of Reproduction* **18**: 279-286.
- Roughan, P.G. and Holland, R. (1977). Predicting in-vitro digestibilities of herbage by exhaustive enzymic hydrolysis of cell walls. *Journal of the Science of Food and Agriculture* **28**: 1057-1064.
- Ryg, M. (1982). Seasonal changes in weight gain, growth hormone, and thyroid hormones in intact and castrated male moose (*Alces alces alces*). *Canadian Journal of Zoology* **60**: 2941-2946.
- Ryg, M. and Jacobsen, E. (1982). Effect of castration on growth and food intake cycles in young male reindeer (*Rangifer tarandus tarandus*). *Canadian Journal of Zoology* **60**: 942-945.
- Ryg, M. and Jacobsen, E. (1982). Effects of thyroid hormones and prolactin on food intake and weight changes in young male reindeer (*Rangifer tarandus tarandus*). *Canadian Journal of Zoology* **60**: 1562-1567.
- Ryg, M. and Jacobsen, E. (1982). Seasonal changes in growth rate, feed intake, growth hormone, and thyroid hormones in young male reindeer (*Rangifer tarandus tarandus*). *Canadian Journal of Zoology* **60**: 15-23.
- Ryg, M. and Langvatn, R. (1982). Seasonal changes in weight gain, growth hormone, and thyroid hormones in male red deer (*Cervus elaphus atlanticus*). *Canadian Journal of Zoology* **60**: 2577-2581.
- Scaramuzzi, R.J., Caldwell, B.V. and Moor, R.M. (1970). Radioimmunoassay of LH and estrogen during the estrous cycle of the ewe. *Biology of Reproduction* **3**: 110-119.
- Schams, D. and Barth, D. (1982). Annual profiles of reproductive hormones in peripheral plasma of the male roe deer (*Capreolus capreolus*). *Journal of Reproduction and Fertility* **66**: 463-468.

- Schanbacher, B.D. and Ford, J.J. (1976). Seasonal profiles of plasma luteinizing hormone, testosterone and estradiol in the ram. *Endocrinology* **99**: 752-757.
- Schulte, B.A., Seal, U.S., Plotka, E.D., Letellier, M.A., Verme, L.J., Ozoga, J.J. and Parsons, J.A. (1981). The effect of pinealectomy on seasonal changes in prolactin secretion in the white-tailed deer (*Odocoileus virginianus borealis*). *Endocrinology* **108**: 173-178.
- Sempéré, A.J. and Boissin, J. (1981). Relationship between antler development and plasma androgen concentrations in adult roe deer (*Capreolus capreolus*). *Journal of Reproduction and Fertility* **62**: 49-53.
- Sempéré, A.J. and Lacroix, A. (1982). Temporal and seasonal relationships between LH, testosterone and antlers in fawn and adult male roe deer (*Capreolus capreolus L.*): a longitudinal study from birth to four years of age. *Acta Endocrinologica* **99**: 295-301.
- Sheath, G.W., Hay, R.J.M. and Giles, K.H. (1987). Managing pastures for grazing animals. In: *Livestock Feeding on Pasture*. Ed. A.M. Nicol. Pp. 65-74. The New Zealand Society of Animal Production. Occasional Publication **10**.
- Simpson, A.M., Suttie, J.M. and Kay, R.N.B. (1984). The Influence of artificial photoperiod on the growth, appetite and reproductive status of male red deer and sheep. *Animal Reproduction Science* **6**: 291-299.
- Spiers, I.B. (1987). The development of the deer industry. *Proceedings of A Deer Course for Veterinarians*. Pp. 1-8. Deer Branch Course # **4**:
- Snyder, D.L., Cowan, R.L., Hagen, D.R. and Schanbacher, B.D. (1983). Effect of pinealectomy on seasonal changes in antler growth and concentrations of testosterone and prolactin in white-tailed deer. *Biology of Reproduction* **29**: 63-71.
- Suckling, F.E.T. (1960). Productivity of pasture species on hill country. *New Zealand Journal of Agricultural Research* **3**: 579-591.

- Suttie, J.M. (1979). Influence of nutrition on growth and sexual maturation of captive red deer stags. *In: Proceedings II International Reindeer/Caribou Symposium*. Roros, Norway. Ed. E. Reimers, E. Gaare and S. Skjenneberg. Direktoratet for vilt og ferskvannsfisk, Trondheim.
- Suttie, J.M., Goodall, E.D., Pennie, K. and Kay, R.N.B. (1983). Winter feed restriction and summer compensation in red deer stags (*Cervus elaphus*). *British Journal of Nutrition* **50**: 737-747.
- Suttie, J.M., Lincoln, G.A. and Kay, R.N.B. (1984). Endocrine control of antler growth in red deer stags. *Journal of Reproduction and Fertility* **71**: 7-15.
- Suttie, J.M., Corson, I.D. and Fennessy, P.F. (1984). Voluntary intake, testis development and antler growth patterns of male red deer under a manipulated photoperiod. *Proceedings of the New Zealand Society of Animal Production* **44**: 167-170.
- Suttie, J.M. and Kay, R.N.B. (1985). Influence of plane of winter nutrition on plasma concentrations of prolactin and testosterone and their association with voluntary food intake in red deer stags (*Cervus elaphus*). *Animal Reproduction Science* **8**: 247-258.
- Suttie, J.M. and Simpson, A.M. (1985). Photoperiodic control of appetite, growth, antlers, and endocrine status of red deer. *In: Biology of Deer Production*. Ed. P.F. Fennessy and K.R. Drew. Pp. 429-432. The Royal Society of New Zealand Bulletin **22**.
- Suttie, J.M., Gluckman, P.D., Butler, J.H., Fennessy, P.F., Corson, I.D. and Laas, F.J. (1985). Insulin-like growth factor 1 (IGF-1) antler-stimulating hormone. *Endocrinology* **116**: 846-848.
- Suttie, J.M. (1987). Deer growth and nutrition. *Proceedings of a Deer Course for Veterinarians*. **4**: 94-108.
- Suttie, J.M., Fennessy, P.F., Gluckman, P.D. and Corson, I.D. (1988). Elevated plasma IGF 1 levels in stags prevented from growing antlers. *Endocrinology* **122**: 3005-3007.

- Suttie, J.M., Fennessy, P.F., Corson, I.D., Laas, F.J., Crosbie, F.S., Butler, J.H. and Gluckman, P.D. (1989). Pulsatile growth hormone, insulin-like growth factors and antler development in red deer (*Cervus elaphus scoticus*) stags. *Journal of Endocrinology* **121**: 351-360.
- Tannenbaum, G.S. and Ling, N. (1984). The interrelationship of growth hormone (GH)-releasing factor and somatomedin in generation of the ultradian rhythm of GH secretion. *Endocrinology* **115**: 1952-1957.
- Thorpe, P.A. and Herbert, J. (1976). Studies on the duration of the breeding season and photorefractorines in female ferrets pinealectomized or treated with melatonin. *Journal of Endocrinology* **70**: 255-262.
- Tizard, I.R. (1977). Humoral immune response. In: *An introduction to Veterinary Immunology*, 1st ed., W.B. Saunders Company, Philadelphia. London. Toronto.
- Ulyatt, M.J. (1971). Studies on the causes of the differences in pasture quality between perennial ryegrass, short-rotation ryegrass and white clover. *New Zealand Journal of Agricultural Research* **14**: 352-367.
- Ulyatt, M.J. and MacRae, J.C. (1974). Quantitative digestion of fresh herbage by sheep (I). *Journal of Agricultural Science (Cambridge)* **82**: 295-307.
- Ulyatt, M.J., MacRae, J.C., Clarke, R.T.J. and Pearce, P.D. (1975). Quantitative digestion of fresh herbage by sheep. IV. Protein synthesis in the stomach. *Journal of Agricultural Science (Cambridge)* **84**: 453-458.
- Ulyatt, M.J., Fennessy, P.F., Rattray, P.V. and Jagusch, K.T. (1980). The nutritive value of supplements. In: *Supplementary Feeding*. Ed. K.R Drew and P.F. Fennessy. Pp.157-184. The New Zealand Society of Animal Production. Occasional publication 7.
- Ulyatt, M.J. (1981). The feeding value of herbage: Can it be improved. *New Zealand Agricultural Science* **15**: 200-205.

- Ulyatt, M.J., Dellow, D.W., John, A., Reid, C.S.W. and Waghorn, G.C. (1986). Contribution of chewing during eating and rumination to the clearance of digesta from the reticulo-rumen. *In: Control of Digestion and Metabolism in Ruminants*. Ed. L.P. Milligan, W.L. Grovum and A. Dobson. Pp. 498-515. Engelwood Cliffs, New Jersey, U.S.A.: Prentice Hall.
- van Landeghem, A.A.J. and van de Weil, D.F.M. (1978). Radioimmunoassay for porcine prolactin: Plasma levels during lactation, suckling and weaning, and after TRH administration. *Acta Endocrinologica* **88**: 653-667.
- Waghorn, G.C. and Barry, T.N. (1987). Pasture as a nutrient source. *In: Livestock Feeding on Pasture*. Ed. A.M. Nicol. Pp. 21-37. The New Zealand Society of Animal Production. Occasional publication **10**.
- Watkins, W.G. and Hudson, R.J. (1984). *In: 63rd Annual Feeder's Day Report*. Pp. 60-61. University of Alberta, Edmonton.
- Webster, J.R. and Barrell, G.K. (1985). Advancement of reproductive activity, seasonal reduction in prolactin secretion and seasonal pelage changes in pubertal red hinds (*Cervus elaphus*) subjected to artificially shortened daily photoperiod or daily melatonin treatments. *Journal of Reproduction and Fertility* **73**: 255-260.
- Webster, J.R., Mackintosh, C.G., Suttie, J.M., Fennessy, P.F., Davis, G.H. and Staples, L.D. (1986). Advancing the breeding season of yearling red deer hinds with melatonin. *Proceedings of the Endocrine Society of Australia* **29** (Supplement 2): Abstract E5.
- West, N.O. and Nordan, H.C. (1976a). Hormonal regulation of reproduction and the antler cycle in the male Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Part I. Seasonal changes in the histology of the reproductive organs, serum testosterone, sperm production, and the antler cycle. *Canadian Journal of Zoology* **54**: 1617-1636.

- West, N.O. and Nordan, H.C. (1976b). Hormonal regulation of reproduction and the antler cycle in the male Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Part II. The effects of methallibure and hormone treatment. *Canadian Journal of Zoology* **54**: 1637-1656.
- Whitehead, P.E. and McEwan, E.H. (1973). Seasonal variation in the plasma testosterone concentration of reindeer and caribou. *Canadian Journal of Zoology* **51**: 651-658.
- Widdup, K.H. and Williams, W.M. (1982). Evaluation of white clover (*Trifolium repens* L.) populations at Gore. *New Zealand Journal of Experimental Agriculture* **10**: 43-47.
- Wilson, P.R., Walker, I.H., Middleburg, A., Bond, D. and Staples, L.D. (1989). Advanced calving; field trials with 'Regulin' implants. *Proceedings of a Deer Course for Veterinarians*. **5**: 28-31.
- Wilson, P.R. (1989). Advanced calving in deer: Practical aspects. *Proceedings of a Deer Course for Veterinarians*. **6**: 54-65.
- Wilson, P.R., Bond, D., Middleberg, A., Walker, I.H. and Staples, L.D. (1990). Field evaluation of melatonin implants to advance the onset of oestrus in first calving red deer hinds. *New Zealand Veterinary Journal*. (Submitted).
- Wilson, P.R. and Staples, L.D. (1990). Further studies of advancing the breeding season using melatonin implants in farmed red deer: two dosage regimes and "stage effect". In: *Biology of Deer Production*. (In Press).
- Wislocki, G.B., Aub, J.C. and Waldo, C.M. (1947). The effects of gonadectomy and administration of testosterone propionate on the growth of antlers in male and female deer. *Endocrinology* **40**: 202-224.
- Wood, A.J., Cowan, I.McT. and Nordan, H.C. (1962). Periodicity of growth in ungulates as shown by deer of the genus *Odocoileus*. *Canadian Journal of Zoology* **40**: 593-603.

Woodford, K.B., Dunning, A. and Winch, J.B. (1990). Production of red deer in a subtropical environment. *Proceedings of the Australian Society of Animal Production* 18: 436-439.

Wurtman, R.J., Axelrod, J. and Kelly, D.E. (1968). Light, the pineal, and biological rhythms. In: *The Pineal*. Academic, New York, Pp. 108-140.

Yerex, D. and Spiers, I. (1990). Financial aspects. In: *Modern Deer Farm Management*. GP Books, Government Printing Office, Private Bag, Wellington, New Zealand.