VENISON AND VELVET PRODUCTION FROM RED AND HYBRID DEER BY ONE YEAR OF AGE

A Thesis Presented in Partial Fulfilment of the
Requirements for the Degree of Master of
Agricultural Science in Animal Science
at Massey University

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1996

ABSTRACT

BYENG-RYEL MIN, Department of Animal Science, Massey University, Palmerston North, **New Zealand.** THE EFFECTS OF GRAZING CHICORY (*Cichorium intybus*) AND LOTUS CORNICULATUS UPON VENISON & VELVET PRODUCTION BY ONE YEAR OF AGE.

A grazing experiment was conducted at Massey University Deer Research Unit, Palmerston North, New Zealand during 1995, to study the effects of grazing chicory (*Cichorium intybus*), *Lotus corniculatus* and perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture upon the growth, voluntary feed intake (VFI), venison and velvet production of red and hybrid (0.75 red;0.25 elk) deer from weaning to slaughter at one year of age. The animals were randomly allocated to graze either chicory, lotus or pasture and grazed these forages during autumn and spring using a rotational grazing system, with each group balanced for genotype and sex. All groups were joined to graze pasture during winter, when chicory and lotus were dormant.

1. Few animals attained the target slaughter weight (50kg carcass or greater) when grazing pasture and spiker velvet antler weight was low at approximately 0.2 kg per stag.

2. In this study the greatest advantages obtained for specialist forages were for chicory. Carcass weight of deer grazing chicory was higher than for deer grazing pasture, due mainly to increasing autumn LWG and dressing-out percentage at slaughter, with a smaller response in spring LWG. The largest carcass weights were consistently obtained from hybrid stags grazing on chicory, with values for red deer and hybrid stags being 56.0 and 59.3 kg when grazed on chicory and 48.6 and 53.3 kg respectively when grazed on pasture. Chicory had a higher organic matter digestibility (OMD) and VFI than pasture during autumn but similar values in spring, accounting for its autumn growth stimulation. Carcass subcutaneous fat depth (GR) was higher for deer grazing chicory than pasture, but after being adjusted to equal carcass weight, there was no difference in GR measurement.

Relative to deer grazing on pasture, grazing on chicory increased total spiker velvet antler production (323 v 225 g/stag), by advancing the dates of pedicle initiation (18 days), velvet antler initiation (24 days), and first velvet cutting (17 days) and increasing the rate of velvet antler length growth. Initiation of velvet growth was correlated with liveweight, with each 10 kg increase in liveweight advancing the dates of pedicle initiation, commencement of velvet growth and first velvet cutting by 10, 18 and 13 days respectively. Correction of the data to equal liveweight removed a component of the advancement produced from feeding on chicory, but an effect still remained due to chicory feeding *per se*. It was concluded that grazing chicory not only increased carcass weight (especially in hybrid stags), but also increased velvet antler production. This was achieved by increased VFI and increased OMD of chicory in autumn, relative to deer grazing pasture, and probably by increased absorption of protein and minerals in deer fed chicory.

3. OMD of lotus was higher than that of pasture during autumn, but not in spring. The OMD of either chicory or lotus showed little change between seasons, but pasture changed with the season, being of lowest OMD in autumn and highest OMD in spring.

4. Responses to deer grazing lotus were limited by the reduced number of grazing days that could be achieved, due to problems in lotus establishment. In spite of these problems, grazing lotus (48 gCT/kg OM) did increase the LWG of stags during autumn (248 v 176 g/day) and increased the efficiency of growth in spring, with LWG being similar to deer grazing pasture, but VFI being lower (1.53 v 2.00 kgOM/day) for lotus compared to pasture. Although deer grazing lotus had a similar carcass weight compared to deer grazing pasture, dressing-out percentages of deer grazing lotus were higher than that of deer grazing pasture (56.4 *v* 53.2 %). The carcass GR tissue depth of deer grazing lotus had similar values compared to pasture. There was no interaction between forage and genotype for carcass weight and dressing out percentage. Stags grazing lotus did not show any advancement in dates of pedicle initiation, velvet antler initiation and weight of velvet production compared to stags grazing pasture.

5. Total condensed tannin (CT) concentration in lotus was 48 and 13 g/kgOM in hand plucked and oesophageal fistulae (OF) extrusa samples respectively. Most CT in hand plucked lotus samples was extractable, with much smaller amounts being protein-bound or fibre-bound. Extractable CT was not detected in lotus OF extrusa samples, and the concentration of protein-bound and fibre-bound CT remained similar to hand plucked samples. Therefore, after chewing during eating, the extractable component of CT in lotus feed could not be extracted and detected by the Butanol/HCl analysis methods and may have been bound to deer salivary proteins. Total CT in both hand plucked and OF extrusa samples was 3.1 v 5.8 g/kgOM for chicory and 0.3 v 1.5 g/kgOM for pasture. As a result, chewing (in OF samples) did not reduce the CT content of pasture or chicory. This may be due to the low concentration of extractable CT (and high proportions of bound CT) in these forages, which may have limited access for the deer salivary CT-binding proteins.

6. Overall it was concluded that chicory was of very high feeding value (FV) and had excellent nutritional advantages for increasing deer production. However, crops of chicory need to have specialised grazing management to increase persistency. New chicory cultivars need to be selected to increase persistency and to reduce reproductive stem formation during summer. Effects of protein supply on initiation of pedicle and velvet antler development in weaner stags grazing fresh forages also needs to be studied.
The small responses obtained in the present study give some indication that the CT content of *Lotus corniculatus* may have a number of values for improving the efficiency of growth in young deer. Further experiments are needed in this area.

ACKNOWLEDGMENTS

I shall always be grateful to my chief supervisor, Professor T.N. Barry, Department of Animal Science, Massey University, for his constant inspiration, valuable guidance, patience and encouragement throughout this study.

I also express my special thanks to my co-supervisors, Associate Professor P.R. Wilson, Department of Veterinary Clinical Science, and Dr. P.D. Kemp, Department of Plant Science, Massey University, for their guidance, criticism and contribution of knowledge. Thanks are extended to Dr, K.J. Stafford, Department of Veterinary Clinical Science, and Mr T.G. Harvey, manager, Animal Research Unit, Massey University for their advice and guidance.

I wish to thank Professor S.N. McCutcheon and Professor H.T. Blair, Heads of Department of Animal Science, and the post graduate committee of Massey University for allowing me to study in the Department of Animal Science, Massey University. The guidance of Massey University Animal Ethics Committee in approving the experimental protocols involving the use of animals is acknowledged.

The advice of Professor D.J. Garrick and Dr. P.C.H. Morel, Department of Animal Science, Massey University, on statistical analysis is appreciated. Dr. R.W. Purchas, Department of Animal Science, Massey University, is acknowledged for his advice on carcass measurement.

I sincerely acknowledge the technical assistance in various ways from:

Mr G.S. Purchas; Mr C.W.H. Howell; Ms F.S. Jackson; Mr J.A. Bateson; Miss M.L. Zou; Miss M.F. Scott, Department of Animal Science, Massey University.

I would like to express my appreciation to "C. Alma Baker Trust" for providing a Scholarship towards my stipend and tuition fees. Financial support from Wrightson Seeds towards my research costs is very much appreciated.
I would like to express my appreciation to Mrs B.J. Purchas and Mrs Annette Barry for their friendship to my family and me.

The opportunity to work on this thesis was provided by the Department of Animal Science, Massey University.

Finally, I would like to express my special thanks to my wife, H.Y. Min, my daughter, Y.K. Min. for their patience, encouragement and support during my Masters study. This thesis is dedicated to them.

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LIST OF ABBREVIATIONS

ADF	acid detergent fibre
cm	centimetre
CT	condensed tannin
D	digestibility
DM	dry matter
DMI	dry matter intake
DOMI	digestible organic matter intake
EAA	essential amino acids
FO	faecal output
FOR	fractional outflow rate
FV	feeding value
GR	a measurement of total soft tissue depth over the 12th rib at a point 11 cm from the carcass line
GIB	Game Industry Board
h	hours
ha	hectare
k_f	efficiency of utilisation of ME for fattening
k_g	efficiency of utilisation of ME for growth
k_l	efficiency of utilisation of ME for lactation
k_m	efficiency of utilisation of ME for maintenance
kg	kilograms
Ltd	limited
LWG	liveweight gain
ME	metabolisable energy
min	minute
MJ	megajoule
N	nitrogen
NAN	non-ammonia nitrogen
ND	not determined
NDF	neutral detergent fibre
NEAA	non-essential amino acids

NH3	ammonia
NV	nutritive value
NZ	New Zeland
OM	organic matter
OMD	organic matter digestibility
OMI	organic matter intake
SD	standard deviation
SE	standard deviation
t	tonne
UK	United Kingdom
USA	United States of America
VFA	volatile fatty acid

CHAPTER 1

LITERATURE REVIEW

1. INTRODUCTION

This review, based on published literature, summaries data on the classification, distribution, seasonality, feeding behaviour, deer farming, nutrient requirements, forage feeding value and venison production from farmed deer. A comparison of tropical and temperate deer, and a limited comparison with sheep and other domesticated livestock, will also be made. Finally, detailed consideration is given to venison production using special forage diets such as chicory and *Lotus corniculatus*.

1.1. CLASSIFICATION AND DISTRIBUTION OF TEMPERATE AND TROPICAL DEER

There are 42 species (Whitehead, 1993) of deer worldwide, grouped into 16 genera which have adapted to a wide variety of environments from the Arctic circle to the tropics (Table 1). The capacity to adapt to these environmental changes and the resulting effects on deer are reflected in their biology at species, subspecies and population levels (Tudge, 1993).

Deer belong to the order Artiodactyla (ungulates), suborder Ruminantia and family Cervidae (Van Soest, 1994). The deer of the world are divided into two families MOSCHIDAE (non-antlered artiodactyls) and CERVIDAE (antlered artiodactyls), which are further divided into seven sub-families (Table 1;Whitehead, 1993). Family Cervidae contains 16 genera which consist of about 41 species and about 196 subspecies (Whitehead, 1993), with wide geographical and ecological distribution in their native ranges and containing the most popular farmed species. Red deer, wapiti and fallow deer are farmed in significant numbers, and rusa, sika, sambar and Pere David's deer are also farmed, but to a much lesser extent (Haigh and Hudson, 1993; Wilson, 1991).

Of the 42 existing species of deer, 15 species live primarily in temperate and cold zones (30^{o}- 80^{o} latitude). Temperate species include reindeer/caribou, musk, huemul, and pudu deer. Twenty five species live in the tropical and subtropical zones (0^{o}-30^{o} latitude) including sambar, swamp, Elds, axis (chital), rusa, hog, muntjac, white-tailed, marsh, pampus, brocket, huemul, and pudu (Lincoln, 1992). Although most species can be clearly defined as adapted to either a tropical/subtropical or temperate/cold climate, there are some species such as the American white-tailed deer whose natural range spans both tropical and cold climates (Woodford, 1993).

Tropical species are mostly concentrated in Southern Asia, with sambar being the largest and most widespread in its distribution (Whitehead, 1993). The most successful introductions of axis (chital) deer have been to Hawaii, Texas and Argentina (Whitehead, 1993). The main contributing factor in the successful naturalization of axis deer in Hawaii may be that the latitude of 19^{o} and 22^{o} N is the same latitude as central India.

New Zealand (NZ), Australian and British experience has shown that deer have a suitable temperament for farming, can be easily managed and handled in groups, reproduce well in captivity, and have diseases that can be effectively controlled. Cervidae have a history of centuries of economic association with man in many countries as food suppliers, for recreation, as producers of hides and as a source of traditional medicinal products.

Table 1. World distribution and status of 42 species (39 species for Klein, 1992) in 17 genera

Family/subfamily Common name	Scientific name	Distribution natural (introduced & status)
CERVIDAE		
HYDROPOTINAE		
Water deer (Chinese water-deer)	*Hydropotes inermis*	China, Korea (England)
MUNTIACINAE		
Indian muntjac	*Muntiacus muntjac*	India, Sri Lanka, Burma, SW China, SE Asia including Borneo (England)
Reeve's muntjac	*M reevesi*	E. China, Formosa (England)
Black muntjac	*M. crinifrons*	C. China (R)
Fea's muntjac	*M. feae*	Thailand, S. Burma (E)
Roosevelt's muntjac	*M. rooseveltorum*	N Vietnam
Tufted deer	*Elaphodus cephalophus*	South & SE China, NE Burma
CERVINAE		
Fallow deer	*Dama dama*	Europe, Asia Minor, Iran (Australia, NZ)
Chital (Axis deer	*Axis axis*	India , Sri Lanka (Australia, Hawaii)
Calamian deer	*A.. calamianeusis*	Calamian Is.-Philippines (T)
Thorold's deer	*Cervus albirostris*	Tibet (R)
Swamp deer	*C. duvauceli*	N & C India, S Nepal, Scandinavia, Europe, N Africa, Asia, Minor, Tibet, Kashmir, Parkestan, Afghanistan, (Australia, NZ) (E)
Red deer	*C. elaphus*	Sweden, Norway, Scotland, Europe, Spain, Corsica & Sardinia, North Africa, Asia, Kashmir, China, Tibet, Russia, Afghanistan
Wapiti	C. *canadensis*	W North America, Tien Shan, Mts to Manchuria & Mongolia, Kansu, China (NZ)
Eld's deer	*C. eldi*	E India, Thailand, Vietnam, Hainan Is., Burma (E)
Sika deer	*C. nippon*	Japan, Vietnam, Taiwan, Manchuria, N & SE China, Korea (NZ, United states, British Isles) (E)
Rusa deer	*C. timorensis*	Indonesian Archipelago (Australia, NZ, Fiji, New Guinea)
Sambar	*C. unicolo*r	SE Asia- Philippines to Sri Lanka (Australia, NZ)
Pe're David's deer	*Elaphurus davidiensis*	China (England) (E)
ODOCOILINAE		
Mule deer & Black-tailed deer	*Odocoileus hemionus*	W North America, Central (E) America (Hawaii)
White-tailed deer	*O. virginianus*	N, C & S America to Peru & Brazil, (NZ, Finland)
Roe deer	*Capreolus capreolus*	Europe, Asia Minor, Siberia, N Asia,Manchuria, N China, Korea.
Marsh deer	*Blastocerus dichotomous*	C Brazil & N Argentina (E)
Pampas deer	*Ozotoceros bezoarticus*	Brazil, Argentina, Paraguay, Bolivia (E)
Chilean huemul	*Hippocamelus bisulcus*	Chile, Argentina (V)
Peruvian huemaul	*H. antisensis*	Peru, Ecuador, Bolivia, N Argentina (T)
Red brocket	*Mazama americana*	C & S America-Mexico to Argentina
Little red broket	*M. rufina*	Venzuela, Ecuador, SE Brazil
Dwarf brocket	*M. Chunyl*	N Bolivia, Peru
Southern pudu	*Pudu pudu*	Chile, Argentina (E)
Northern pudu	*P. mephistophiles*	Ecuador, Peru, Columia (U)
ALCINAE		
Moose Elk	*Alces alces*	N Europe, Siberia, Mongolia, Manchuria, (NZ), Alaska, Canada, N USA
RANGIFERINAE		
Reindeer/caribou	*Rangifer tarandus*	Scandinavia, Svalbard, USSR, N China, Alaska, Canada, Greenland (S Georgia, Scotland)
MOSCHIDA		
MOSCHINAE		
Siberian musk deer	*Moschus sibiricus*	C & E Siberia, N Mongolia, Korea, Sakhalin
Southern musk deer	*M. moschiferus*	C & SW China, N India Pakistan, Tibet (V)
Berezovski musk deer	*M. berezovskii*	Szechwan & Kansu, China (T), W Nepal

Status; R; rare, E; endangered, T; threatened, V; vulnera, U; undetected. From Whitehead, 1993; Klein, 1992

1.1.1. HYBRIDIZATION

Recent research in NZ has focused on the reproductive manipulation of deer farming through hybridization, inducing twinning, altering sex ratios and advancing the calving season (Pearse, 1992).

Hybridization between deer of the same species but different subspecies, has frequently been recorded among wild or feral populations such as red deer with wapiti in NZ, and elsewhere (British Isles, Australia and USSR). There have also been attempts to exploit the potential of hybrid some other species of deer for farming such as Pere David's deer x red deer in NZ (Fennessy and Mackintosh, 1992), the white-tailed deer in North America, the roe deer in Europe, and both rusa and chital deer in the southern states of Australia (Woodford, 1993). Hybridization between a sambar stag and rusa or red hinds (this new breed has been named "Samson" deer by Whitehead, 1993) may be of potential significance for commercial deer farming in NZ and some other countries. A summary of results of successful hybridization between species and genera is shown in Table 2.

Table 2 Summary of results of successful hybridization between species (Whitehead, 1993).

Between genera	Between species
Axis x White-tail deer	Red x Wapiti
Axis x Red deer	Hangul x Sika deer
Axis x Swamp deer	Sambar x Rusa deer
Hog x Roe deer	Philippine spotted x Basilan deer
Hog x Fallow deer	Indian Muntjac x Reeves's Muntjac
Red x Pe're David's deer[1]	White tail x Mule deer
	N White tail x Columbian blacktail
	Red x Sambar deer

[1] Fennessy & Mackintosh, 1992; Krzywinski, 1993.

1.2. SEASONALITY OF TEMPERATE & TROPICAL DEER

Temperate deer have very strong seasonal patterns of voluntary feed intake (VFI), body growth rates, metabolic rate and reproductive activity (Barry *et al.*, 1991).

To adapt to a changing temperate climate and seasonal variation in the quality and quantity of forage available to them, temperate deer have evolved a pronounced yearly seasonal physiology with a neuroendocrine mechanism which relays effects of changes in day length (Suttie & Corson, 1991; Lincoln, 1992). Although the species adapted to tropical and subtropical climates have a less marked seasonal physiology, they still show some seasonality (Sadleir, 1987; Mylrea, 1991; Semiadi *et al.,* 1995b).

1.2.1. VOLUNTARY FEED INTAKE

Forage intake is a function of digestibility, which primarily reflects reticulo-ruminal rates of fermentation and passage characteristics in the gut (Meissner and Paulsmeier, 1995). Digestibility also has a major influence, especially on the M/D value (MJ ME/kg DM) of pasture (Poppi *et al.*, 1987). With forages intake is often expressed per unit of metabolic body weight ($BW^{0.75}$) (Demment and VanSoest, 1985).

In temperate deer there is a markedly seasonal pattern of voluntary feed intake (VFI), with the highest intakes shown in spring and early summer and the lowest intakes in winter (Domingue *et al.*, 1991 a; Semiadi *et al.*, 1995b), as shown for red deer in Fig. 1a. Food intake increased briefly, before declining again in mid winter.

A decline in VFI of 32% in red hinds and 57% in red stags coincided with the breeding season in autumn (Semiadi *et al.*, 1995b), even when a high quality pelleted feed was provided *ad libitum* (Fennessy and Milligan, 1987). This was possibly due to high plasma testosterone concentration during the rut in stags (Suttie *et al.*, 1987, Semiadi *et al.*, 1995b).

This seasonal pattern of VFI is pronounced in two year old and older stags (Fennessy and Milligan, 1987) and it also occurs in younger males and to a lesser extent in females (Suttie *et al.*, 1989). The timing of these cycles can be adjusted by changing photoperiod (Suttie *et al.*, 1992) and by administration of melatonin (Asher *et al.*, 1988).
However, sambar deer showed weak seasonal patterns of VFI (Fig. 1a) with maximum feed intake in autumn and minimum values in spring. The period of low VFI in sambar was longer than in red deer. Grimaud *et al.,* (1994) reported that VFI in rusa deer in New Caledonia was highly correlated among animals of both sexes and was not influenced by daylight duration.

Similar seasonal variation of food intake has been recorded in other Cervids such as mule deer (Wood *et al.*, 1962), reindeer (McEwan and Whitehead, 1970), moose (Gasaway and Coady, 1974), roe deer (Drozdz *et al.*, 1975), and wapiti (Jiang and Hudson, 1992). Food intake for wapiti in winter pen trials were equal to, or below maintenance requirements (32 g/kg$^{0.75}$/day in herbage and 37 g/kg$^{0.75}$/day in pellets of digestible dry matter). Intakes increased threefold on spring pasture to 105 g/kg$^{0.75}$/day, and the animals rapidly gained weight (Jiang and Hudson, 1992).

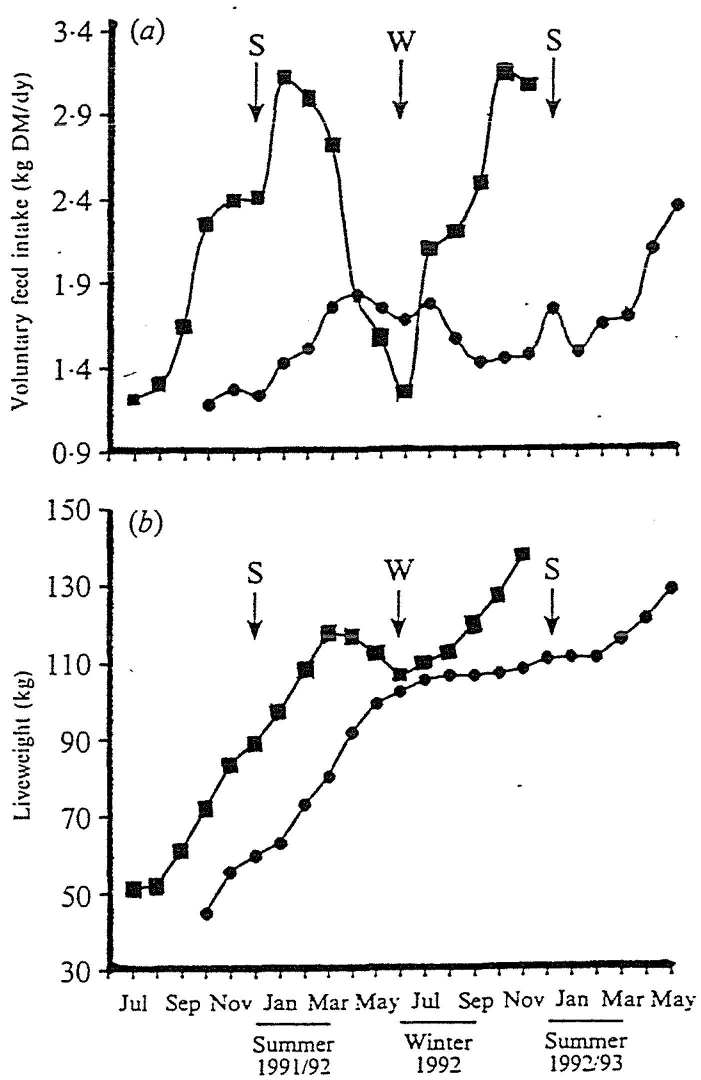

Figure 1 Seasonal changes in (a) voluntary feed intake (kg DM/day) and (b) liveweight in young red deer stags (temperate) (■) and sambar deer stags (tropical) (•) individually fed a pelleted concentrate diet under indoor conditions. The diet contained 29 g N/kg DM and 12.2 MJ ME/kg DM. Red deer were aged 8 months and sambar deer 6 months when the study commenced. ↓S, summer solstice; ↓W, winter solstice (Southern Hemisphere; latitude 40°S; natural daylength) (Semiadi *et al.*, 1995b).

1.2.2. DIGESTIVE PROCESSES

Feed particulate matter must be reduced to below a critical particle size before it can leave the rumen (<1mm) for deer and sheep (Domingue *et al.*, 1991b; Ulyatt *et al.*, 1986), and reduction to this size occurs through chewing during both eating and ruminating (Ulyatt *et al.*, 1986). Because no further particle reduction occurs after leaving the rumen (Poppi *et al.,* 1980), faeces particle size can be used as an index of particle size of material leaving the rumen.

Although there were seasonal changes in VFI in red deer, apparent digestibility did not change between winter and summer, even through there was a marked increase in feed intake from winter to summer (Milne *et al.*, 1978; Barry *et al.*, 1991, Freudenberger *et al.*, 1994a). Recent studies have identified the mechanism as increased rumen mean retention time (MRT) and increased rumen ammonia production in summer compared to winter (Domingue *et al.*, 1991; Freudenberger *et al.*, 1994a), showing that, at least in red deer, there are also seasonal cycles in digestive function.

Apparent rumen MRT of particulate matter (1/lignin rumen fractional disappearance rate: FDPR) can be calculated as 29.2 and 34.8 h for winter and summer in deer fed lucerne chaff (Freudenberger *et al.*, 1994a). Similar values of 28.8 h for winter and 36.1 h for summer can be calculated from Domingue *et al.,* (1991b) for true particulate MRT on a similar diet.

The mechanism of the increased rumen ammonia (NH_3) production in summer may be one of the components responsible for maintaining fibre digestion as VFI increases during summer. A large increase in rumen pool size (51%) and rumen retention time in summer than in winter may allow longer time for rumen microbial fermentation and account for the increased rumen ammonia irreversible loss rate (IRL) (Domingue *et al.*, 1991a). The increased rumen NH_3-IRL presumably involves increased recycling of N into the rumen during summer, as dietary N intakes were similar. More information is needed on digestive processes, rumen dynamics, absorption and utilization of individual nutrients.

Digestive kinetics studies for three ruminants species in wapiti (mixed feeders), moose (browsers) and cattle (grazers) showed no differences in the potentially digestible fraction between seasons (summer & winter) for grass, browse, and lucerne diets (Renecker and Hudson, 1990). However, as a proportion of body weight, ruminal liquid volumes and rumen retention times of particulate matter were generally greatest for moose particularly in winter and on grass diets whereas wapiti had the lowest or shortest values.

Spalinger *et al.*, (1993) concluded that rumen function of deer can be adapted to both diet quality and availability in elk and mule deer experiments. Switching elk and mule deer between alfalfa and pea hays resulted in a significant drop in VFI and rumen dry-matter fill, but no changes in liquid volumes, particle breakdown rates and passage rates.

In tropical species, sambar deer slightly increased VFI from summer to winter, with an increase in chewing frequency. One of the major differences between sambar deer and red deer was rumination behaviour, with sambar deer spending more time ruminating (per gDMI), having shorter time (sec) per ruminated bolus than red deer (Semiadi *et al.*, 1994). Such differences might be expected to lead to a more efficient rate of particle break down during rumination in sambar deer. Digestive function in sambar deer, and how this differs from red deer, requires further study.

Freudenberger *et al.,* (1994b) also found that relative to winter, both summer-*ad lib.* and summer-restricted feeding increased rumen total VFA concentration and rumen VFA pool size (per Kg $W^{0.75}$) in deer fed lucerne chaff. The increased rumen VFA pool size may indicate increased VFA production during summer. Deer appear to show a seasonal increase in rumen total VFA pool size during summer that is independent of changes in

VFI. The mechanism of seasonal change in rumen VFA production and rumen liquid volume, related to VFI, requires further research.

1.2.3. GROWTH PATTERN AND GROWTH RATE

Growth of young red deer stags is known to be highly seasonal (Barry *et al.*, 1991), with maximum growth occurring in summer and minimum growth occurring in winter, as shown in Fig. 1b. Red deer stags showed a slowing growth rate in their first winter, and increasing liveweight gain (LWG) over their second spring and summer (Fig.1b). Seasonal patterns of LWG in red and sambar deer indicated that red deer showed maximum LWG (191-348 g/day) in spring/summer and minimum LWG in winter (4-23 g/day) (Semiadi *et al.*, 1995b). In contrast, highest growth rates in sambar deer occurred in autumn (254 g/day LWG in hinds & 260 g/day in stags), and lowest growth rates in spring (25 g/day), with the increase being especially large for stags. For both sambar and red deer species, liveweight gain (g) per day per kg$W^{0.75}$ was strongly related to ME intake (MEI), with growing sambar deer tending to have lower ME requirements for both maintenance and gain than for growing red deer. Seasonal growth pattern of young red deer was also related to photoperiodic timing of growth via insulin-like growth factor 1 (IGF1) (Suttie and Webster, 1995) and melatonin levels (Barry *et al.*, 1993).

Red deer yearling stags were more seasonal than hinds because of a high pressure to grow rapidly to enter the breeding population as early as possible (Suttie and Webster, 1995). On average, growth rate of young red deer stags was higher than that of females by 8 % in autumn, 76 % in winter, and 48 % during spring-summer (Moore *et al.*, 1988a). Webster *et al.*, (1992) noted a dramatic increase in the weight of the reproductive tract and liveweight between 12 and 15 months of age which coincided with the seasonal rut, with increased depositional subcutaneous and depot fat, as well as increased neck muscle mass. On the other hand, during the rut (March-May), liveweight in red deer decreased by as much as 7% in stags and 3% in hinds. During the rut and over winter (15 to 21 months of age) male deer reduce feed intake with increasing rutting activities, with the resultant negative energy balance leading to very rapid mobilisation of fat reserves and decrease in reproductive tract and liveweight (Jopson, 1993). In contrast, seasonal weights of the hind are mostly related to pregnancy and the demands of lactation, although pregnant hinds may lose up to 10% of their autumn weight by spring (Haigh and Hudson, 1993).

Comparative studies show that the recorded winter/summer growth ratios vary greatly from -0.11 for moose to 0.81 for rusa deer (Suttie and Webster, 1995). In tropical deer species, yearling male rusa deer grew linearly, but reindeer in arctic conditions appeared to grow more rapidly during shorter summer periods than during winter. This suggests that latitude of origin may play a role in determining relative growth pattern and its rate via the amplitude of the summer elevation of IGF 1. Higher latitudes (in arctic deer) deer grow faster in summer than in winter due to an adaptive strategy to limit growth to periods of predictable food abundance related with long periods of daylight during summer and long winter darkness (Suttie and Webster, 1995). Photoperiodic effects are believed to be the major cause in slowing growth during winter and increasing growth in spring (Suttie *et al,* 1989).

Seasonal growth patterns have been studied in temperate, arctic and boreal deer so far studied, including red deer (Simpson *et al.*, 1983), fallow deer (Asher *et al.*, 1993), wapiti (Hudson *et al.*, 1985), roe deer (Drozdz *et al.*, 1975), reindeer (Ryg and Jacobsen, 1982) and caribou (McEwan and Whitehead, 1970).

1.2.4. REPRODUCTION

It is generally recognised that entrainment of seasonal reproductive cycles in temperate deer is effected by endogenous recognition of photoperiodic changes, with the majority of temperate species initiating mating activity during decreasing day-length of late summer and autumn (Lincoln and Short, 1980). Growth and casting of the antlers is associated with the cycle of growth and secretion of testosterone by the testis (Lincoln, 1971: Bubenik *et al.* 1975), with conception occurring in autumn and parturition in summer (Chapman and Chapman, 1975). The onset of first oestrus marks the beginning of the rut, which occurs in late March or early April in NZ. Duration of the oestrus cycle varies from 18 to 21 days in red deer (Adam *et al.*, 1985), 21-22 days in fallow deer (Asher, 1985), 22-29 days in white- tailed deer (Thomas and Cowan, 1975), and 17-21 days in chital deer (Chapple *et al.*, 1993).

Prior to the rut, the testes progressively develop and testosterone secretion and spermatogenesis increase to reach reproduction levels during the rut associated with strong reproductive behaviour (Loudon and Brinklow, 1992). The pineal gland produces melatonin during the hours of darkness, which controls hypothalamic release of gonadotrophin-releasing hormone (GnRH) and various metabolic hormones. Seasonal breeding is a manifestation of changes in the release of lutenizing hormones (LH) and follicle-stimulating hormone (FSH) arising from changes in secretion of GnRH (Lincoln & Short, 1980).

Administration of melatonin in feed or by implant has been used to manipulate the timing of physiological cycles, particularly advancing breeding and calving dates (Lincoln *et al.* 1984; Asher *et al.* 1993). The maximum degree of calving advancement so far achieved by melatonin treatment has been 54 days for red deer and 56 days for fallow deer (Asher *et al.*, 1993).

However, species of tropical origin often exhibit reverse seasonality (i.e. spring mating and autumn/winter calving in javan rusa deer and Eld's deer), long breeding season (e.g. axis and sambar deer) or aseasonality (e.g. calving year round in Moluccan rusa deer) (Loudon and Curlewis, 1988; Semiadi, *et al.*, 1993b; Mackenzie, 1985; Woodford and Duning, 1992; Monfort *et al.*, 1993; Mylrea, 1991). The calving pattern of sambar in NZ shows a peak in autumn (April-May) with a very large spread (Semiadi, 1993). Sambar deer had a wide spread of calving in Nepal (Mishra, 1982) or no distinct seasonality in reproduction in Southern India (Varman and Sukumar, 1993).

Loudon & Curlewis (1988) found that chital (*Axis axis*) stags in UK did not respond to melatonin treatment and calved throughout the year. Treatment of axis deer hinds with exogenous melatonin gave resulted in continuous oestrus cycles throughout the year and hastened antler casting in stags, indicating photoperiod responsiveness in a species considered to exhibit limited seasonality in both tropical and temperate environments (Mylrea, 1991). Javan rusa deer appear to initiate mating activity in response to increasing daylength in spring, thus calving in autumn/winter (Monfort *et al.*, 1993). Thus, there is some evidence that tropical species may also perceive and respond to changes in photoperiod, although in a markedly different manner than temperate species.

1.2.5. ANTLER GROWTH PATTERN AND VELVET PRODUCTION

Antlers may be thought of as growing in 4 phases (Fennessy and Suttie, 1985):

1. The pedicle (the antler bud) grows under the control of testosterone.
2. When the pedicle has reached about 5-6 cm the velvet antler develops with decreased plasma testosterone secretion and increased plasma levels of insulin-like growth factor.
3. The antler is cleaned of velvet while testosterone level are high.
4. After testosterone levels have fallen, the antler is cast.

Antler development cycles are closely related to the activity of the reproductive system and secretion of various hormones (Bubenik, 1990). These antler development cycles are associated with various hormones either acting indirectly on antlerogenesis (e.g. prolactin, growth hormone, GnRH, LH, glucocorticoids etc.) through a general metabolic effect or stimulating other hormones acting directly (e.g. androgen, sterogens, somatomedins, T_3)

on the target tissue of the pedicle, growing antler tissues, or on the antler nerves.The hormones melatonin, prolactin and estradiol synchronize the timing of antler development cycles (Bubenik, 1990). Treatment with the pineal hormone melatonin can disrupt the normal timing of seasonal antler growth in deer (Bubenik, 1983). On the other hand, the nerve supply plays a role in determining antler size (Li et al., 1993).

Development of both the pedicle and the first antler in red deer stags are delayed if animals are on a low plane of nutrition (1.1 vs 0.2 kg/day) (Table 3). The growth of both the pedicle and the first antler in the high plane of nutrition occurried much earlier than in the restricted group, but each stage happened when the stags had attained the same body weight, the attainment of which was hastened by a high plane of nutrition. Likewise, antlers were initiated at similar body weights, but at a significantly ($P<0.025$) earlier age in high plane stags. The high-plane supplemental feed group had heavier, longer, antlers with more points than the low plane group (Suttie and Kay, 1982). Therefore, the development of the pedicle and the first antler appear to more closely related to the nutritional status of deer as reflected by body weight than to the prevailing photoperiod. However, antler casting is strongly dependent on an increasing photoperiod for stimulation (Suttie and Kay, 1982). Fennessy and Suttie (1985) reported that pedicle development is positively correlated with body weight and is dependent on the level of nutrition.

In red deer stags, antler weights increased at a rate of 0.1-0.2 kg/10 kg liveweight (Fennessy, 1989) or 62 g for a 10 kg increase in late summer liveweight (Moore *et al.* 1988b). There is a generally positive relationship between body weight and hard antler weight (Audige', 1995; Muir and Sykes, 1988). Thus, nutrition during early growth may influence antler weight since, if sufficiently restricted, antler weight may reduce the rate of attainment of antler weight and ultimate mature size of the antler (Muir and Sykes, 1988). It has been shown that good nutrition influences future velvet weight. However, Suttiê (1992) indicates that luxury feeding, high protein rations or high levels of protected protein do not have an additive effect over good breeding and good management. Good nutrition allows the genetic potential for velvet production of mature stags to be achieved but super nutrition doesn't increase antler weight. Antler growth seems to be more related to heritability and endocrine factors than to body condition and access to feed (Haigh and Hudson, 1993). Effect of early nutrition on pedicle and velvet development in weaner stags needs to be further investigated in future experiments.

Table 3. Effects of supplemental feed during first winter on antler characteristics of red deer.[a]

	Pedicle initiation	Antler initiation	Antler cleaned
Liveweight (kg)			
High supplement (1.1 kg/day)	47.9	57.9	63.8
Low supplement (0.23 kg/day)	47.4	56.7	62.0
Age (weeks)			
High supplement	37.9	52.0	64.3
Low supplement	52.8	64.1	72.5

From Suttie and Kay, 1982.

[a] Supplement was a mixture of 90% barley, 10% protein pellets, and vitamins;hay and water were give *ad libitum*.

In NZ, most red deer stag antlers are cut at 45 to 55 days after casting and older stags and wapiti up to 60 to 75 days from casting. Antler weights and sizes increase each year to a maximum at around 8 years of age (Schroder, 1983). Two year old velvet antler weight has a strong positive relationship with subsequent velvet antler weight such that it is a very good predictor of subsequent velvet production (Fennessy, 1989). Ranking of stags on 15 month liveweight can also provide an early selection of stags for velvet production (Moore *et al.*, 1988b), but this is not as good as selecting on two year velvet weight.

1.3. HERBAGE INTAKE AND GRAZING BEHAVIOUR

Estimates of forage intake of ruminants are usually based on (i) pasture biomass depletion, (ii) direct estimates of ingestion using oesophageal or ruminal fistulae, (iii) bite rate, bite sizes, and grazing times, and (iv) faecal output (by total collection, or inert marker) combined with a measure of digestibility. For ruminants, the last two may offer the greatest prospects (Jiang and Hudson, 1992; Milne, 1991; Hodgson, 1982)

The factors influencing daily intake rate (short and long term), bite selection and patch selection were associated with nutrient intake during grazing (Hodgson, 1982). Langvatn & Hanley (1993) recently reported that patch selection by red deer with estimated rates of intake of digestible protein (CP) and digestible dry matter (DDM) was more strongly correlated with short term rates of intake of protein than of dry matter. However, Wilmshurst *et al.*, (1995b) argued that patch selection may be as highly correlated with daily rates of energy gain in red deer. Such short term measures overlook the effects of gut fill, which may constrain intake by ruminants over longer time scales (i.e., daily rates of gain) (Wilmshurst and Fryxell, 1995b). Daily rates of intake by herbivores are constrained by rates of processing and clearance of digesta through the gut (Fryxell *et al.*, 1994).

In general, the time spent grazing will depend on the feed requirement of each animal, the amount and distribution of vegetation, and rate of eating (Arnold, 1981). Other factors which influence grazing activities are weather, temperature and time of day (van Mourik, 1985).

Grazing behaviour was recorded in red and sambar deer for 24-h continuous periods, at 2-monthly intervals, as shown in Table 4 (Semiadi *et al.*, 1993b).

Semiadi *et al.,* (1993b) concluded that red and sambar deer had different grazing patterns; red deer grazed mainly during the day, whereas sambar deer mainly had at night. The rate of prehending biting was 35% faster in sambar deer than in red deer. Such a marked behavioural difference between red and sambar deer species in the same environment may reflect the evolution of different strategies for survival in their natural habitats.

Table 4. Time spent grazing (h/24 h) and rate of prehending biting (number/min) in red deer (temperate) and sambar (tropical) deer.

	Red deer	Sambar deer
Annual time spent grazing time (h/24 h)		
Day time	4.5	2.9
Night time	4.9	6.2
Day + night (range)	9.1 (8.8-10.0)	9.4 (8.5-9.7)
Night:day	1.1	2.3
Rate of prehending biting (number/min)		
Stags	44.2 (43.6-44.7)	66.2 (65.5-66.9)
Hinds	51.3 (50.8-51.8)	62.7 (62.9-63.4)

From Semiadi *et al.*, 1993b

1.3.1. FEEDING CLASSIFICATION & DIET SELECTION

The feeding behaviours of Cervidae have been classified in several ways. Hofmann (1985) classified Cervidae into three major classes based on morphophysiological feeding types as grazers (grass & roughage eaters), intermediate feeders (adaptable mixed feeders) and concentrate selectors (browsers). Langer (1988), on the other hand, classified these animals according to a herbivory rating (grasses are more fibrous than non-grass forage) from 1 to 6 levels. It parallels that of Hofmann.

Wild red deer are intermediate feeders which can adapt well to browse and to forage grazing (Kay *et al.*, 1980; Hofmann, 1985; 1989). These categories correspond to adaptations for digestion based on rumen size and structure (Hofmann, 1989). Small, simple stomachs are an adaptation to highly digestible materials (ie concentrate selectors), while large complex stomachs are an adaptation for the extended retention of slowly digesting, fibrous foods (ie roughage eaters).

Recent evidence indicates that both red deer and sambar deer are intermediate feeders, with similar preferences for grasses, but different preferences for forage legumes and browse as shown in Table 4 (Semiadi *et al.*, 1995a). Top dietary preference ranking was willow for sambar and red clover for red deer, with Yorkshire fog and prairie grass being lowly preference ranked by both deer species. Relative to grasses, red deer showed a strong preference for forage legumes of high nutritive value and a very low preference for browse (Semiadi *et al.*, 1995a; Hunt & Hay, 1989), whilst sambar deer showed a strong preference for browse and a low preference for forage legumes.

Differences in dietary preference ranking between the two species may also have evolved through the ability of sambar deer to neutralize secondary compounds (e.g. condensed tannins) present in plant species (Table 5) and their more efficient rumination pattern compared with red deer (Semiadi *et al.*, 1995a). The role of such secondary compounds in plants in influencing diet selection is currently being actively studied in sheep, but needs to be studied in deer.

Wild sambar populations in NZ are found in poplar (*populus sp.*) and willow plantation areas and flax swamp areas (Kelton and Skipworth, 1987). Sambar deer clearly utilise the moist or dry deciduous forests with tall grass cover (Varman and Sukumar, 1993).

Table 5. Dietary preferences of red (temperate) and sambar (tropical) deer offered browse, forage legume and grass species

Plant species	Total N	Total condensed tannins (% DM)	Preference ranking Red deer	 Sambar deer
Willow*	2.4	6.84	9	1
Lupin*	2.4	ND	4	6
Red clover	3.6	0.04	1	5
Lotus	2.8	2.06	2	4
Yorkshire fog	2.6	<0.01	8	8
Prairie grass	2.2	0.05	7	9
Perennial ryegrass:				
Low endophyte	2.2	0.11	3	3
Medium endophyte	2.1	0.12	5	7
High endophyte	2.1	<0.01	6	2

1, Highly preferred; 9, lowly preferred.

*Plant parts sampled *c.* 20 cm from the tips, at a maximum of 1 m above ground level. ND = not determined. Grazing red and sambar deer were offered a free choice of seven different plant species (forage legumes, browse and grasses). From Semiadi *et al.*, 1995a.

Clutton-Brock and Albon (1989) found that wild red deer avoided diets with high fibre, high lignin and low digestibility. In the wild, red deer selected grasses, the shoots and leaves of deciduous trees and shrubs in summer, while in winter small branches were consumed. Red deer males selected poorer quality vegetation than females (Kay & Staines, 1981). It was due to larger body size (Clutton- Brock *et al.*, 1982) or related to differential scaling of incisor breadth and metabolic requirements (Illius & Gordon, 1987).

Differences in acceptability between species or varieties of herbage plants are matched by differences between parts of the same plant, reflecting varying accessibility or presentation for grazing, physical or structural differences, or variable chemical composition (such as protein & fibre), and genotype and previous experience (Hodson, 1985).

1.3.2. TIME SPENT GRAZING

The activities of foraging ruminants can be categorized into three groups, grazing, ruminating and resting (Hodgson, 1982), with each animal species having its own pattern.

Comparative studies of the behaviour, diet and habitat use of sheep and red deer have concluded that deer graze for shorter times than sheep (37% vs 53% of daylight time), and that deer graze grassland less and areas of heather more (36-48%), than sheep do (9-43%). Both species spent more time grazing in the late afternoon and evening (19.00-21.30h.) than earlier in the day (10.00-12.30 h.) (Clarke *et al.*, 1995). However, they were observed for daylight and evening hours only. In woodland, red deer use open areas more frequently at night than in the day, as shown by radiotelemetry (Catt & Staines, 1987) and spotlighting (Thirgood & Staines, 1989). Wild red deer grazed for 6-10 h (6-9 feeding cycles/24h; Kay & Staines, 1981) with a peak time 16.00-20.00 h in both summer and winter (Clutton- Brock *et al.*, 1982). However, the amount of time spent grazing decreased exponentially with increasing forage availability (Wickstrom *et al.*, 1984). The physiological state of animals can affects their feeding behaviour. According to Clutton-Brock *et al.*, (1982), lactating wild red deer used 49-56% of daylight for grazing. This declined with increasing lactation. Differential habitat use at different time of the day has also been demonstrated for roe (Chapman *et al.,* 1993), white-tailed deer (Beier & McCullough, 1990), fallow deer (Thirgood, 1990), Eld's deer (Song, 1993), and elk and mule deer (Wickstrom *et al.*, 1984).

Feed intake rates were 2.22 g DM/min on herbaceous forage for mule deer, 14.04 g DM/min for elk, and 11 g/min on green pasture and 22 g/min on cured pasture for wapiti (Wickstrom *et al.*, 1984). The cost of eating (using indirect calorimetry) herbaceous forage averaged 0.32 kcal/kg body weight/hour, an energetic increment of 26% over standing costs. (Wickstrom *et al.*, 1984; Hudson and Watkins, 1986).

1.3.3 RATE OF BITING

Biting rate tends to decline as sward height or herbage mass increases and as intake per bite increases in sheep and cattle, principally because the ratio of manipulative to biting jaw movements increases as intake per bite and the size of individual plant components prehended increase (Chambers *et al.*, 1981).

Bite rate in ruminants varies from 150 to 230 bites per minute, and intake per bite from 5 to 50 mg (Arnold, 1985). The rate of biting was 15 bites/min (1.8 to 3.3 g/min intake) for mule deer, 60 bites/min (3.7 to 17.2 g/min intake) for elk (Wickstrom *et al.*, 1984; Collins and Urness, 1983), 65 bites/min for sambar and 48 bites/min for red deer (Semiadi, 1993), and it was inversely related to bite size (Wickstrom *et al.*, 1984). Wild red deer ranged from 50 to 60 bites/min and 84.6 and 85.3 chews/min for rumination time in stags and hinds, respectively (Clutton-Brock *et al.*, 1982). Recently, Laca *et al.*, (1993) reported that time per bite is linearly related to total number of jaw movement (JM) per bite (96% of variance), but non-linearly related to bite weight.

Dry matter consumption rate and mean bite size increased curvilinearly as functions of forage biomass (Hudson and Watkins, 1986; Wickstrom *et al.*, 1984). Bite size in wapiti on green and cured pastures increased at an equivalent forage biomass, but bite rates declined from 50 to 25 bites/min as bite sizes increased from 0.1 to 1g (Hudson and Watkins, 1986). A similar result for biting rate patterns has been recorded on tundra reindeer when grazed on vascular plants, but when reindeer were grazed on lichens, biting rate decreased (bite size increased) with increasing eating rate (Trudell and White, 1981). Thus, changes in bite rate and intake per bite depend on plant structure and animal species.

1.4. DEER FARMING

1.4.1. THE NEW ZEALAND DEER INDUSTRY

Farming of deer began in New Zealand (NZ) in 1970 when government legislation allowed the farming of wild deer. The basis of the deer industry is venison, but there is a substantial income from velvet antler. The most efficient way of doing venison production is with animals at one year old age or less. Several strategies can be employed such as manipulation of calving date, the use of large terminal sires (hybridization with elk), and good nutritional techniques.

Five forms of cervus and one each of dama and axis are, or have been established in the wild in NZ (King, 1990). About 85% of the deer in NZ are European red deer, 10% are wapiti (elk), or elk/red deer cross-breeds, 5% are fallow deer with small numbers of other species (Barry and Wilson, 1994). The elk or wapiti are commonly farmed in North America; they are larger and produce bigger antlers than red deer. NZ deer farmers have been increasingly using elk:red deer hybrids for venison production.

From 1970 to 1994, the NZ deer industry grew steadily, although the deer population has recently fluctuated (Fig. 2). In 1995, farmed deer numbers in NZ were around 1.4 million on 4100 properties (Game Industry Board;GIB, 1993). GIB predictions are that the NZ deer industry will continue to expand, and will attain 2.2 million animals by the year 2000.

The ongoing development of export markets for high quality farm-raised venison is the key to the future of deer farming in NZ. Export revenue for NZ deer products for 1994/95 was around NZ$ 200 million, a 3% increase from 1993/94 (Ministry of Agriculture & Fisheries;MAF, 1995). Venison exports to March 1995 totalled NZ$ 130.8 million (up 2 % from 1994), and NZ velvet exports were increased from 496 tonnes ($47.5 million) in 1993/94 to 520 tonnes ($66million) in 1994/95 (GIB, 1995).

Farmed venison production for the year ended June 1995 increased by about 13% to 20,000 tonnes (carcass weight), and the 1995/96 velvet harvest is forecast to increase by 3% to around 549 tonnes. The weighted average price for velvet is estimated to improve 24% to about $125/kg (MAF, 1995). The main velvet markets are Korea and Hong Kong.

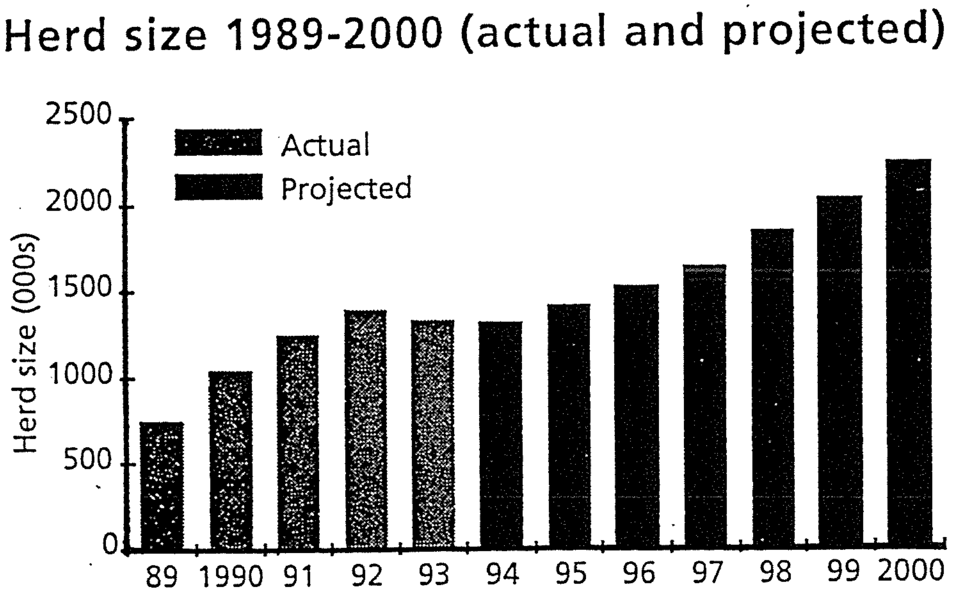

Figure 2. Actual and projected size of the NZ farmed deer herd for the years 1989-2000 (Game Industry Board;GIB, 1993).

The NZ industry has a strategic marketing plan to coordinate all sectors to maintain profitability using the quality assured, branded product "Cervena", which was first launched in the USA and NZ in 1993. The total quality approach is also a feature in other markets which operate under the "Zeal" quality mark. "Cervena" is intended to develop new markets for venison (ie USA), whilst "Zeal" identifies NZ farm raised venison in established markets (ie Germany). Almost all farmed venison produced in NZ is exported, mainly in the chilled form.

Seasonal changes in the venison price schedule in response to market demand for a chilled product in the Northern hemisphere winter in a reasonably well established peak in the NZ venison schedule from October to November, with a dramatic reduction in January. In order for the farmer to receive the best prices for his venison he must produce an animal that is a minimum of 92kg liveweight or 50-65kg carcass weight by September-November (Spring).

1.4.2. DEER FARMING WORLD-WIDE

In many tropical countries (South East Asia and the Pacific Islands) a deer industry may be developed as a source of alternative animal protein for the local population, rather than an export industry (Barry and Wilson, 1994). However, the farming of temperate deer species for venison production is now spreading to many European and North American countries, and to Southern Australia; the deer industries in these countries may well develop along similar lines to the NZ model.

There are 21 countries that have significant populations of farmed deer (Table 6). The estimated number of farmed deer in the world is around 6.5 million as of 1993. Some 60 % of the total are reindeer farmed in Russia (Bailey, 1994). If reindeer are excluded from the total, NZ has around 56%

(1.4 million) of the remaining farmed deer population (about 2.5 million), and is the world leader in terms of the population of farmed deer.

Table 6. Farmed deer species and estimated numbers in the major deer producing countries in the world.

Country	Principal species farmed	Total number	Out put	Sources
Argentina	Red,	6000		Wilson, 1993
Australia	Fallow, Red, Wapiti, Chital, Rusa, Sambar	150-180,000	200 t Venison	Holder, 1993
Canada	Fallow, Red, Elk, Reindeer, White-tailed deer	70,000		Fiedel & Hudson, 1994
P.R. China	Sika, Wapiti, Reindeer, Musk	300,000	Velvet only	Chunyi, 1993
China-Taipei	Sambar, Sika, Red, Fallow, Wapiti	30,000	Velvet	Wilson, 1993
Denmark	Fallow, Red	? 20,000		Wilson, 1993
East Europe	Red, Fallow	?>4000		Somogyva, 1993
France	Red, Fallow	30,000		Cappelle, 1993
Germany	Fallow, Red	70,000	1000 t Venison	Hermann krog, 1993
Ireland	Red	10,000		Mulcahy, 1993
Japan	Sika, Red	4201	Tourism	Wilson, 1993
Korea	Sika, Red, Wapiti	143,000	Velvet only	Kwon, 1993
Malaysia	Fallow, Sambar	?4000		Wilson, 1993
Mauritius	Rusa	60,000	420 t venison	De Maudave Bestel, 1993
New-Caledonia	Rusa	12,000		Wilson, 1993
New Zealand	Red, Wapiti, Fallow	1.44 million	12,000 t venison, 400 t velvet	Anonymous, 1993
Norway	Reindeer	220,000	2674 t venison	Tyler & Jonasson, 1993
Russia	Reindeer, Elk	3-4million farmed or ranched	400,000 Velvet	Wallis, 1993
Sweden	Fallow, Red	2000		Wilson, 1993
UK	Red, Fallow	50,000	500 t venison	Fullerton-Smith, 1993
USA	Fallow, Elk, White-tailed deer, Red, Axis, Sika	100,000	2300 t venison farmed & ranched	Chase, 1993

Woodhouse, 1993

The main tropical species of farmed deer are rusa, sambar and chital. There have been attempts to exploit the potential of farming other deer species such as Pe're David's deer (*Elaphurus davidianus*) in U.K. and NZ, white-tailed deer (*Odocoileus virginianus*) in North America, and the roe deer (*Capreolus capreolus*) (Woodhouse, 1993) in Europe. Sambar is known as the largest tropical deer, and sambar x red hybrids may also be of potential significance to the NZ deer industry because of advanced calving and more efficient feed conversion (Semiadi *et al.*, 1995b).

In the late 1980s, the international market for game meats from all sources was about 35,000 metric tonnes (Luxmore, 1989), but venison is a relatively small portion of the total. Main deer consumers are primarily European countries, particularly Germany, and demand for such products has risen with increased human population. Other consumers are countries such as the USA, Canada, Australia, Japan and NZ.

1.5. NUTRIENT REQUIREMENTS OF DEER.

1.5.1. Feed energy requirement

Energy requirements of deer can be assessed more directly by determining the amount of feed needed to maintain body energy throughout the year than by measuring energy expenditure (Blaxter, 1989). Energy requirements for seasonal maintenance and LWG can be estimated by regression of metabolizable energy (ME) intake (MJ) per day per kg metabolic weight on liveweight gain per day per kg metabolic weight ($W^{0.75}$) (Fennessy, 1982).

Feed requirements for red deer are shown in Table 7. These requirements are for hinds reaching a mature liveweight of 100 kg and for stags a mature liveweight of 200 kg. The metabolisable energy requirement of grazing young red stags is estimated at 16, 20.9, 27 and 26.5 MJ ME/hd/day for the periods of autumn, winter, spring and summer, respectively (Fennessy *et al.*, 1981). Fennessy *et al.*, (1982) estimated that the ME requirements for red stags kept outdoors were 30, 50, 30 and 10% higher than those kept indoors during autumn, winter, spring and summer, respectively. The lactating red hind requires 47.5 MJ ME/head/day for maintenance and lactation (summer period), which is double its feed requirement in any other season (22.5-24.0 MJ ME/head/day). Summer (December to March) in NZ is the most critical period of the year for hinds and their calves. It is the quality and quantity of feed available which largely determines the hind's milk production and hence growth of the suckling calf. Suttie *et al.* (1987) has shown that the energy requirement for growth is 37 MJ ME/kg LWG for stags and 55 MJ ME/kg LWG for hinds. The reason for the higher energy requirement for growth of females is not known but there may be differences in metabolism and fat content which contribute to the difference.

The ME requirements for maintenance in male deer is generally higher than that of females. Maintenance requirement determined for penned wapiti hinds during winter (0.493 MJ ME/ $kg^{0.75}$/d; Jian & Hudson, 1993) are comparable to 0.52 MJ ME/$kg^{0.75}$ /d for penned red hinds (Suttie *et al.* 1987) and 0.57 MJ ME/$Kg^{0.75}$/d for red stags (Fennessy *et al.*, 1982). Semiadi *et al.*, (1995b) obtained estimates of indoor maintenance requirements of 0.63 MJ ME/$kg^{0.75}$/d for red hinds and red stags. For red stags, maintenance requirements for ME were slightly higher than those calculated by Fennessey *et al.*; (1982).

Table 7. Seasonal metabolizable energy (ME) requirement at various ages of red deer.

Species	Target live weight	Daily ME requirement (MJ ME/h/day)			
		Autumn (65d)	Winter (100d)	Spring (100d)	Summer (100d)
Red stags					
(age-years)					
0.25-1.25	48	16.0	20.9	27.0	26.5
1.25-2.25	105	24.5	28.0	31.5	30.0
2.25-3.25	140	23.5	33.0	38.0	36.2
3.25-4.25	175	19.5	33.0	38.5	38.2
4.25-5.25	190	18.5	34.5	43.5	39.0
> - 5.25	200	19.0	36.0	42.5	38.0
Red hinds					
(age-years)					
0.25-1.25	44	15.0	17.5	22.0	21.0
1.25-2.25	83	20.5	23.5	23.5	45.0
2.25-3.25	94	22.5	24.0	24.5	47.5
> - 3.25	100	23.5	22.5	24.5	47.5

From Fennessy *et al.*, 1987. 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" (Fennessy *et al.*, 1981) of 1.30 for autumn, 1.50 for winter, 1.20 for spring and 1.20 for summer and DLWG is daily liveweight gain in kg/day.

(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.

1.5.2 NUTRITION OF DEER

The feed requirements of red deer given in Table 7 emphasise the very high maintenance costs of deer, especially for stags in winter and lactating hinds in summer. The peak feed requirements for deer occur during spring and summer, coinciding with high VFI and late calving. Pasture production patterns in NZ often do not coincide with feed energy requirements of breeding hinds and fawns for a good supply of high quality feed during lactation in November- January (Fig. 3). Conventional ryegrass/ white clover pasture matures, reduced in nutritive value and decreasing in available dry matter due to moisture stress during summer. It is important to achieve good weaning weights in March, because subsequent lifetime performance is affected by weaning weights. In order to achieve this the farmer needs to provide a high quality feeding during the summer period to ensure optimum calf growth (Heydon *et al.*, 1992), which can be helped by earlier calving. Moreover, feed shortage during this period may result in delayed calving dates in the following season (Hamilton, 1988).

Post weaning growth rates are dependent mainly on feed supply. Potential growth rates of red deer calves in winter are lower than in autumn, or in the spring-summer, due to a winter depression in the quantity of feed and to the seasonal decline in growth and VFI. Farmers need to wean onto a good quality, palatable pasture that will encourage the newly weaned calves to recover quickly.

In spring the weaners for venison production (50 kg carcass) or for replacement breeding stock (a minimum of 70 Kg liveweight for two-year old hind mating weight in March; Fennessy, 1982) will have reached certain target liveweights.

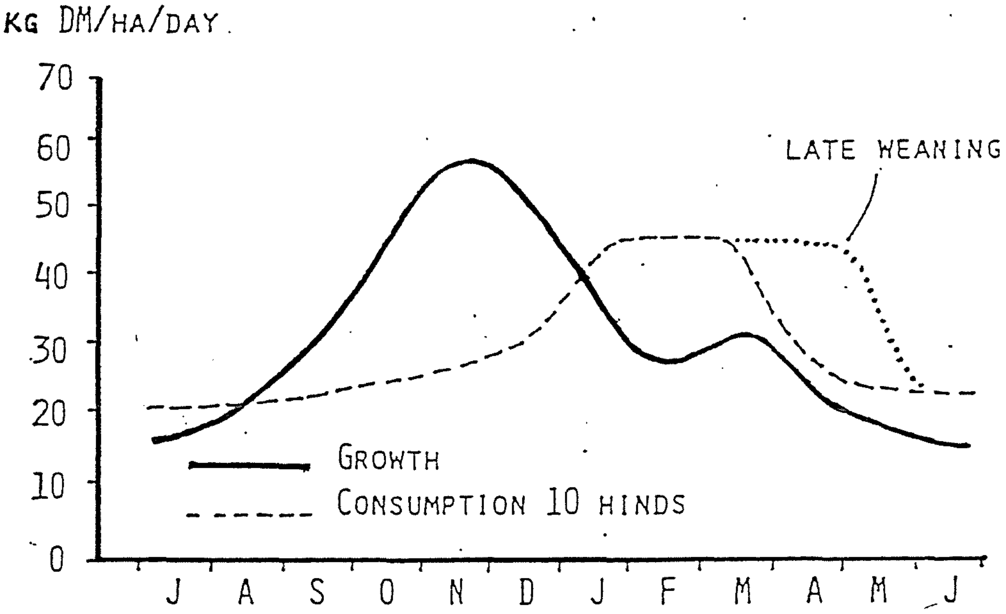

Figure 3 The pasture production pattern in Manawatu downland, New Zealand and peak feed requirements for deer (Wilson, 1991b).

1.6. PRINCIPLES OF FORAGE FEEDING VALUE

1.6.1 Definition of feeding Value

Feeding value (FV) is defined as the animal production response to grazing a specific forage (Ulyatt, 1973) under a given set of environmental circumstance:

FV = Animal production = VFI x Nutritive value

The FV of a forage species or herbage fraction is the animal production response to the particular herbage (total consumption) expressed in units such as liveweight gain (LWG) per day (gLWG/d) in growing animals and milk production in lactating animals.

Grasses and legumes are the main forage sources in NZ and the FV of legumes is generally superior to that of grasses (Ulyatt, 1981). The FV of annual or short rotation grasses are also generally higher than those of perennial grasses.

VFI is influenced by both animal factors (genotype, physiological state) and feed factors (digestibility, herbage mass, herbage allowance, pasture structure and post grazing pasture mass). Other possible factors have been investigated, such as rumen mean retention time (MRT) of digesta, quantity of material in the rumen and rumen fermentation rate (Poppi *et al.*, 1981). Digestibility has a marked effect on VFI (Minson *et al.*, 1964), with a high digestibility positively correlated with high VFI. However, the relationship between intake and digestibility is not consistent for all pasture species, with intake of legumes being up to 40% greater than grasses and leaf 100% greater than stem when compared at the same digestibility (Laredo & Minson, 1973; Ulyatt, 1971). VFI is highly and negatively correlated with the MRT of DM in the rumen. MRT is reduced if the fermentation rate is high, or if forage is rapidly broken-down in the rumen to below the critical particle size (Faichney, 1986; Poppi *et al.*, 1981).

1.6.2. NUTRITIVE VALUE

Nutritive value (NV) is defined as the composition of nutrients in a forage, their digestion and the efficiency with which they are utilised for maintenance and animal production (meat, milk, and wool production) per unit of feed intake (Ulyatt, 1973).

Factors making up NV are:

1. Apparent digestibility of dry matter (DM), and digestion and absorption of nutrients (including site of digestion):
2. The efficiency of utilisation of absorbed nutrients for maintenance and production.

The efficiency of utilisation of absorbed nutrients can best be described as the efficiency of utilisation of ME, which is defined as:

$$\mathbf{K = \frac{\Delta\ Energy\ retained}{\Delta\ ME\ intake}}$$

The efficiency of utilisation of ME is usually quoted as a coefficient *k*, with a suffix *m*, *f* or *l* depending on whether *k* refers to the use of the feed for maintenance, fattening/growth or lactation.

High digestibility of a forage increases the nutritive value, and hence the feeding value, of the forage directly but also has an indirect effect on feeding value via effects on VFI.

Factors affecting digestibility are related to forage maturity and there is a general pattern for all plant species. In general, digestibility of plant material decreases with increases in stem:leaf ratio, cell wall carbohydrates and lignin concentration (Waghorn and Barry, 1987). A high apparent digestibility is associated with the vegetative state as found in spring and this declines as the plant matures over the summer.

The utilisation of the end products of digestion depends both on the type of animal used and on the forage quality. *Km* is relatively similar between legumes (white clover; 0.67) and grasses (Ruanui perennial ryegrass; 0.62), but *Kg* is higher for legumes (white clover; 0.51) than for grass (Ruanui ryegrass; 0.33) (Rattray and Joyce, 1974). Season also has a great effect on ME utilisation from forage diets, with *Kg* being higher in spring than autumn (Waghorn and Barry, 1987), while *Km* is similar between seasons. Autumn forages was associated with a lower proportion of propionic acid produced in the rumen of animals grazing autumn pasture than spring pasture, due to a lower soluble carbohydrate content of autumn than spring forages which limited microbial protein synthesis in autumn, causing the lower *Kg* of autumn forages (MacRae *et al.*, 1985).

1.7. THE DEVELOPMENT OF VENISON PRODUCTION SYSTEMS USING FORAGE DIETS.

1.7.1. VENISON PRODUCTION SYSTEMS FROM PASTURE

In recent years, the Massey University Deer Research Unit has shown a very significant advantage in the growth rates of fawns and weaners when they are offered pasture 10 cm in height (25-44 g N and 10.5-11.6 MJ ME/kg DM), with 75% reaching 50 kg carcass weight by the end of November compared to pasture 5 cm in height (none reached 50 kg by the end of November). Addition of red clover (*Trifolium pratense*; 7 kgDM/hd/day for autumn and 8 kgDM/hd/day, respectively) increased growth rates, and 100% reached the 50 kg target by the end of November in 1990 and 1991 (Table 8) (Semiadi *et al.*, 1993a; Soetrisno *et al.*, 1994).

Table 8 Growth of young red deer stags grazing perennial ryegrass/white clover pasture (PRG/WC) or red clover (RC) at the Massey University Deer Unit during 1990 and 1991, and slaughtered at one year of age. Both forages were compared at the same DM allowance/deer: 12 kg/day for lactation and 6-8 kg/day for post-weaning growth.

	1990		1991	
	PRG/WC	RC	PRG/WC	RC
Lactation[a]				
Calf growth (g/day)	333	433	331	410
Calf weaning weight (Kg)	42.8	49.5	46.7	50.5
Hind weight change (g/d)	-52	58	27	70
Post-weaning growth[b]				
Autumn	197	263	207	237
Winter[c]	110	103	95	94
Spring	343	366	281	346
Mean liveweight (kg) at end of November[d]	101	108	99	105
Carcass dressing out percentage	53.2	55.3	52.4	56.2
Carcass weight (kg)	54.5	59.9	53.3	58.9

[a] Niezen *et al.* 1993.

[b] Semiadi *et al.*, 1993a and Soetrisno *et al.*, 1994.

[c] Both groups grazed on PRG/WC during winter, when RC was dormant.

[d] Approximately 1 year of age.

Grazing on pure red clover increased both pre- and post-weaning growth rates (Niezen *et al.*, 1993), and 100% of the stags on red clover pastures attained the target in both years (Semiadi *et al.*, 1993a; Soetrisno *et al.*, 1994). It may be due to improved milk yield of hinds and a high nutritive value feed and increased VFI grazing on red clover. The carcass dressing-out percentage of deer grazing red clover was higher (55.3-56.2%) than for comparable perennial ryegrass (52.4-53.2%) (Table 8).

1.7.2. DEVELOPMENT OF SYSTEMS USING SPECIALIST CROPS

The introduction of chicory into a deer farming system has been chosen as an example of early premium carcass production at the Massey Deer Research Unit. Chicory is an important feed for deer farming because of its high feeding value (Hoskin *et al.*, 1995), high animal performance, and its fast vegetative growth rate during spring and summer (Li *et al.*, 1994) due to deep tap roots resisting moisture stress. However, the plant density of chicory grazed by deer decreased by more than 35% each year, with the greatest decrease in spring due to an inability to recover after hard grazing and death of roots by *Fusarium sp.* (Li *et al.*, 1995). Therefore, spring when chicory has very high growth rate but also a high plant death rate is a critical period in the management of the crop. In order to increase its persistency, heavy grazing should be avoided, particularly in wet weather during winter.

1.8. NUTRITIONAL EFFECTS OF TANNIN CONTAINING LEGUMES FOR VENISON PRODUCTION

Ruminant animal production in NZ is based upon the grazing of high-quality fresh forages (ME and nitrogen concentration being 10.0-11.5 MJ/kg DM and 25-35g /kg DM), and there is substantial degradation (75%) of feed protein to ammonia in the rumen. Duodenal N flow is only 65-75% of the N eaten (MacRae and Ulyatt, 1974) due to the excessive degradation of soluble protein in the rumen exceeding the capacity of rumen micro-organisms to synthesize protein from ammonia; it represents inefficient nitrogen use in ruminants fed fresh forages.

Condensed tannins (CT) are secondary plant compounds that are currently being evaluated in NZ as a natural means of improving the efficiency of dietary protein (N) utilisation in ruminants fed solely on diets of high quality fresh forage. The nutritional effects of CT in forage species fed to ruminant animals depend upon the concentration and reactivity of CT in the forage.

Wild ruminants such as deer and antelope preferentially consume plant species high in phenolic compounds (Van Soest, 1994). Recent evidence shows that mule deer consuming which CT produced tannin-binding salivary proteins that reduced faecal nitrogen losses per unit of ingested tannin relative to domestic sheep and prairie voles (Robbins *et al.*, 1991).

However, there is no information on the effect of plant CT on the feeding value grazed forages in young red deer. Thus, the productivity of young red deer grazing tannin-containing forages diets (eg *Lotus corniculatus*) needs to be investigated.

1.8.1 CHEMICAL PROPERTIES OF TANNIN

Tannins are plant secondary compounds and have been classified into two groups based on their structures: hydrolyzable tannins (HT) and condensed tannins (CT). Only CT will be considered in this thesis, as HT rarely occur in temperate forages. Condensed tannins are polymeric flavanols (flavan-3-ols, flavan-3,4-diols and biflavans), also known as leucoanthocyanidins.

Condensed tannins (CT) occur in the leaves and stems of sainfoin (molecular weight;MW 2900 (sample collected in January)-3600 (sample collected in March)) and of Lotus species (MW 2000-4000) (Foo *et al.*, 1982). In some plants, such as white clover and red clover (MW 2050), CT occur only in the flower petals (Barry, 1989). The molecular weight (MW) of sainfoin tannin may vary considerably on a seasonal and cultivar basis, and the particular sample used in the binding studies did, indeed, have a much higher MW in March than in January.

CT react with protein and carbohydrates by hydrogen (H) bonding. The binding reactions between CT and proteins are influenced by pH, structure and molecular sizes of CT and protein properties. The reactions are strong at pH 3.5-7.0. However, when pH is < 3.0 and > 8.0, the CT-protein complexes dissociate and proteins are released from complexes (Jones and Mangan, 1977). Horigome *et al.* (1988) reported that for, a given CT, the protein-precipitating capacity increased with increasing degree of polymerisation.

Perez-Maldonado *et al.*, (1995) showed that insoluble tannin-protein binding reactions were formed at pH 4.5-5.5 for bovine serum albumin and 3.5-5.5 for white clover leaf protein. The amount of tannin and protein precipitated in the complex was significantly higher at pH 4.5 for *Desmodium intortum* but significantly higher at pH 5.5 for *Lotus pedunculatus* CT (Perez-Maldonado *et al.*, 1995). Physiologically significant salivary protein-tannin interactions in deer are expected to occur near pH 8 (Robbins, 1983). However, pH alone was not the sole determinant for tannin-protein complex formation, since the tannin-protein complex was found in the pH range 6.0-6.5 when different inorganic ions were added to the solutions. The presence of inorganic ions (Ca, Mg, Na and K) was essential for the formation of insoluble tannin-protein complexes normally in the rumen such as to improve the activity of extracted leaf ribulose biphosphate carboxylase (Krieger and Miziorko, 1986; Viitanen *et al.*, 1990) and to increase the formation of insoluble tannin-plant protein complexes (Mole and Waterman, 1987).

When the ratio of pure tannin to protein exceeds 1:1, there is sufficient tannin to precipitate available proteins (Perez-Maldonado *et al.*, 1995). Using *in-vitro* assay procedures, Perez-Maldonado *et al.*, (1995) calculated that 27-43% and 19-40% of available plant protein may interact with CT from *Desmodium intortum* and *L. pedunculatus*, respectively. Dawra *et al.*, (1988) also found that condensed tannins in oak species contributed 7.9-17.8% respectively, in the total protein-tannin binding capacity of extracts.

1.8.2 EFFECTS OF CONDENSED TANNIN (CT) FORAGE FEEDING VALUE FOR GRAZING ANIMALS

1.8.2.1 Animal production and VFI in ruminants fed fresh forages

High concentrations of CT (50-100 g extractable/ kg DM) depressed VFI and reduced apparent digestibility of OM, DM and fibre in sheep fed *L. pedunculatus* (Barry and Duncan, 1984). However, low levels of CT (20-40g /kg DM) such as found in *L. corniculatus* appeared to be beneficial in ruminant diets (Barry, 1989) for increasing rates of body and wool growth in growing sheep. Wang *et al.*, (1994) reported that lambs grazing *L. corniculatus* (23 g/kg DM) had higher LWG, carcass gain and wool growth than lambs grazing lucerne (no CT). Twice-daily oral polyethylene glycol (PEG) administration to inactivate CT lowered wool growth on lotus but not on lucerne (Table 9).

On the other hand, Terrill *et al.* (1992) reported that CT in sulla (*Hedysarum cornarium*, total CT 40-50 g/kg DM) had no effect on VFI of grazing sheep. VFI in sheep fed *L. pedunculatus* (Waghorn *et al.*, 1990) forage containing 55 g extractable CT/kg DM began to decline after two weeks and was 10% lower after 18 days compared to the PEG sheep (CT inactivated). Barry and Duncan (1984) showed that reducing extractable CT from 63 to 7 g/kg DM increased ME intake of sheep fed *L. pedunculatus* by 44%. However, there is no information on the effect of CT on the VFI and productivity of grazing deer. This needs to be investigated for CT-containing forages for venison production, such as *L. corniculatus*.

Table 9. Voluntary feed intake, liveweight gain (LWG) and wool growth of sheep grazing *Lotus corniculatus* and lucerne with or without twice daily oral polyethylene glycol (PEG) administration.

	LOTUS		LUCERNE		SEM
	Control	PEG	Control	PEG	
OMI (kg/day)	1.19	1.20	1.32	1.30	0.056
LWG (g/day)	203	188	185	178	5.8
Carcass gain (g/day)	78.8	75.2	67.7	62.9	2.87
Wool growth (g/day)	12.1	10.9	10.8	10.2	0.39

(From Wang *et al.*, 1994).

1.8.2.2 NUTRIENT DIGESTION AND METABOLISM IN RUMINANT ANIMALS FED FRESH FORAGES

Non ammonia nitrogen (NAN) flowing out of the rumen into the abomasum is positively related to total N intake (Waghorn and Barry, 1987). However, this relationship differs between herbages and animal species. Barry and Manley (1984) established a significant linear relationship between dietary CT concentration and NAN flow per unit total N intake in sheep fed fresh *L. pedunculatus* and *L. corniculatus* (Fig. 4). Duodenal NAN flow per unit total N intake on lotus species increased as extractable condensed tannin (ECT) concentration increased, and it became unity at the value of about 40 g ECT/kg DM (i.e., no loss of N across the rumen).

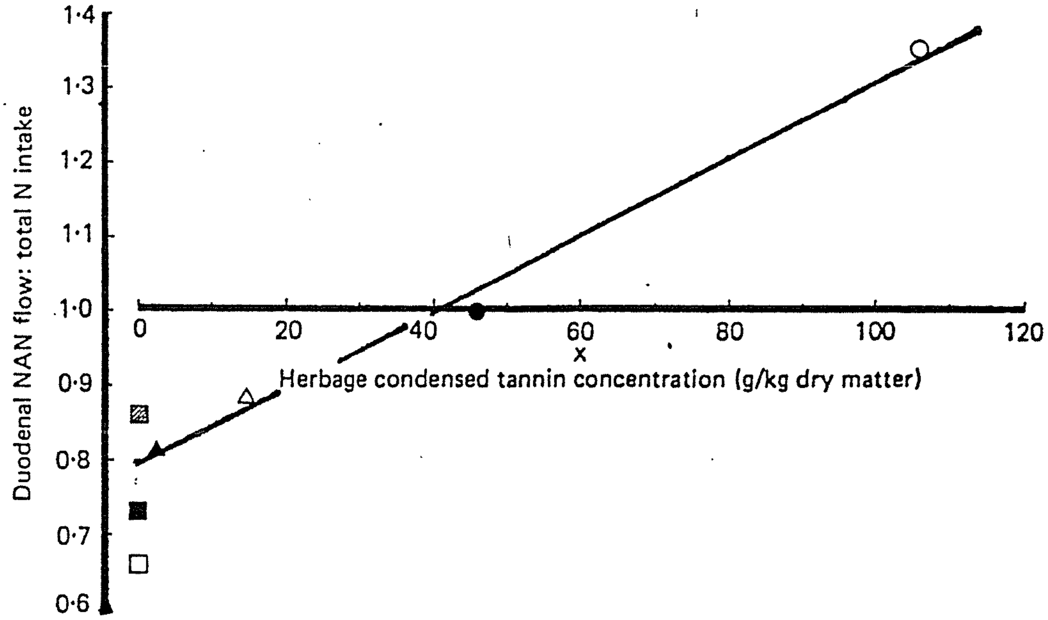

Figure 4 Duodenal non-ammonia nitrogen (NAN) flow per unit total N intake as a function of herbage condensed tannin concentration in sheep fed on *lotus* species. (o) high CT (106 g extractable CT/kg DM) *Lotus pedunculatus*; (•) low CT (46 g extractable CT/kg DM) *L. pedunculatus*; (Δ) high CT (14.5 g extractable CT/kg DM) *L. corniculatus*; (▲) low CT (2.5 g extractable CT/kg DM) *L. corniculatus* (John & Lancashire, 1981); (▨) short rotation ryegrass; (□) perennial ryegrass; (■) white clover (MacRae & Ulyatt, 1974) and (x) sainfoin (Ulyatt & Egan, 1979) (From Barry & Manley, 1984).

There are a number of important differences between deer and sheep in the pattern of CT digestion and metabolism. Comparative studies between sheep and mule deer showed that dry matter and protein digestibilities decreased significantly in both sheep and deer, but neutral-detergent fibre decreased significantly only in sheep when dietary tannin content increased (Robbins *et al.*, 1991). Dietary soluble phenolics (5.2-6.1 % tannin content/kg DM) also depressed neutral-detergent soluble (NDS) digestibility but not fibre digestibility in both elk and white-tailed deer (Mould & Robbins,1982). Fibre digestibility in both elk and white-tailed deer seems to be related more to increasing lignin-cutin content than dietary tannin contents (Mould and Robbins, 1982). The digestibility amounts in both elk and white-tailed deer were reduced 31.1 % when fed fireweed (5.2% tannin content/ kg DM), 40.0 % for maple leaves (6.1 % tannin content/ kg DM) (Mould and Robbins, 1982), but digestibility decreased less when CT were fed diluted in mixed diets (grasses or legumes added to maple leaves containing CT) than when fed as a high-content of tannin only diets (maple leaves).

van Hoven and Furstenburg (1992) reported that volatile fatty acid production during *in vitro* fermentation was greatly reduced when the substrate contained more than 6% condensed tannin. The dietary tannins used in the *in vitro* fermentation had not been exposed to any saliva prior to entering the microbial fermentation environment.

The tannin-binding protein from deer saliva was characterised (Table 10) and is a low molecular weight (MW 5000-25,000), high affinity for tannin and proline-rich proteins (PRP) (Austin *et al.*, 1989; Robinson *et al.*, 1989). The high affinity of the salivary protein for tannin suggests that during the chewing/rumination process, dietary tannin preferentially bound the salivary protein (Austin *et al.*, 1989). The tannin-binding protein from mule deer saliva contains larger amounts of proline (30-45%), glutamate/glutamine, and glycine than other amino acids (AA) (Table 10). The protein does not contain any sulfur-containing AA and contains low amounts of aromatic AA.

In these instances the salivary factor bind the tannins and spares valuable forage protein (Van Soest, 1994). It needs to be established if the saliva of farmed red deer contains tannin binding proteins. However, farmed deer in NZ are grazed on perennial ryegrass and white clover only (which contain only traces of CT (1g/kgDM) and would rarely encounter a feeds of medium (50g/kgDM) or high (100g/kg DM) CT content. The tannin-binding protein from deer saliva may not be producted in the saliva of farmed red deer by short-term exposure to CT feeding (i.e. a few days or weeks) (Barry and Hagerman Personal Communication).

Table 10. Amino acid composition of tannin-binding protein from mule deer saliva.

Amino acid	Deer tannin-binding protein (mole %)	Amino acid	Deer tannin-binding protein (mole %)
Asx	8.5	Ile	2.1
Thr	6.0	Leu	5.1
Ser	8.3	Tyr	1.3
Glx	13.4	Phe	2.6
Pro	19.7	Lys	3.9
Gly	14.4	His	1.7
Ala	5.3	Arg	2.8
Val	5.1		

(From Austin *et al.*, 1989).

The protein was purified by trichloroacetic acid fractionation and electrophoresis. The AA composition was determined after acid hydrolysis. Tryptophan was not determined.

CT in lotus increased the amount of cystine available (plasma cystine irreversible loss rate;IRL) for body synthesis reactions and increased wool growth in grazing sheep, maybe due to reduced breakdown of methionine and cysteine in the rumen (Wang *et al.*, 1994). Waghorn *et al.,* (1987) reported that CT (22g extractable/kg DM) in *Lotus corniculatus* increased essential amino acid (EAA) apparent absorption from the small intestine by 62% due to the effect of CT in increasing abomasal flow and decreased non-EAA (NEAA) apparent absorption by 10% in sheep. McNabb *et al.,* (1993) reported that CT in *L. pedunculatus* (55 g extractable /kg DM) markedly increased the IRL of cystine and reduced the IRL of inorganic sulphate from blood plasma. They also found that CT at this level reduced the oxidation of both methionine and cystine to inorganic sulphate and increased the amount of cystine transferred to body synthetic reactions. The effect of CT on the post rumen N digestion in deer is not known and should be determined in future studies.

1.8.2.3 SUGGESTIONS FOR IMPROVING THE EFFICIENCY OF VENISON PRODUCTION BY TANNIN CONTAINING FORAGES DIETS

There is no information available on the effect of CT on the efficiency of venison production from tannin-containing forage diets. In general, the low production associated with high levels of CT is caused mainly by low VFI and low digestibility in domestic sheep, while deer may have a higher tannin-binding capacity at high levels of CT compared to cattle or sheep.

Grazers (e.g., sheep & cattle) consume virtually tannin-free diets and have a minimal ability to tolerate CT (40 g extractable CT/kg DM in the diets) (Barry and Manley, 1984; van Hoven & Furstenburg, 1992), while browsers (e.g., deer and antelope) normally consume a variety of tannin-containing plants and are well prepared to tolerate high tannins content levels (Robbins *et al.*, 1987). The saliva of mule deer, browsers, contains two or three times more nitrogen and has a greater tannin binding capacity (proline-rich protein) than the saliva of cattle and sheep (Robbins *et al.*, 1987).

Hoskin *et al.*, (1995) showed that when red and hybrid deer were fed sulla pastures containing about 4-6% extractable condensed tannins (ECT)/kg DM, faster LWG (10%) than those on chicory and pasture was recorded. This could in part be due to CT effects. Deer may minimise nitrogen loss and toxicity due to dietary tannin by complexing the tannin efficiently with salivary tannin-binding proteins. There is a need to test this using different type of forages containing different levels of CT such as *Lotus* species and sulla.

1.9 CONCLUSION

The seasonality of red deer is significantly linked to photoperiod, with peak VFI and growth occurring during spring and summer, and the low VFI and growth occurring in winter. Rumen pool size and VFI in red deer changes between summer and winter, although the apparent digestibility remains the same. It was associated with increased total rumen pool size, mean retention time (MRT) of digesta and ammonia production in summer compared to winter. However, more information is needed on the digestive processes, rumen dynamics, absorption and utilization of individual nutrients.

Antler development cycles are closely related to the activity of the reproductive system and various hormones. They also require high feeding levels during velvet antler growth. There is a general positive relationship between body weight and hard antler weight, and is dependent on the level of nutrition in adult stags. Nutrition during early growth may also influence antler weight. However, effect of early nutrition on pedicle and velvet development is not clear, and it needs to be investigated in future experiments.

Both red and sambar deer are classified as intermediate feeders, selecting a mixture of grasses, forage legumes and browse. Whilst both deer species showed a similar preference ranking for grasses, red deer showed a strong preference for selecting legumes of high nutritive value, whilst sambar showed a strong preference for browse species such as willow (high CT levels:6.84 % CT/DM). Differences in dietary preference ranking between the two animal species may have evolved through the differing ability of the animals to neutralize secondary compounds present in plant species, such as CT. However, there is no information and research in these areas needs to be conducted. In addition a legume forage crop *Lotus corniculatus* needs to be evaluated for use in growing weaner deer to slaughter by one year of age.

Venison schedules are normally highest in the spring (September to November) and deer farmers aim to produce carcass weights of 50kg-65kg by one year of age or less. Due to the poor alignment between pasture production and feed requirements of lactating hinds, caused by late calving (Nov/Dec) and low in pasture production, there is a need to develop special purpose forages which have good dry matter (DM) production during summer and autumn, have deep tap roots to resist moisture stress, and are of high nutritive value. Chicory fulfils these criteria, but information on chicory as a forage for deer production is limited. The nutritive value of chicory needs to be compared with that of conventional pastures (perennial ryegrass/white clover) for boosting the growth of red deer and hybrid weaners.

Wild deer may minimise nitrogen loss and toxicity due to dietary tannin by complexing the tannin efficiently with salivary tannin-binding proteins.
The saliva of wild deer contains higher levels of nitrogen and has a greater tannin binding capacity (proline-rich protein) than the saliva of cattle and sheep. The tannin-binding protein from deer saliva contains larger amounts of proline (30-45%), glutamate/glutamine, and glycine than other amino acids. In these instances the salivary factors binds the tannins and spares valuable forage protein. This hypothesis needs to be tested using grazing experiments with forages fed to deer containing different concentrations of CT. It needs to be established if the saliva of farmed red deer contains tannin-binding proteins.

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CHAPTER 2

THE EFFECTS OF GRAZING CHICORY (*Cichorium intybus L*) AND LOTUS CORNICULATUS UPON VENISON & VELVET PRODUCTION BY ONE YEAR OF AGE.

The material contained in this chapter is being prepared for submission to the *Journal of Agricultural Science, Cambridge*.

2.1 INTRODUCTION

The NZ venison price is normally highest between August and December and pays the highest premium for carcasses weighing 50-65 kg (92-120 kg liveweight), reflecting northern hemisphere consumer demand. A production target of the NZ deer industry is to achieve premium carcass weights by November/December (early spring), preferably by one year of age. Under current pasture management, young red deer stags usually reach this slaughter liveweight when 15 months old (Drew, 1989), when venison schedule prices have declined. A contributing cause is the poor alignment between pasture production and feed requirements of lactating hinds and young weaners, caused by late calving (Nov/Dec). In order to grow animals to reach premium carcass weights by one year of age or less, farmers must employ superior nutritional strategies such as the use of specialist crops.

'Grasslands Puna' chicory (*Cichorium intybus L.*) is a perennial herb cultivar of the Asteraceae family that has been evaluated as a bulk summer green feed (Hare *et al.*, 1987) and as a special purpose forage for increasing the growth of male and female weaner deer from 3-12 months of age. Puna chicory establishes well and has good drought resistance characteristics, with excellent summer dry matter (DM) production (25 t DM/ha) from December to May in NZ due to its deep root (Hare and Rolston, 1987; Hare *et al.*, 1987). Chicory was one of the most preferred forages by red deer (Hunt and Hay, 1990) and can produce weaner stag autumn liveweight gains of over 300g/day (Kusmartono *et al.*, 1996). A major reason for superior deer production on chicory is higher voluntary feed intake (VFI), and less ruminating time compared with deer fed on perennial pasture (Kusmartono *et al.*, 1996), indicating more rapid breakdown in the rumen.

Condensed tannins (CT) are secondary compounds that are currently being evaluated in NZ as a natural means of improving the efficiency of protein digestion. CT have been shown to combine with protein, carbohydrate and other compounds to form complexes by hydrogen (H) bonding. The reactions between CT and proteins are influenced by pH, structure and molecular sizes of CT and protein properties (Jones and Mangan, 1977). The reactions are strong at pH 3.5-7.0. However, when pH is <3.0 and >8.0, the CT-protein complexes dissociate and proteins are released.

Nutritional effects of CT in the ruminant animal are dependent in part upon their concentration in the plant. High levels of CT (50-100 g extractable CT/kg DM) in *L. pedunculatus* have been demonstrated to depress VFI and reduce apparent digestibility of DM, OM and fibre in sheep (Barry and Duncan, 1984; Barry and Manley, 1984). However, low levels of CT (22 g extractable CT/kg DM) in *L. corniculatus* are believed to be beneficial in ruminant sheep diets by reducing protein degradation in the rumen and increasing amino acid absorption from the small intestine, without depressing rumen fibre digestion and VFI (Barry *et al.*, 1986 Waghorn *et al.*, 1987). Recent evidence shows that compared to lambs grazing lucerne (0.5-0.3 g CT/kg DM), lambs grazing *L. corniculatus* (22.3-34.0 gCT/kg DM) had slightly lower VFI, and higher LWG (196 v. 181 g/day), carcass weight gain and wool growth (11.5 v. 10.5 g/day) (Wang *et al.*, 1995). Thus, CT in lotus increased wool growth and improved the efficiency of feed utilization.
However, there is no information available on the effect of CT on the efficiency of venison production from tannin-containing forage diets, and research in these areas needs to be carried out using different type of forages containing different levels of CT such as Lotus species and sulla. This experiment was designed to compare the feeding value of chicory and *L. corniculatus* with that of perennial ryegrass/white clover pasture for increasing the growth of red deer and 0.25 elk;0.75 red deer (hybrid) calves from weaning to slaughter at one year of age, and to study the effects of these diets upon the initiation and growth of velvet antler in the young stags.

2.2 MATERIALS AND METHODS

2.2.1 *Experimental design*

A grazing experiment was conducted at Massey University Deer Research Unit (DRU), Palmerston North, NZ during 1995. The experiment involved growth from weaning to slaughter at one year of age, and took place between 7th March and 8th December 1995.

The experiment was 3 x 2 x 2 factorially designed, with three types of forage (chicory vs *L. corniculatus* vs perennial ryegrass/white clover pasture), two deer genotypes (pure red deer vs hybrid) and two sexes (male vs female). The animals were rotationally grazed on chicory, perennial ryegrass/white clover pasture and *L. corniculatus* with DM allowances that did not restricted intake and production.

2.2.2 *Animals*

Fifty three weaners consisting of 26 red deer (14 stags;12 hinds) and 27 hybrids (13 stags;14hinds) were used. The animals were randomly allocated to three groups on 7 March 1995 (hybrid= 0.75 red deer:0.25 elk). The groups were allocated to graze either chicory, perennial ryegrass/white clover pasture and *L. corniculatus*, with each group balanced for genotype and sex. All animals were eartagged and vaccinated against clostridial infections (Coopers, Animal Health Ltd, NZ) at the start of the trial (7th March 1995). In order to protect deer from clinical yersiniosis caused by *Yersinia pseudotuberculosis*, all calves were treated with Yersiniavax vaccine (AgResearch, Upper Hutt, NZ) in the upper half of the neck on 1th March and 28th March 1995. Copper needles (Bayer NZ LTD, Petone) were given orally (12 g/head) on 7th March 1995 to prevent Cu deficiency. Animals were drenched orally with Invermectin (IVOMEC-0.4% w/v at 200 μg/kg liveweight; Merck, Sharp and Dohme, NZ) to prevent lungworm and internal parasite infections, at 3-week intervals until end of June, and then 6-weekly until slaughter.

2.2.3 *Forages*

The chicory (1.95 ha;7 paddocks) was three years old (Plate 2.2.2. A) and perennial ryegrass/white clover was several years old. Pure swards of *L. corniculatus* (Plate 2.2.2. B; birdsfoot trefoil; cv. Grasslands Goldie) was grazed by the red and hybrid weaners. Primary growth of swards was mature in places when the experiment commenced. The area for *L. corniculatus* (1.57ha; 4 paddocks) was ploughed, disk harrowed and power harrowed in December 1994. Lotus seed was then sown by direct drill during the summer of 1994 at the rate of 10kg/ha. After the Lotus emmerged, MCPB (Shell Chemicals Ltd.) at 4 litres/ha was sprayed to control clover. However, young Lotus was completly damaged by herbicide (2 paddocks). Thus, these two paddocks of lotus had no growth for autumn grazing trial, but were re-sown and were available for spring grazing. Two urea applications both chicory and perennial ryegrass/white clover pasture each at 37 kg N/ha were made in early autumn (February) and late spring (October) 1995.

2.2.4 *Grazing Management*

Animals were rotationally grazed on all three forages from 7th March to 6th June 1995 (91 days), and during spring from 22th September to 8th December 1995 (77days). Because chicory and Lotus are dormant during winter, animals from the three groups were joined and grazed on perennial ryegrass/white clover pasture (4.01 ha; 9 paddocks) over winter (107 days). They were split up again in spring into their original pasture, chicory and Lotus groups. Pasture allowances were at 6 kg DM/deer/day in autumn and winter, and 7 kg DM/deer/day in spring. Pasture residual mass was maintained at 1500 kg DM/ha during autumn and spring, and 1300 kg DM/ha during winter with 1.51 kgDM/animal/day of hay supplementation from 10th July to 11th August 1995. Feed allowance in lotus group was 6 kg DM/deer/day for 20 days in autumn May 1995 and 7 kg DM/deer/day for 50 days in spring from October to November, caused by limited lotus estabilishment.

A

B

Plate 2.2.2 (A) Experimental chicory (*Cichorium intybus L.*) paddock (1.69 ha), during March 1995 (three years old). (B) Experimental *L. corniculatus* (birdsfoot trefoil; cv. Grasslands Goldie) paddock (0.75 ha) during October 1995 (9 months old).

The length of the time for the animals grazing each paddock based on specified allowances was calculated as follows:

$$\text{Total days} = \frac{\text{Herbage mass (kg DM/ha) x total area of paddock}}{\text{(Total animals/group) x (Pasture DM allowance/hd/day)}} \qquad (1)$$

2.2.5 *Pasture measurements.*

Pre-grazing herbage mass (kg DM/ha) was measured before animals were introduced into each paddock, while post-grazing herbage mass was measured immediately after the animals were shifted from the paddock. On each occasion eight quadrats per paddock, each of 0.1 m^2 size were cut to soil level using a hand-clipper. The herbage samples were then washed, oven-dried at 90°C for 18 h, and weighed.

For laboratory analysis, eight 0.1 m^2 quadrats of fresh herbage/feed on offer were cut to ground-level from each paddock when the deer were introduced. Samples were then combined for each paddock, mixed and divided into two parts. The first part was used for botanical composition, whilst the second part was stored at -20°C to determine nutritive value.

Diet selection was carried out by hand-plucking plants in the areas that were grazed by the animals. The samples were collected daily, pooled for each paddock, and then divided two parts; one for nutritive value and one for botanical composition. In autumn and spring the diet selected was also determined using two oesophageal fistulated (OF) red deer (Plate 2.2.5. A), which allows a second sampling procedure for chemical compositon. Forage samples were washed and stored at -20°C, and then freeze dried and ground, whilst OF extrusa samples were stored at -20°C, and the freeze dried and ground.

2.2.6 *Animal Measurements*.

All animals were weighed at 3-weekly intervals. In order to estimate faecal organic matter output, the deer were administered with intra-ruminal chromium (Cr) slow-release capsules (CRD, Cr_2O_3 matrix, Captec Ltd., Auckland, NZ). Faeces were sampled from the rectum of individual animals from Day 8 to Day 22 after CRD administration, at 2-day 2hours intervals from 07.00h to 21.00h, respectively. The faecal samples were collected in plastic pottles and oven-dried at 90°C for 72 hours. Each sample was then crushed, and equal amounts of each sample where pooled for each weaner over the two week sampling period. These were sent for laboratory analysis.

Six hand-reared rumen fistulate castrated red deer stags for autumn and 9 rumen fistulate castrated red deer stags for spring were grazed in each forage over 27 days, to measure rate of plunger travel of chromium capsules suspended in the rumen, in order to calculate Cr release rate. The measurement was first done at day 5 after CRD insertion and proceeded at 3-day intervals until day 27.

2.2.6.1 *Pedicle Development and Velvet Antler Removal*

Pedicle development was measured twice per week from 14th April 1995 to 25th May 1995. Spiker velvet antler length (Plate 2.2.6.1) was measured twice per week from 26th May 1995 to 3th October. When the pedicle reached 4 cm long, this was regarded as velvet antler initiation and when velvet reached 20 cm long, this was regarded as length for cutting. Velveting was done either by sedating the animals with 10% xylazine (Rompun, Bayer Ltd, NZ) administered intramuscularly at a dosage rate of 0.5 mg/kg body, or restraining in a pneumatic deer crush. After the animals had been mildly sedated or restrained, they were given local anaesthetic by injecting 15 ml lignocaine hydro-chloride (Xylotox, A.H. Robins CO. Ltd., England) in a ring block around each antler, which was then tied with tape to form a tourniquet. About 5 minutes later, the velvet was cut with a sterilised saw.

Plate 2.2.5 Diet selection was carried out by hand-plucking plants and by using oesophageal fistulated (OF) red deer in autumn and spring.

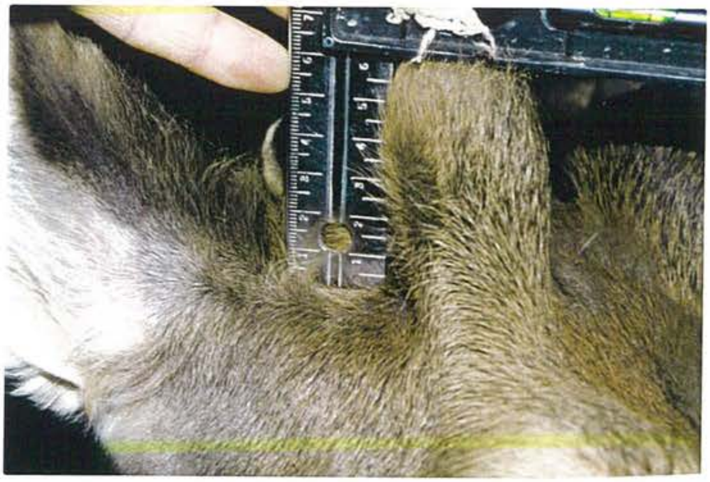

Plate 2.2.6.1 Spiker velvet length was measured twice per week from 26th May 1995 to 3th October 1995, until it reached 20 cm long (for velvet cutting).

The sedated animals were then administered 1.5-2.0 ml yohimbine hydrochloride (Reservyl, Aspiring Veterinary Service, NZ) to reverse the xylazine effect. The tapes were then removed and the animals were released. Velvet antler was then weighed, date of removal, velvet length and cross-sectional area recorded Cross-section areas were measured by Tamaya Digiting Area-line Meter (Planix 5000, Japan).

2.2.7 *Slaughter Procedure*

Stags and hybrid hinds attaining 92 kg liveweight (50 kg carcass) or greater were identified and sent for slaughter; red deer hinds were retained for breeding. Antler revelveting was done before being transported to the Deer Slaughter Premises (DSP) in Feilding. Hot carcasses (kg) were weighed, and the carcass GR (soft tissue depth over the 12th rib 16 cm from the mid line) measured as an indirect measure of fatness (Kirton, 1989). Carcass dressing percentage was then calculated as hot carcass weight divided by liveweight.

2.2.8 *Laboratory Analysis*

Prior to laboratory analyses, all herbage samples were stored at -20°C, freeze-dried and ground to pass a 1 mm mesh diameter sieve (Wiley mill, USA). DM was determined by oven-heating at 100°C for 16 h. Organic matter content was measured by ashing the samples in a furnace at 500 °C for 16h. Forage *in-vitro* digestibility was determined using the enzymic method of Roughan and Holland (1977), whilst total nitrogen (N) was determined by the Kjeldhal procedure using a selenium catalyst and sulphuric acid digestion. Chromium analysis of faeces was done following the method of Costigan and Ellis (1987). Extractable and bound condensed tannins (CT) were determined by the modified butanol/HCL procedure of Terrill *et al.*, (1992a).

Pasture on offer and hand-plucked samples used for botanical composition were dissected into grasses, clover (red or white clover), chicory, lotus, dead matter and weed. Each component was separately oven-dried at 90°C for 17 h, and weighed.

2.3.9. *Data Calculation and Statistical Analysis*

Faecal output (FO) was calculated as:

$$\text{FO (g OM/day)} = \frac{\text{Cr release rate (RR) (mg/day)}}{\text{Faecal Cr concentration (mg/g OM)}} \qquad (2)$$

Voluntary feed intake (VFI) was then calculated using Equation 3, using organic matter digestibility (OMD) from estimated diet selected (hand-plucking and OF samples).

$$\text{VFI (g OM/day)} = \frac{\text{FO (g OM/day)}}{\text{1-OMD}} \qquad (3)$$

Liveweight gain, carcass weight, GR measurement, VFI were analysed using General Linear Model (GLM) Procedure (SAS, 1987), as 3 x 2x 2 factorial design, with three types of forages (chicory, *L. corniculatus* and perennial ryegrass/white clover), two genotypes (red and hybrid deer) and two sexes (male and female). The same procedure was used in the measurement of in pedicle development, velvet length and velvet weight in stags. Age was used as a covariate for all liveweight data, whilst carcass weight was used as a covariate for carcass GR.

2.3 RESULTS

2.3.1. Herbage mass and botanical composition

Pre- and post-grazing herbage masses were slightly higher for pasture than for chicory (Table 11) , with the lowest post-grazing herbage masses being 1184 and 1444 kgDM/ha for pasture during winter and spring respectively. Pre-grazing herbage masses during spring were higher for lotus than for either pasture or chicory. Pasture on offer (Table 12) contained predominantly perennial ryegrass with 4-11% of white clover. Dead matter was at a maximum of 9% in autumn and was lower in winter and spring (2%).

Table 11 Pre- and post-grazing herbage mass (kgDM/ha) for perennial ryegrass/white clover pasture (PRG), chicory and *Lotus corniculatus* grazed by red and hybrid weaner deer during autumn, winter and spring of 1995. Mean values with their standard error.

Herbage mass	PRG			Chicory			Lotus[2]		
Season	N[1]	Pre-	Post-	N[1]	Pre-	Post-	N[1]	Pre-	Post-
Autumn (91 days)	11	2487	1971	12	2158	1326	2	2043	1493
SE		343.6	212.7		563.6	328.5		94.0	25.4
Winter[3] (107 days)	13	1594	1184		-	-		-	-
SE		402.1	225.2						
Spring (77days)	9	2260	1444	17	2030	1466	4	2786	1736
SE		68.4	257.2		241.4	138.9		510.7	203.1

1. Number of samples taken per season
2. Lotus was grazed for 20 days in autumn and for 50 days in spring, due to limited lotus estabilishment.
3. Deer on pasture, lotus and chicory were joined and grazed together on pasture during winter, with 1.5 kg/animal/day of hay supplementation from 10th July to 11th August 1995

The chicory forage on offer contained 80-85 % chicory (Table 13), interspersed with white clover and weed ranging from a minimum of 6 and 3% in autumn to a maximum of 11 and 9% in spring. Dead matter ranged from 6% in autumn to 0% in spring. The lotus forage was very pure, with the lotus content of feed on offer being 92-94% (Table 13). White clover increased in spring to attain 3% of the sward DM. Forage samples of "diet selected" were of similar botanical composition to "feed on offer", except the weed and dead matter contents were lower.

Table 12 Botanical composition (%DM ± SE) of perennial ryegrass/white clover pasture grazed by growing Red and Hybrid deer during autumn, winter and spring of 1995. Mean values with their standard error.

Season	N[1]	Perennial ryegrass	White clover	Dead matter	Weed
		Forage on offer			
Autumn	11	80.9	6.9	9.4	2.8
SE		3.6	0.5	0.5	0.1
Winter	8	91.3	4.0	2.5	2.2
SE		1.4	0.2	0.1	0.1
Spring	8	85.5	11.1	2.0	1.4
SE		1.5	0.4	0.1	0.1
		Diet selected (hand-plucked)			
Autumn	10	88.7	5.8	3.4	2.1
SE		4.1	0.2	0.2	0.1
Winter	8	94.9	3.0	2.2	0
SE		1.0	0.1	0.1	0
Spring	6	89.2	7.6	1.8	0.8
SE		0.6	0.3	0.1	0.1

[1] Number of samples taken per season

Table 13. Botanical composition (%DM ± SE) of chicory and *Lotus corniculatus* forages grazed by growing Red and Hybrid deer during autumn and spring of 1995. Mean values with their standard arror.

Season	Chicory					Lotus[2]				
	N[1]	Chicory	White clover	Dead matter	Weed	N[1]	Lotus	White clover	Dead matter	Weed
					Forage on offer					
Autumn	14	84.7	5.9	6.3	3.1	2	94.1	1.5	0.1	4.4
SE		6.1	0.6	0.4	0.4		0.4	0.1	0.1	0.1
Spring	11	80.1	11.0	0	8.9	4	92.0	3.1	0.1	4.9
SE		0.8	0.4	0	0.6		1.7	0.4	0.1	0.1
					Diet Selected (hand-plucked)					
Autumn	13	89.6	7.1	0.7	2.6	2	96.4	1.7	0.1	1.9
SE		2.6	0.3	0.1	0.2		1.6	0.1	0.1	0.1
Spring	10	91.2	7.4	0	1.4		91.5	4.1	0	4.4
SE		1.1	0.4	0	0.1		1.9	0.4	0	0.4

[1] Number of samples taken per season

[2] Lotus was grazed for 20 days in autumn and for 50 days in spring 1995. Chicory and lotus animals were grazed together on perennial ryegrass/white clover pasture during the winter.

2.3.2. Nutritive value of forages

Mean nutritive values for forage during autumn and spring are given in Tables 14 and 15. Organic matter digestibility (OMD) of chicory was generally higher than for pasture (Table 14) in autumn, either for forage on offer or hand-plucked samples ($P<0.001$), but that of oesophageal fistulae (OF) sample was similar for both forages in autumn. The OMD of chicory was slightly higher, but not significantly different, than that of pasture in spring for both forage on offer and hand-plucked samples. OF samples in deer grazing chicory during spring were similar in OMD to that of deer grazing pasture. OMD of lotus on offer was significantly higher than that of pasture during autumn ($P<0.05$), whilst that of lotus for hand-plucked samples was similar to that of pasture. OMD of lotus was generally similar for both feed on offer and hand- plucked samples. OF samples in deer grazing lotus were significantly lower in OMD than that of pasture during spring ($P<0.001$).

Samples of diet selected were generally of higher OMD than samples of feed on offer, for all three forages, with the differences being largest when diet selected was measured using OF deer, especially when grazing pasture in autumn. The OMD of chicory showed little change between seasons, but pasture changed with season, being of lowest OMD in autumn and highest OMD in spring. Lotus both feed on offer and diet selected was relatively similar in terms of total N content and OMD in autumn and spring.

Table 14 Total nitrogen (N;%DM ± SE) and organic matter digestibility (OMD;%DM ± SE) of forage on offer and diet selected for growing Red and Hybrid weaner deer grazing perennial ryegrass/white clover, chicory and *Lotus corniculatus* during autumn, winter and spring of 1995. Mean values with their standard error.

	Pasture (n=6)	Chicory (n=6)	Lotus (n=6)
		Forage on offer	
Total N:			
autumn	3.87±0.11	3.49±0.11	3.77±0.15[a]
winter	4.07±0.15	-	-
spring	2.70±0.24	3.49±0.22	3.22±0.27
OMD:			
autumn	66.59±1.85	81.87±1.85	75.27±2.61[a]
winter	77.60±1.14	-	-
spring	80.24±1.44	85.34±1.33	75.28± 1.58
		Diet selected (hand-plucked)	
Total N:			
autumn	4.22±0.11	3.61±0.11	3.56±0.20
winter	4.39±1.00	-	-
spring	3.14±0.24	3.64±0.24	3.59±0.28
OMD:			
autumn	69.5±1.85	84.63±1.84	71.74±2.61
winter	80.1±1.45	-	-
spring	80.7±1.44	86.31±1.44	76.71±1.58
		Diet selected (oesophageal fistulae)	
Total N:	(n=4)	(n=6)	(n=6)
autumn	3.46±0.36	3.03±0.30	-
winter	-	-	-
spring	3.31±0.10	2.97±0.11	3.64±0.10
OMD:			
autumn	86.9±0.65	85.9±0.53	-
winter	-	-	-
spring	85.67±0.81	83.63±0.89	80.47±0.81

[1] Number of samples taken per season. The same samples were used for total N and OMD. [a] n=3.

Organic matter (OM) content of pasture, chicory and lotus were much lower for OF samples than hand-plucked samples due to saliva contamination (Table 15). Consequently, total N and CT values were expressed per 100 g OM. Total N content was generally higher for OF samples than hand-plucked samples. Total condensed tannin (CT) in the lotus was 48.2 and 13.1 g/kg OM in hand plucked and OF samples respectively. Most CT in the lotus hand-plucked samples was readily extractable, with much smaller amounts being protein-bound or fibre-bound. In lotus OF extrusa, extractable CT was not detectable, with a similar concentrations of protein-bound or fibre-bound CT compared to hand-plucked samples. Thus, after chewing during eating, the largest component of CT was not detected in lotus OF samples. Small amounts of total CT were detected in both chicory and pasture, with chicory being higher in total CT concentration than pasture, and extractable CT being negligible in OF samples.

Table 15 Chemical composition (g/kg OM) of the perennial ryegrass/white clover (pasture), chicory and *Lotus corniculatus*. Values for 3 samples per mean.

	Pasture		Chicory		Lotus	
	HP[a]	OF[b]	HP	OF	HP	OF
Organic matter	908.9	716.6	862.1	727.4	913.4	761.0
SE	9.13	14.56	3.58	16.99	2.11	11.84
Total N	34.5	45.9	42.1	40.7	39.3	47.8
SE	3.17	1.00	2.22	2.39	2.12	0.80
Condensed tannin[c]:						
Extractable	0.11	ND	1.70	ND	36.10	ND
Protein-bound	ND	1.15	1.16	4.12	10.90	10.60
Fibre-bound	0.14	0.32	0.19	1.65	1.20	2.50
Total	0.25	1.47	3.05	5.77	48.20	13.10
SE	0.06	0.23	0.83	0.48	7.11	0.25

[a] HP= hand plucked. [b] OF= oesophageal fistulae

[c] Butanol/HCl method. ND = Not detectable

2.3.3. Voluntary feed intake

The VFI of deer weaners grazing chicory was significantly higher than that of deer grazing pasture in autumn (P<0.05), but not spring (Table 16). The VFI of lotus was significantly lower than that of both pasture and chicory (P<0.001) in spring. For the deer grazing chicory, VFI was higher for hybrid than for red deer in autumn (P<0.05; 1.47 v 1.30 kgOM/day).

Table 16. Organic matter intake (kgOM/animal/day) of deer grazing perennial ryegrass/white clover (PRG), chicory and *Lotus corniculatus* forages during autumn and spring of 1995. Mean values with standard error.

Forage	PRG	Chicory	Lotus	SEM
Autumn	1.27	1.39	-	19.810
Spring	2.00	2.10	1.53	25.312

2.3.4. Liveweight change

The growth of hybrid deer was consistently higher than that of pure red deer during autumn, winter and spring (P<0.001). The LWG of stag weaners was higher than that of hind weaners in all three seasons (autumn, winter and spring) (P<0.01; Table 17). There were no interactions involving sex, genotype and forage in LWG for all three seasons. During autumn, LWG was significantly higher in weaners grazing chicory than perennial ryegrass/white clover pasture (*P*<0.001). The LWG of stags grazing lotus was significantly higher than that of stags grazing pasture (P<0.001). Hinds grazing lotus were not significantly different. In winter, when all three groups grazed pasture, growth rates were reduced to -4 to 89 g/day with no differences between the three groups. In spring, LWG was consistently higher for deer grazing on chicory than deer grazing on pasture ($P<0.05$). A greater LWG response occurred in stags grazing chicory ($P<0.001$). In spring, LWG was similar for weaners grazing lotus to those grazing pasture.

Table 17 Liveweight (kg) and liveweight gain (g/day) of red and hybrid weaner deer grazing perennial ryegrass/white clover pasture, chicory and *Lotus corniculatus* during autumn, winter and spring of 1995.

Forage	Pasture				Chicory				Lotus				
Sex	Stag		Hind		Stag		Hind		Stag		Hind		SEM
Genotype	R[a]	H[b]	R	H	R	H	R	H	R	H	R	H	
No. of animals	5	4	4	5	5	5	4	5	4	4	4	4	4.7
Mean initial age (10.3.95)	103	102	113	104	100	104	108	99	108	101	105	109	2.6
Mean liveweight (kg)[1]:													
Initial (10.3.95)	45.0	51.8	42.9	47.1	46.3	50.3	43.0	48.0	45.1	49.0	44.3	49.2	2.4
End autumn (6.6.95)	60.6	69.7	54.0	64.9	67.8	74.2	58.9	69.4	60.4	72.5	56.2	64.9	1.7
End winter (8.9.95)	67.9	77.9	57.9	67.7	72.8	80.7	64.1	70.6	65.7	77.7	58.2	67.5	2.0
End spring (8.12.95)	89.2	99.9	71.8	84.7	97.3	105.4	80.7	89.7	87.4	97.9	75.0	85.4	2.2
Liveweight gain (g/d):													
Autumn (91 days)	152	199	145	201	235	271	188	232	235	260	138	189	11.4
Winter (107 days)	72	89	34	34	53	86	39	21	63	79	-4	28	12.2
Spring (77 days)	285	298	185	227	335	331	218	267	283	275	191	233	18.6

1 Adjusted to equal age.

[a]R=pure red deer

[b]H=hybrid (0.25 elk;0.75 red deer)

The effect of genotype on age at weaning approached significance ($P=0.07$), with hybrids being on average four days younger than pure red deer and stags being on average four days younger than hinds (Table 17). All liveweight data in this experiment was therefore adjusted to a constant age (Table 17), and these age effects may be due to differences in gestation length. There were no interactions involving sex, genotype and forage for liveweight. Animals grazing chicory consistently had higher liveweights than those deer grazing pasture (end autumn, $P<0.05$ and end spring, $P<0.01$). Hybrid weaner deer (especially stags) were considerably heavier than pure red deer at the end of all seasons ($P<0.001$), and stags were significantly heavier than hinds at the end of all seasons ($P<0.01$). Compared to pasture, deer grazing lotus were of similar liweight in all three seasons, but hybrid stags were significantly heavier than pure red deer at the end of autumn ($P<0.05$).

2.3.5. Effects of treatment on carcass production

More hybrid stags attained the target slaughter liveweight of 92 kg or over 50 kg carcass weight than pure red stags (Table 18). There were no interactions between forage and genotype for carcass weight and dressing-out percentage. Stags grazing chicory had higher carcass weights and dressing-out percentage ($P<0.05$) than those grazing pasture. Hybrid stags had a significantly higher carcass weight ($P<0.01$) than pure red deer stags. Stags grazing lotus were similar carcass weight compared to stags grazing pasture, but stags grazing lotus (especially hybrid stags) had higher dressing-out percentage ($P<0.05$). Carcass subcutaneous fat depth (GR) was significant higher for deer grazing chicory than pasture ($P<0.05$), but after being adjusted to equal carcass weight, there was no difference in GR measurement. There was no interaction in GR between genotype and forage.

There was no interaction between forage and genotype for carcass weight and dressing-out percentage.

Hybrid hinds grazing chicory had a significantly higher in carcass weight ($P<0.05$) and dressing-out percentage ($P<0.01$) than those grazing pasture. Hybrid hinds grazing lotus were similar in carcass weight and dressing-out percentage compared to those grazing pasture. There was no interaction between forage and genotype for carcass weight and dressing-out percentage. After being adjusted to an equal carcass weight, there was no difference in GR.

Table 18. Carcass production from stags and hinds grazing perennial ryegrass/white clover, chicory and *Lotus cornicularus* forages and attaining slaughter liveweight (92kg or greater) by one year of age. Mean values with their standards error.

Sex	Stags							Hinds			
Forage	Pasture		Chicory		Lotus		SEM	Pasture	Chicory	Lotus	SEM
Genotype	R[a]	H[b]	R	H	R	H		H	H	H	
No. of animals	4	4	5	5	3	4	4.2	4	5	3	4
No. of animals attaining target slaughter LW (%)	1 (25)	3 (75)	4 (80)	4 (80)	1 (33)	4 (100)		1 (25)	3 (60)	1 (33)	
Carcass weight (kg)	48.6	53.3	56.0	59.3	51.5	55.6	2.4	48.5	54.5	51.0	2.4
Dressing-out percentage (%)	52.6	53.7	57.6	56.2	55.8	56.9	1.2	55.2	60.9	58.5	2.3
GR tissue depth	2.7	3.0	5.6	5.6	4.0	4.7	1.2	4.2	5.4	5.6	2.6
GR tissue depth[1] (mm)	3.8	3.2	5.3	4.8	4.5	4.5	1.3	5.4	4.3	5.9	1.5

[1] Adjusted to equal carcass weight.

[a] R=pure red deer.

[b] H=hybrid (0.25 elk;0.75 red deer).

2.3.6. Pedicle development and velvet antler production

The mean date of antler pedicle initiation occurred earlier for young stags grazing chicory (18 days; $P<0.05$) than for stags grazing pasture (Table 19). Grazing on lotus advanced the mean date of pedicle initiation by 5 days, but this did not attain significance. The relationship between date of pedicle initiation and LW (W) is shown in Figure 5. The date of pedicle initiation (D) was found to be best correlated with liveweight at the end of autumn (Figure 5; equation 4; $P<0.01$). Each 10 kg increase in liveweight (W) at the end of autumn advanced the date of pedicle initiation by an average of 10 days. When liveweight at the end of autumn was used as a co-variate, there were no differences between the three forage groups in date of pedicle initiation.

$$\mathbf{D = 83.7013 - 1.00162W} \qquad (4)$$

$$\text{SE} \pm 0.183$$

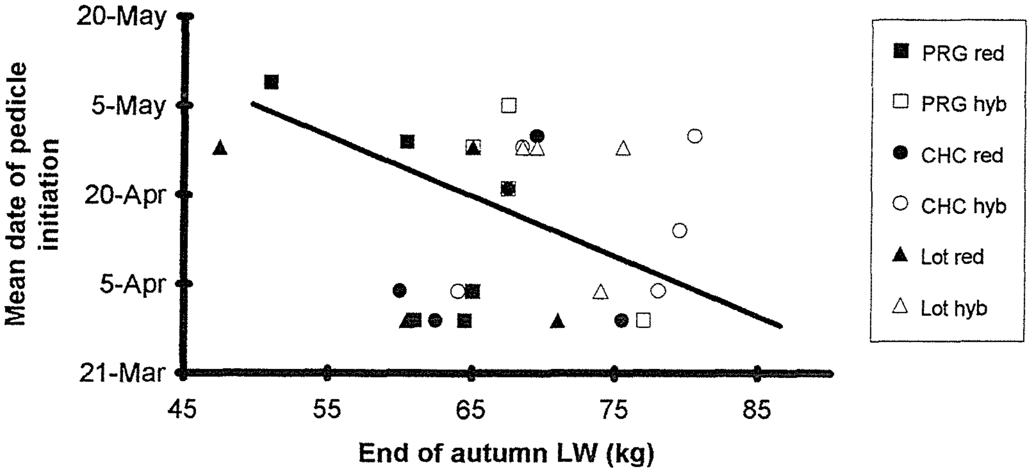

Figure 5. The effect of liveweight at the end of autumn upon date of pedicle initiation.

Table 19 The effect of nutrition and body weight on initiation of the pedicle and initiation of velvet antler growth in red and hybrid weaner stags grazed on perennial ryegrass/white clover (PRG), chicory or *Lotus corniculatus* during 1995.

Forage	PRG		Chicory		Lotus		SEM
Genotype	R	H	R	H	R	H	
Number of animals	5	4	5	5	4	4	
Pedicle-initiation							
- uncorrected	19 Apr	28Apr	5Apr	6Apr	14Apr	23Apr	8.68
- corrected[1]	7 Apr	1May	4Apr	18 Apr	3Apr	4 May	7.52
Antler-initiation							
- uncorrected	28Sept	26Sept	7Sept	28Aug	26Sept	15Oct	14.20
- corrected[1]	11Sept	02Oct	7Sept	16Sept	9Sept	27Oct	12.86
Body weight (kg)							
End of autumn	60.4	69.2	67.0	74.1	61.0	71.9	2.5

[1] Corrected by analysis of co-variance to equal liveweight at the end of autumn. When the pedicle reached 4 cm long, this was regarded as velvet antler initiation. R=pure red deer. H=hybrid deer (0.25 elk; 0.75 red deer).

Velvet antler initiation tended to be earlier on stags grazing chicory (24 days; P=0.08) than for stags grazing pasture (Table 19). Grazing on lotus did not change the date of velvet antler initiation compared to young stags grazing pasture. A number of liveweight (W) relationships were examined. The date of velvet antler initiation (D) was found to be best correlated with liveweight at the end of autumn (Figure 6;equation 5; $P<0.01$).

Each 10 kg increase in liveweight (W) at the end of autumn advanced date of antler initiation by an average of 18 days. When liveweight at the end of autumn was used as a co-variate (Table 19), grazing on chicory appeared to advance date of antler initiation by 10 days, but this did not attain significance

(P=0.47). There were no forage x genotype interactions for date of velvet antler initiation.

$$\mathbf{D = 222.785 - 1.79967W} \qquad (5)$$

SE ± 0.215

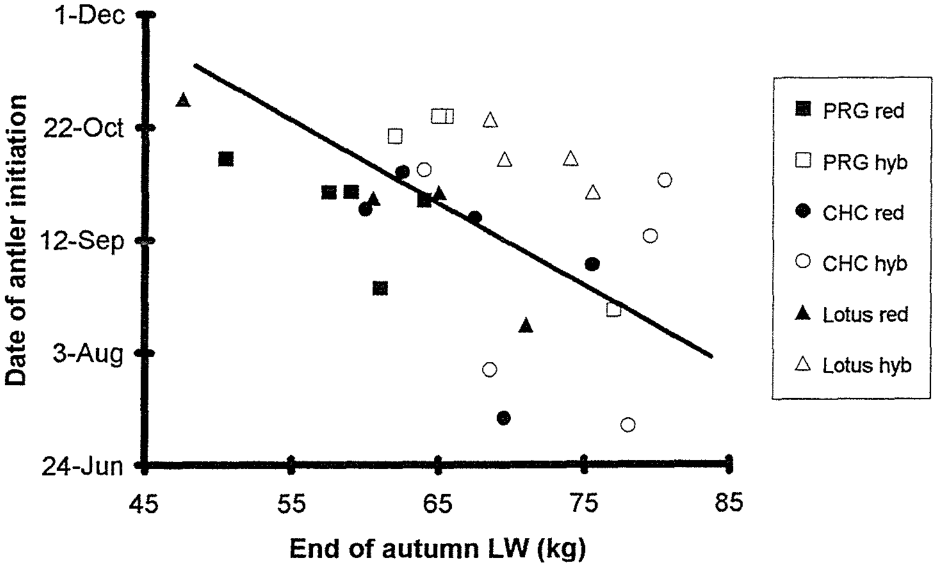

Figure 6. The effect of liveweight at the end of autumn upon date of initiation of velvet growth, defined as the pedicle reaching a height of 4 cm.

Velvet antler length (L;cm) was related to time after pedicle initiation (*t*;days) by equation 6, where *A* and *c* are constants. The relationship between length and time is shown in Figure 7.

$$\mathbf{L} = Ae^{ct} \qquad (6)$$

Table 20 gives values for the constants *A* and *c* for the prediction of velvet antler length (L). For stags grazing chicory, constant *A* was significantly higher than for stags grazing pasture (P<0.05), whilst for for stags grazing lotus, constant *A* tended to be higher than for stags grazing pasture (P=0.11). Relative to grazing on pasture, constant c was increased by grazing on chicory (P<0.01) but not on lotus. There were interactions involving pasture, genotype and time (*t*) for constants *A* and *c* (P<0.001). Predictions of velvet growth length can be made with parameters "*A*" and "c". Thus from Table 20, velvet antler length at day 200 days after pedicle initiation could be estimated 5.19, 7.76 and 4.11 cm grazing on pasture, chicory and lotus respectively.

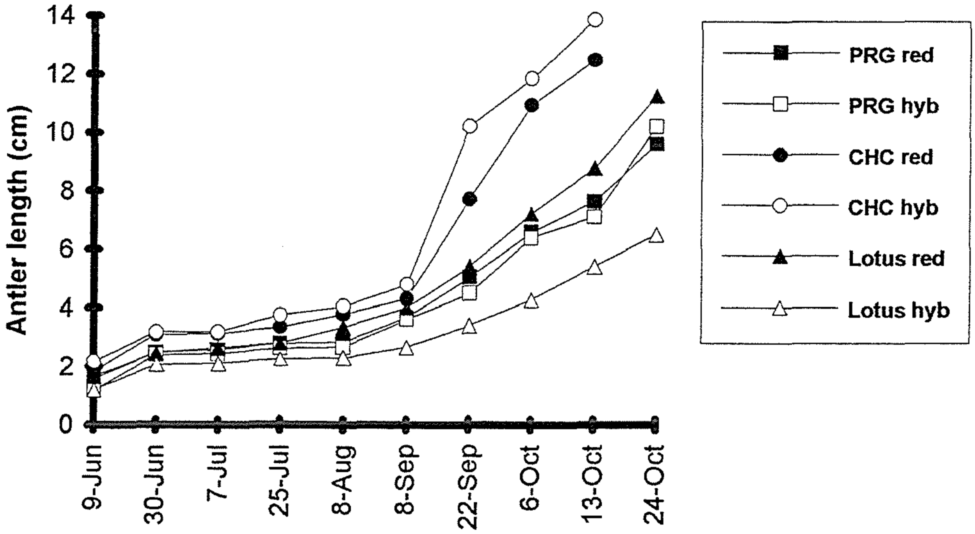

Figure 7. Antler length growth in young stags grazing pasture, chicory or lotus.

Relative to grazing on pasture, deer grazing on chicory advanced the mean date of first cut velvet antler by 17 days (P<0.05; Table 20). Deer grazing on lotus had a similar date of first velvet cut compared to those grazing pasture. A number of LW (W) relationships were examined, and the date of the first velvet cut (D) was found to be best correlated with LW at the end of winter ($P<0.01$; Figure 8 and equation 7). Each 10 kg increase in liveweight (W) at the end of winter advanced date of first cut velvet by an average of 13.2 days.

$$D = 251.827 - 1.32464W \qquad (7)$$

SE ± 0.356

When LW at the end of winter was used as a co-variate (Table 20), grazing on chicory advanced the date of the first velvet cut ($P=0.15$) by an average of 12 days. There were no forage x genotype interactions for the date of first velvet cut. Relative to grazing on pasture, deer grazing on chicory tended to increase the weight of the first velvet cut ($P=0.09$) and total velvet ($P=0.06$); Table 20). Grazing deer on lotus did not increase the weight of first cut and total velvet compared to those grazing pasture.

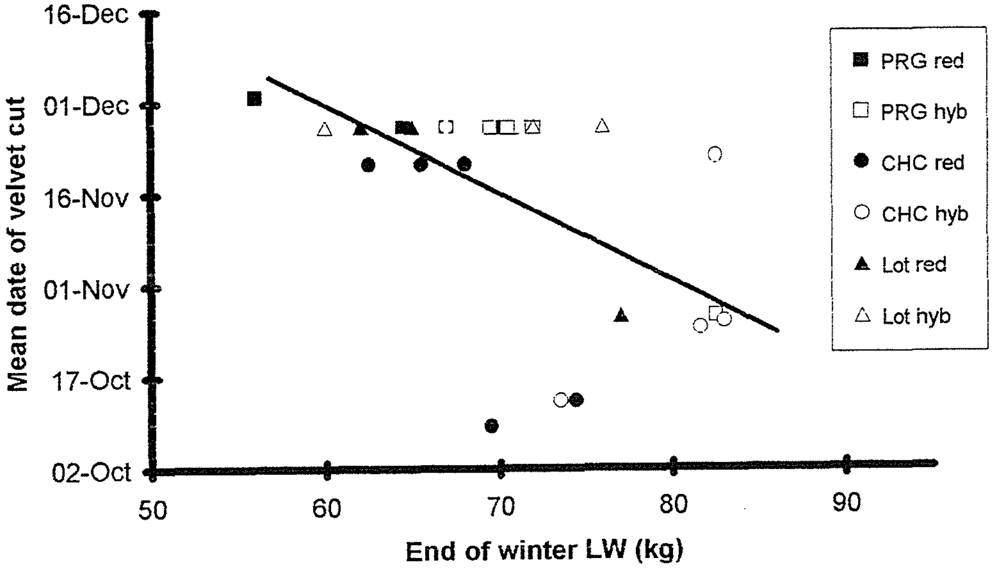

Figure 8. The relationship between date of first cut velvet antler and liveweight at the end of winter.

Table 20 Velvet antler production from red and hybrid yearling stags grazed on perennial ryegrass/white clover, chicory and *Lotus corniculatus* forages during 1995. Mean values with their standard errors.

Forage	Pasture		Chicory		Lotus		SEM
Genotype	Red[a]	Hybrid[b]	Red	Hybrid	Red	Hybrid	
Total No. of stags	5	4	5	5	4	4	
Length growth:							
Constant *A*	0.175	0.158	0.482	0.287	0.196	0.327	0.1463
Constant *c*	0.022	0.022	0.029	0.023	0.021	0.015	0.0010
Stags producing velvet (%)	100	75	100	100	75	75	
First cut (g)	257 (5)[1]	156 (3)	300 (5)	240(5)	266 (3)	187 (3)	31.3
Regrowth (g)	0	107 (1)	179 (1)	343 (1)	56(1)	0	34.5
First cut and regrowth (g)	257 (5)	192 (3)	336 (5)	309 (5)	285 (3)	187 (3)	61.2
Mean date of first cut							
-uncorrected	27Nov	19Nov	10Nov	03Nov	16Nov	27Nov	6.1
-corrected[2]	20Nov	22Nov	07Nov	12Nov	13Nov	25Nov	5.2
Cross-section area (cm^2)	9	8.6	11.4	8.7	10.6	7.1	1.1

[1] Number of stags per group

[2] Corrected by co-variate to equal liveweight at the end of winter.

[a] Red= pure red deer. [b] Hybrid= hybrid deer (0.25 elk; 0.75 red deer).

The velvet cross-section area for pure red deer was larger than for hybrid deer (10.2 cm^2 v 8.1 cm^2; P=0.06). Relative to grazing pasture, grazing deer on chicory did not increase velvet cross-section area (10.1 v 8.8; P=0.4). There were no forage x genotype interactions. Grazing deer on lotus did not increase velvet cross-section area compared to those grazing pasture. A selection of velvet cross-section area relationships were examined, and the weight of first cut (P<0.05), regrowth (P<0.05) and total velvet (P<0.01) were all found to be potentially correlated with cross-section area.

2.4. DISCUSSION

The present study showed problems in relying entirely on perennial ryegrass/white clover pasture for 12 month venison production, with a low proportion of animals reaching the target slaughter liveweight (92kg or greater) and carcass weight barely attaining 50 kg in those sent for slaughter. Velvet production was low at approximately 0.2 kg per stag. A similar result was achieved by Ataja *et al.* (1992) and Semiadi *et al.* (1993) with red deer stags grazing perennial ryegrass/white clover pasture, in 12 month venison systems, indicating the need for input of specialist forages.

In this study the best responses obtained for special purpose forages were for chicory. A comparison of the present results with those of Kusmartono *et al.* (1996 a) is shown in Table 21. Relative to deer grazing on perennial ryegrass/white clover pasture, grazing chicory consistently increased carcass weight, due mainly to increasing autumn LWG and dressing out percentage at slaughter, with smaller responses in spring LWG. Largest carcass weights were consistently obtained from grazing hybrid stags on chicory.

Table 21 Liveweight gain (g/day), carcass weight and dressing out percentage (%) from red and hybrid stags grazing either perennial ryegrass/white clover pasture or chicory to one year of age.

Author (s)	Pasture		Chicory	
	R	H	R	H
Present study:				
Autumn LWG	152	199	235	271
Spring LWG	285	298	335	331
Carcass weight (kg)	48.6	53.3	56.0	59.3
Dressing-out percentage (%)	52.6	53.7	57.6	56.2
Kusmartono *et al.* (1996 a):				
Autumn LWG	178	203	246	318
Spring LWG	260	271	255	310
Carcass weight (kg)	56.6	57.0	63.2	73.0
Dressing-out percentage (%)	54.1	54.1	58.4	58.6

R = Pure red deer

H = Hybrid (0.25 elk;0.75 red) deer

Grazing red clover has also increased carcass production. This includes increased carcass dressing out percentage and increased LWG (Niezen *et al.*, 1993; Semiadi *et al.*, 1993). The evidence suggests that chicory and red clover had higher feeding value (FV) for deer than perennial ryegrass/white clover pasture.

Chicory had higher OMD and VFI than pasture during autumn (Tables 14 and 16) but similar values in spring, accounting for its autumn growth stimulation. Similar results were found by Kusmartono *et al.* (1996a). Recent evidence has shown that deer grazing chicory spent slightly less time eating and substantially less time ruminating than those grazing pasture (Kusmartono *et al.*, 1996a). Hoskin *et al.* (1995) showed that deer fed freshly-cut pure chicory indoors spent a similar time eating (361 v 379 min/24h) but markedly less time ruminating (33 v 270 min/24h) than those fed perennial ryegrass. Kusmartono *et al.* (1996b) showed that the reduced ruminating time was associated with faster rumen particle breakdown and faster disappearance of DM from the rumen in deer fed chicory, thus explaining its greater autumn VFI. Carcass subcutaneous fat depth (GR) was higher for chicory than for pasture, but after being adjusted to equal carcass weight, there was no difference in GR measurement.

In the present study grazing on chicory also increased spiker velvet antler production, due to advancing the time of pedicle initiation (18 days), advancing the initiation of velvet growth (24 days), advancing the date of first velvet cutting (17 days) and increasing the rate of velvet antler length growth. Kusmartono *et al.* (1996a) obtained similar results for date of velvet cutting and for velvet weight (Table 22). However, initiation of velvet growth was negatively correlated with liveweight, and correction of the data to equal liveweight removed a component of the advancement produced from feeding chicory. However, a component due to feeding chicory *per se* still remained, indicating that the effects of chicory feeding on spiker velvet production were partly due to its effect in increasing liveweight and partly due to some component of chicory initiating early growth of the antler.

Table 22 Velvet antler production from red and hybrid yearling stags grazing either perennial ryegrass/white clover pasture or chicory.

	Pasture		Chicory	
	Red[a]	Hybrid[b]	Red	Hybrid
Present study:				
Mean date of first cut				
-uncorrected	27 Nov	19 Nov	10 Nov	3 Nov
-corrected[1]	20 Nov	22 Nov	7 Nov	12 Nov
Weight of first cut (g)	257 (5)[2]	156 (3)	300 (5)	240 (5)
Weight of first cut + regrowth (g)	257 (5)[2]	192 (3)	336 (5)	309 (5)
Kusmartono *et al.* (1996a):				
Mean date of first cut				
-uncorrected	29 Oct	15 Nov	4 Oct	14 Oct
-corrected[1]	23 Oct	10 Nov	3 Oct	23 Oct
Weight of first cut (g)	280 (7)[2]	269 (6)	349 (5)	399 (8)
Weight of first cut + regrowth	438 (7)[2]	296 (6)	727 (5)	783 (8)

[1] Corrected by co-variate to equal liveweight at the end of winter.

[2] Number of stags.

[a] Red = pure red deer

[b] Hybrid = hybrid (0.25 elk; 0.75 red) deer

Semiadi *et al.* (1993) found that yearling stags grazing red clover had superior LWG but similar spiker velvet antler production to young stags grazing pasture. Similar results were obtained from 4 year old red deer stags grazing either perennial ryegrass/white clover pasture or chicory, with no difference in velvet weight (Cosgrove *et al.* 1995). Whilst feeding chicory during autumn stimulates the earlier development (and perhaps size) of the pedicle, so giving greater velvet production in spiker stags over a longer time period, feeding of chicory does not seem to increase velvet antler production in mature stags.

Differences in plant chemical composition could be responsible for the earlier antler growth in young stags grazing chicory. Total N content was similar and total CT content was slightly higher for chicory than for pasture, suggesting that amino acid absorption may be higher for chicory than for pasture. Ullrey (1983) found that energy, protein and minerals were important for antler production. Dietary energy (complete diet *ad libitum* *v* 80 or 60% of *ad libitum*) restriction decreased antler volume, beam diameter and length in yearling white-tailed deer. Protein and mineral (especially calcium) restriction tended to produce the same effects, with evidence that higher dietary protein (9.5% *v* 4.5 % DM diets) are particularly important in the month just before the start of antler development. Calcium deficiency decreases antler specific gravity and tends to decrease antler ash content (Ullrey, 1983). Thus these data suggest that the timing of nutrient (ie energy, protein and calcium) availability in relation to antlergenesis may be important for normal antler development. The data of Vogt (1941) supports this hypothesis. High calcium content of sesame cake, and possibly other nutritive components facilitates rapid and increased development of the antlers (50% increase) in red deer, wapiti and reindeer. Total ash concentration (ie mineral concentration) was consistently higher for chicory, and content of calcium, potassium and phosphorus in chicory has been reported to exceed the range of values compared to ryegrass pasture (Kusmartono 1996; Thomas *et al.*, 1952). This evidence suggests that a combination of high mineral concentration and increased protein absorption in chicory may have increased velvet antler growth in young stags. Effects of protein supply on initiation of pedicle and velvet development in weaner stags grazing fresh forages needs to be studied.

Pedicle initiation and velvet antler growth rate were highly associated with age, liveweight, and level of nutrition (Fennessy and Suttie, 1985; Muir and

Sykes,1988). Young stags fed a nutritious diet advanced pedicle initiation by 12 weeks, compared to those under restricted feeding (Suttie and Kay, 1983). A low plane of nutrition before and during antler development resulted in lighter, shorter antlers (Fennessy and Suttie, 1985).

If chicory is to be included in deer production systems under grazing conditions, it is very important to maintain the plant in the vegetative state. Li *et al.* (1994) reported that the plant density (number of plants/m^2) of chicory grazed by deer decreased by about 33% each year, with the greatest decrease in spring due to an inability to recover after hard grazing and death of roots by *Fusarium fungal sp.* However, it was compensated by increases in shoot numbers/plant, which led to less dense or more open swards of chicory. In order to increase its persistency, heavy grazing should be avoided, particularly in wet weather during winter. Specialist crop plants of chicory require further plant breeding programmes to increase persistency and to reduce reproductive stem formation during summer.

The animal results for lotus are undoubtedly influenced by the low number of grazing days that could be achieved, due to problems of lotus establishment. Nevertheless, relative to grazing on pasture grazing on lotus did increase LWG of stags during autumn and increased the efficiency of growth in spring, with the same LWG requiring a lower VFI on lotus. Wang *et al.* (1995) also observed lower VFI but higher rates of carcass weight gain and wool growth in lambs grazing *Lotus corniculatus* than lucerne, with part of the increased efficiency on lotus due to its CT content. In *Lotus corniculatus*, CT has been demonstrated to reduce dietary protein degradation in the rumen, and to increase amino acid (AA) supply for absorption in the small intestine in sheep (Waghorn *et al.*, 1987b; Wang *et al.*, 1994). The small responses obtained in the present work give some indication that the CT content of *Lotus corniculatus* may have some value for improving the efficiency of growth in young deer and further experiments are needed in this area.

Compared to pasture, OMD of lotus on offer was generally higher than that of pasture in autumn, whilst that of lotus for hand plucked samples was similar to that of pasture. Lotus showed little change in OMD between seasons, but pasture changed with season, being of lowest OMD in autumn and highest OMD in spring.

Table 23 Condensed tannin (CT) concentrations (g/kg OM) in the hand plucked (or feed offered) and diet selected by deer grazing *Lotus corniculatus* or sheep grazing sulla (*Hedysarum coronarium).*

	Lotus		Sulla[1]	
	HP[a]	OF[b] (deer)	Offered	OF (sheep)
Condensed tannin[2]:				
Extractable	36.1	ND	41.6	9.5
Protein-bound	10.9	10.6	11.0	36.3
Fibre-bound	1.2	2.5	3.4	9.3
Total	48.2	13.1	56.0	55.1

[1] Terrill *et al.*, (1992b)

[2] Butanol/HCl method. ND= Not detectable

[a] HP = hand plucked. [b] OF = oesophageal fistulae.

In Table 23 the CT content determined in *Lotus corniculatus* before and after chewing by deer has been compared with similar data from Terill *et al.* (1992b) for sulla (*Hedysarum coronarium*) eaten by sheep. Total CT for both forages before chewing was approximately 52 g/kgOM, with most of this being readily extractable and low proportions bound to protein or fibre. Chewing both forages markedly reduced extractable CT concentration. However, this was counteracted by higher levels of protein-bound and fibre-bound CT in sulla chewed by sheep, whereas there was no increase in these components in *Lotus corniculatus* chewed by deer.

An explanation may be that deer species have produced tannin-binding salivary proteins (Robbins *et al.*, 1991). The tannin-binding salivary proteins from mule deer saliva have demonstrated a high affinity for tannin. It is proline-rich protein with a low molecular weight (Austin *et al.*, 1989; Robinson *et al.*, 1989). These proteins are not produced in sheep saliva. The high affinity of the deer saliva for tannin suggests that during the chewing/rumination process, dietary tannin preferentially bound with the salivary protein (Austin *et al.*, 1989). In these instances the salivary factor bound the tannins and reduced faecal nitrogen losses per unit of ingested tannin, relative to domestic sheep and prairie voles (Robbins *et al.*, 1991). It may have bound a component of extractable CT in lotus during this study, thus it could not be extracted and detected in the analytical system used. Chewing by red deer did not reduce the CT content of pasture or chicory (Table 23), but this may be due to the low concentration of extractable CT in these forages, which may have limited access for the salivary CT-binding proteins.

It can be concluded that pasture is of lowest feeding value during autumn, and that the nutritional advantages of either lotus or chicory over pasture are likely to be greatest during autumn. However, data was obtained from lotus using limited grazing time during autumn. Therefore, future venison and velvet antler production research with lotus should use a longer time to expose deer to grazing on lotus rather than limited periods of time. Further research is needed to determine the effects of nutritional factors (such as protein and mineral supply) on initiation of pedicle and velvet initiation in weaner stags grazing either chicory or lotus. The efficiency of protein degradation in deer fed either lotus or chicory needs to be studied in yearling stags. The use of lotus for lactating hinds and their fawns needs investigation on venison production, because high fawn weaning weights increase the chance of achieving target LW at 12 months of age. The lotus species can be used as a specialist crop to complement integrated grazing management systems. However, lotus species require further refinement in plant establishment techniques.

These studies have also defined a potential role for chicory in stimulating velvet antler growth, at least in weaner stags. As velvet is normally harvested at a constant stage of growth, it is possible that velvet weight is largely determined by genetic factors. The present data and that of Kusmartono *et al.* (1996a) indicate that chicory may have a role to play in attaining that growth stage earlier, due to earlier development of the pedicle and faster length growth rate. Thus grazing on chicory may permit two cuts of velvet to be obtained in one season compared with the one cut that is normally obtained from stags grazing pasture. This remains an avenue for future research.

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