Effects of grazing chicory (*Cichorium intybus*) and perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture upon the growth and voluntary feed intake of red and hybrid deer during lactation and post-weaning growth

KUSMARTONO[1], T. N. BARRY[1*], P. R. WILSON[2], P. D. KEMP[3] AND K. J. STAFFORD[2]

[1] *Department of Animal Science, Massey University, Palmerston North, New Zealand*
[2] *Department of Veterinary Clinical Science, Massey University, Palmerston North, New Zealand*
[3] *Department of Plant Science, Massey University, Palmerston North, New Zealand*

(*Revised MS received 10 October 1995*)

SUMMARY

Two grazing trials were carried out at Palmerston North, New Zealand using lactating red deer hinds in summer 1994 (Expt 1) and using weaner deer during the autumn, winter and spring of 1993 (Expt 2), to compare the feeding value of chicory (*Cichorium intybus*) and perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture for increasing the growth of deer calves. Red deer and hybrid (0·25 elk; 0·75 red deer) calves were used in both experiments. Experiment 2 concluded with slaughter at the end of spring, when the deer were *c*. 12 months old. In both experiments, animals were rotationally grazed on either pasture or chicory with DM allowances being 12 kg DM/hind per day (Expt 1), and 6, 6 and 7 kg DM/head per day during autumn, winter and spring respectively (Expt 2).

Perennial ryegrass comprised 62% of pasture on offer in Expt 1 and 78–90% in Expt 2, whilst chicory comprised 90–92% of forage on offer in both experiments. Relative to pasture, chicory had a higher ratio of readily fermentable:structural carbohydrate and had higher organic matter digestibility (OMD) in summer and autumn but not in spring.

Deer grazing chicory had higher voluntary feed intake (VFI), bite weight, liveweight gain (LWG), carcass dressing percentage and carcass weight and much shorter ruminating time than deer grazing pasture. Hybrid deer grew better than red deer and there were forage × genotype interactions in Expt 2, with LWG and carcass weight of hybrid deer being much greater when grazed on chicory. Carcass weight for red deer and hybrid stags was 63·2 and 73·0 kg when grazed on chicory and 56·6 and 57·0 kg when grazed on pasture. Grazing chicory advanced the date of first-cut velvet antler by 28 days and increased the weight of total harvestable (first-cut + regrowth) velvet antler. It is concluded that grazing chicory increased carcass weight, especially in hybrid stags with increased growth potential, and increased velvet antler production. This was achieved by increased VFI in all seasons and increased OMD of chicory in summer and autumn relative to deer grazing pasture. Further research is need to determine the efficiency of rumination on particle size breakdown and to measure rumen outflow rate in deer fed chicory.

INTRODUCTION

The New Zealand (NZ) deer industry has a potential target of achieving carcass weights of 50–65 kg by 1 year of age or less, to meet spring export market requirements. Most deer in NZ are grazed on perennial ryegrass/white clover pasture for the complete 12-month production cycle, and initial research (Ataja *et al.* 1992) showed that deer production could be substantially increased by grazing at 10 cm surface height compared with 5 cm height. In NZ, the feed requirements of deer are not well aligned with pasture

* To whom correspondence should be addressed.

75

production, due to calving (Nov/Dec) occurring later than the spring increase in pasture production (September). Consequently, hinds are at peak lactation during summer (Jan/Feb) when pasture production has declined due to moisture stress and when pasture is also of lower nutritive value. Therefore, there is a need to develop special purpose forages for deer production, which have good dry matter (DM) production during summer, have deep tap-roots to resist moisture stress and are of high nutritive value. Red clover (*Trifolium pratense*) and chicory (*Cichorium intybus*) fulfil these criteria and, relative to perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture, inputs of red clover have increased the growth of deer calves during lactation (Niezen *et al.* 1993) and during post-weaning growth to 1 year of age (Semiadi *et al.* 1993; Soetrisno *et al.* 1994).

Less information is available for chicory. In a series of preference experiments, chicory was one of the most preferred forages by red deer, while perennial ryegrass was the least preferred species (Hunt & Hay 1990). Chicory is also substantially higher in digestibility than perennial ryegrass (Hoskin *et al.* 1995). Niezen *et al.* (1993) reported a 16% increase in growth of red deer calves grazed with their dams on chicory during lactation relative to those grazed on perennial/white clover pasture, whilst Hunt (1993) found grazing on chicory increased weaning weight by 15%.

The present study compared the feeding value of chicory with that of perennial ryegrass/white clover pasture for increasing the growth of red deer calves and hybrid (0·25 elk; 0·75 red deer) calves both during lactation, and from weaning to slaughter at 1 year of age. Measurements of voluntary food intake (VFI) and of eating and ruminating times were also made.

MATERIALS AND METHODS

Experimental design

Two grazing experiments were conducted at Massey University Deer Research Unit (DRU), Palmerston North, NZ during 1994 (Expt 1) and 1993 (Expt 2). Experiment 1 involved lactating hinds and their calves and commenced on 7 January and concluded at weaning on 28 February 1994. Experiment 2 involved growth from weaning to slaughter at 1 year of age, and took place between 1 March and 12 December 1993.

Both experiments were $2 \times 2 \times 2$ factorially designed, with two types of forage (chicory *v.* perennial ryegrass/white clover pasture), two deer genotypes (pure red deer *v.* hybrid) and two sexes (male *v.* female). The animals used in both experiments were rotationally grazed on either chicory or perennial ryegrass/white clover pasture with DM allowances that did not restrict intake and production.

Forages

Areas for chicory (2·4 ha; 8 paddocks) were ploughed, disk harrowed and power harrowed in January 1993. Chicory seed was then sown by direct drilling during the summer of 1993 at the rate of 4 kg/ha. After the chicory emerged, Gramoxone (ICI, NZ, Ltd) at 3 litres/ha was sprayed to control grasses. The perennial ryegrass/white clover pasture was several years old. Potassic superphosphate (9% P; 10% S and 7% K) was applied in late April 1994 at 250 kg/ha, corresponding to 22·5 kg P/ha, onto chicory and perennial ryegrass/white clover pasture. Also, three applications of urea, each at 37 kg N/ha, were made in early spring (August), late spring (October) 1993 and early autumn (February) 1994, respectively. In the winter of 1993, chicory paddocks were sprayed with herbicide (Galant; DowElanco, NZ, Ltd) at 3 litres/ha to control grasses, mainly *Poa annua*.

Animals

Experiment 1

Forty lactating red deer hinds and their calves were used during the summer of 1994. Calving occurred during Nov/Dec 1993. Mean weight of hinds and calves at the start of the experiment was $113{\cdot}9 \pm 1{\cdot}64$ kg and $28{\cdot}6 \pm 0{\cdot}75$ kg respectively. The calves consisted of 21 red (9 stags; 12 hinds) and 19 hybrid deer (6 stags; 13 hinds). The hybrid calves used were produced from mating hybrid (0·5 elk; 0·5 red) stags to red deer hinds. To identify new-born calves, numbered collars were used until weaning. The hinds and their calves were randomly allocated to graze either chicory or perennial ryegrass/white clover pasture.

Experiment 2

Forty-eight weaners consisting of 24 red deer (13 stags; 11 hinds) and 24 hybrids (16 stags; 8 hinds) were used. The animals were randomly allocated to graze either chicory or perennial ryegrass/white clover pasture on 1 March 1993. All animals were ear-tagged and vaccinated against clostridial infections (Coopers, Animal Health Ltd, NZ) and yersinia infections (Yersiniavax; AgResearch, Upper Hutt, NZ) in the upper half of the neck on 1 March and 5 April 1993. Animals were drenched orally with ivermectin (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 the end of June and then 6-weekly until slaughter.

Grazing management

In Expt 1, DM allowance was 12 kg DM/hind per day, whilst in Expt 2, DM allowances were 6, 6 and

7 kg DM/head per day during autumn, winter and spring respectively. Animals were rotationally grazed in both experiments, with rotation length being *c.* 4–5 weeks. In Expt 2, autumn was defined from 1 March to 8 June 1993, winter from 12 June to 20 September 1993 and spring from 24 September to 12 December 1993. Because chicory is dormant during the winter, animals from the two groups were joined and grazed on perennial ryegrass/white clover pasture (5·8 ha; 11 paddocks) over winter. They were separated in spring into their original pasture and chicory groups. Pasture residual mass was maintained at 1700 kg DM/ha during winter. Reproductive stem formation and flower production occurred with chicory during summer. Follow-up grazing with non-experimental deer and mechanical topping were used to cut the stems and to maximize leaf production by the chicory.

The time animals grazed each paddock was based on specified allowances calculated as follows:

$$\text{Total days} = \frac{\text{Herbage mass (kg DM/ha)} \times \text{total area of paddock}}{\text{(Total animals/group)} \times \text{(pasture allowance/deer/day)}} \quad (1)$$

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 out of 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 soil level from each paddock when the deer were introduced. Samples were then combined, mixed and divided into two parts. The first part was used to determine botanical composition, whilst the second part was stored at −20 °C prior to measurement of nutritive value.

Hand-plucked samples were taken each day from the area where the deer were grazing by imitating the animal's selection of plants. Earlier studies had showed that under these grazing conditions with young deer, hand-plucked samples were of identical digestibility to extrusa samples taken with deer fistulated in the oesophagus (Semiadi *et al.* 1993). Samples collected daily were then pooled for each paddock, and stored at −20 °C prior to determination of botanical composition and nutritive value.

Animal measurements

All animals were weighed at 3-weekly intervals. In both experiments, 24 h studies of grazing behaviour were carried out. Numbered collars with different colours were used to identify the grazing hinds (Expt 1) rearing calves of different genotype and sex (i.e. red and hybrid; male and female), and the same system was used for weaner deer in Expt 2. Grazing activities of the animals such as eating, ruminating, resting and biting rate were recorded by observation at 12-min intervals (Jamieson & Hodgson 1979). During the hours of darkness, two 12 V spotlights were used to aid identification. Two 24 h observation periods over alternate days were used for animals grazing each forage in Expt 1 and in autumn and spring in Expt 2.

In order to estimate faecal organic matter output, an intra-ruminal chromium (Cr) slow-release capsule (CRD, Cr_2O_3 matrix, Captec Ltd, Auckland, NZ) was administered to each deer (Parker *et al.* 1989). Faecal samples were taken from the rectum of individual animals on Days 8–22 after CRD administration, at 2-day intervals, with the samples in Expt 2 being taken at different times on each day. Faecal sampling on Days 8, 10, 12, 14, 16, 18, 20 and 22 was done at 07.00, 09.00, 11.00, 13.00, 15.00, 17.00, 19.00 and 21.00h, respectively. Due to forage shortages during the long dry summer period of 1994, faecal samples in Expt 1 were taken only on Days 8, 10 and 12 from the lactating hinds. The faecal samples were collected in plastic bottles, oven-dried at 90 °C for 72 h, crushed and stored until required for laboratory analysis.

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

Velvet antler removal

Velvet antler harvesting was done when the velvet antler reached *c.* 20 cm long. The animals were treated either by sedating with 10% xylazine (Rompun, Bayer Ltd, NZ) administered intramuscularly at a dosage rate of 0·5 mg/kg body weight, or by 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 hydrochloride (Xylotox, A. H. Robins Co Ltd, England) in a ring block around each antler, which was then tied to form a tourniquet. About 5 min later, the velvet was cut with a sterilized saw. The sedated animals were then injected with yohimbine hydrochloride (1·5–2·0 ml; Reservyl, Aspiring Veterinary Service, NZ) intrajugularly to reverse the effect of the xylazine. Subsequently, the tourniquet was removed and the animals were released. Velvet was weighed, and date of harvesting recorded.

Slaughter procedure

The post-weaning trial (Expt 2) concluded on 12 December 1993. All stags and hinds attaining 92 kg liveweight (50 kg carcass) or greater were identified and had their antlers removed before being transported to the Deer Slaughter Premises (DSP) in Kaimai. 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). The weight and volume of rumen contents were measured after slaughter and then discarded. The emptied stomachs of all the deer were brought to Massey University, preserved with 10% formalin and kept at −20 °C until required. Weight of the digesta-free reticulorumen, omasum and abomasum were measured directly, whilst their volumes were measured by filling with water, except for the volume of the omasum which was measured by water displacement. The length and width of ten papilla on samples of rumen wall taken from the roof of the dorsal sac, the floor of the atrium ruminis and the caudo ventral blindsac were measured by caliper (Stafford 1995).

Laboratory analysis

Prior to laboratory analyses, all herbage samples were stored at −20 °C, then 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. Total nitrogen (N) was determined by the Kjeldahl procedure, using a selenium catalyst and sulphuric acid digestion. Water-soluble carbohydrates and pectin were determined following the procedure of Bailey (1967), whilst neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin were determined by the detergent system of Van Soest (1994). Cell wall data are presented as hemicellulose (NDF−ADF), cellulose (ADF−lignin) and lignin. *In vitro* digestibility was determined using the enzymic method developed by Roughan & Holland (1977). Chromium analysis of faeces was done following the method of Costigan & Ellis (1987).

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

Data calculation and statistical analysis

Faecal output (FO) was calculated as:

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

Voluntary feed intake was then calculated using Eqn (3), using organic matter digestibility (OMD) from estimated diet selected (hand-plucked) samples.

$$\text{Voluntary feed intake (g OM/day)} = \frac{\text{FO (g OM/day)}}{1-\text{OMD}} \quad (3)$$

The duration of grazing (h/24 h) for each deer type was calculated using Eqn (4).

$$\text{Grazing time (h/24 h)} = \frac{\Sigma \text{ animals observed as grazing} \times 24}{\Sigma \text{ animals observed}} \quad (4)$$

Total time spent ruminating/24 h was calculated in a similar manner.

Bite weight (BW; g OM/bite) was calculated from Eqn (5) (Hodgson 1982), using measured values for voluntary intake (I; g OM/day), grazing time (GT; min/24 h) and bite rate (BR; bites/min).

$$I = \text{GT} \times \text{BR} \times \text{BW} \quad (5)$$

Liveweight gain, carcass weight, GR measurement, velvet antler weight, VFI, eating and ruminating times were analysed using the General Linear Model (GLM) Procedure (SAS 1987), as a $2 \times 2 \times 2$ factorial design, with two types of forage (chicory and perennial ryegrass/white clover), two genotypes (red and hybrid deer) and two sexes (male and female). Age was used as a covariate for initial and final liveweights of calves in Expt 1 and all liveweights of weaner deer in Expt 2, whilst carcass weight was used as a covariate for carcass GR and rump fat cover. Least square means (L.S.M.) analysis was used to test the differences between treatments.

RESULTS

Herbage mass and botanical composition

In both experiments, pre- and post-grazing herbage masses were generally slightly higher for chicory than for pasture (Table 1), with the lowest post-grazing herbage masses being 1382 and 1737 kg DM/ha for pasture during summer and winter respectively. Perennial ryegrass was the principal component of the pasture on offer, ranging from 62% in summer to 90% in winter (Tables 2 and 3). White clover ranged from a maximum of 25% in summer to a minimum of 5% in winter, whilst dead matter was at a maximum of 10–12% in summer and autumn. The chicory sward was very pure, with chicory content of feed on offer being 90–92% (Tables 2 and 4). Contents of grass, weeds and dead matter were generally each 2–3% or less, whilst white clover ranged from a low of 1·5% in summer and autumn to *c.* 5% in spring. Both the pasture and chicory swards were relatively free of weeds, and for both forages, samples of estimated diet selected were of similar botanical

Table 1. *Pre- and post-grazing herbage mass (kgDM/ha) of perennial ryegrass/white clover pasture and chicory grazed by hinds and their calves during lactation in 1994 and by red and hybrid weaner deer during autumn, winter and spring of 1993. Mean values with their standard errors*

Season	n*	Pasture Pre-grazing	Pasture Post-grazing	n*	Chicory Pre-grazing	Chicory Post-grazing
Expt 1						
Summer	8	2489	1382	12	3119	1641
S.E.		164·6	53·1		254·2	124·4
Expt 2						
Autumn	11	2488	1843	12	3202	2138
S.E.		209·8	125·4		335·7	112·2
Winter†	21	2277	1737		0	0
S.E.		75·9	58·0			
Spring	11	2988	2082	11	4110	2634
S.E.		217·3	117·5		533·2	310·9

* Number of samples taken per season.
† Both pasture and chicory animals were joined and grazed together on pasture during winter.

Table 2. *Expt 1. Botanical composition (% DM ± S.E.) of perennial ryegrass/white clover pasture and chicory during the summer 1994 lactation trial*

Species	Pasture ($n = 12$)	Chicory ($n = 12$)
	Forage on offer	
Grass	61·7±2·51	2·2±0·58
Clover	24·6±3·53	1·6±0·64
Chicory	—	92·1±0·28
Weed	2·8±0·78	0·5±0·33
Dead matter	10·8±1·98	3·3±2·05
	Diet selected	
Grass	72·7±1·83	3·3±0·57
Clover	16·6±1·80	2·0±0·75
Chicory	—	93·7±1·06
Weed	0·9±0·16	0·5±0·31
Dead matter	9·8±1·08	0·4±0·21

Table 3. *Expt 2. Botanical composition (% DM ± S.E.) of perennial ryegrass/white clover pasture grazed by red and hybrid weaner deer during autumn, winter and spring in 1993*

Season	Perennial ryegrass	White clover	Dead matter	Weed	n*
		Forage on offer			
Autumn	77·5	9·3	12·0	1·2	12
S.E.	2·0	1·4	0·5	2·4	
Winter	89·5	4·8	5·6	0·1	24
S.E.	1·0	0·7	0·7	0·1	
Spring	84·5	13·0	2·0	0·5	11
S.E.	2·4	2·1	0·5	0·2	
		Diet selected			
Autumn	86·6	7·7	4·6	1·1	12
S.E.	1·0	0·6	0·7	0·2	
Winter	91·4	2·7	5·6	0·4	24
S.E.	1·2	0·6	0·3	0·5	
Spring	90·2	8·4	1·1	0·3	11
S.E.	1·2	1·1	0·3	0·1	

* Number of samples taken per season.

composition to the feed on offer, except that dead matter content was lower.

Nutritive value of forages

For both forages, diet selected was generally slightly higher in total N and organic matter digestibility (OMD) than the feed on offer (Tables 5 and 6). In terms of carbohydrate (CHO) composition, chicory contained higher concentrations of water-soluble CHO and pectin and lower concentrations of cellulose and hemicellulose than pasture ($P < 0·01$) in the diet selected. Consequently, the ratio of readily fermentable CHO (water-soluble carbohydrate + pectin) to structural CHO (cellulose + hemicellulose) was higher for chicory than for pasture, in both autumn and in spring ($P < 0·01$). Hence, OMD was higher for chicory than for pasture in summer and autumn, but not in spring ($P < 0·01$). Relative to pasture, chicory had a much higher ash content ($P < 0·01$), a slightly lower total N content in autumn and spring, but a similar lignin content.

Liveweight change

The effects of genotype, sex and their interaction on age of calves at weaning in Expt 1 were not significant.

Table 4. *Expt 2. Botanical composition (% DM ± S.E.) of chicory grazed by red and hybrid weaner deer during autumn and spring in 1993*

Season	Chicory	Perennial ryegrass	White clover	Dead matter	Weed	*n**
			Forage on offer			
Autumn	89·0	6·5	1·7	1·3	1·5	12
S.E.	1·8	1·1	0·3	0·2	0·6	
Spring	90·0	2·0	5·7	2·0	0·3	11
S.E.	1·8	0·6	1·9	0·5	0·1	
			Diet selected			
Autumn	95·0	3·5	1·5	0	0	12
S.E.	0·6	0·4	0·4	0	0	
Spring	86·4	4·8	6·1	2·5	0·2	11
S.E.	3·7	1·7	3·0	0·8	0·2	

* Number of samples taken per season.
Chicory was dormant during winter.

Table 5. *Expt 1. Chemical composition (% DM ± S.E.) of forage on offer and diet selected by red deer hinds during lactation in summer 1994*

	Pasture ($n = 6$)	Chicory ($n = 6$)
	Forage on offer	
Total N	2·97 ± 0·16	3·62 ± 0·16
OMD	74·0 ± 0·80 (10·4)*	84·8 ± 0·80 (15·3)
	Diet selected	
Total N	3·44 ± 0·16	3·21 ± 0·16
Water-soluble carbohydrate (*a*)	8·5 ± 1·45	14·4 ± 1·45
Pectin (*a*)	1·9 ± 0·25	7·2 ± 0·25
Cellulose (*b*)	20·7 ± 0·29	10·9 ± 0·29
Hemicellulose (*b*)	19·0 ± 0·9	5·2 ± 0·90
Ratio (*a*:*b*)	0·26 ± 0·12	1·39 ± 0·12
Lignin	2·2 ± 0·23	1·9 ± 0·23
OMD	76·5 ± 0·80 (11·0)	86·4 ± 0·80 (15·0)

* Ash content. 100 − ash content = OM content.
D.F. = 10.

Calves used in Expt 1 were weaned at 96·6 ± 4·9 and 94·8 ± 9·2 days of age (mean ± standard deviation) for male and female red deer calves, respectively, whilst hybrid male and female were weaned at 94·4 ± 5·6 and 95·8 ± 4·0 days of age, respectively. Hybrid calves had significantly higher initial weight ($P < 0·05$), liveweight gain (LWG: $P = 0·08$) and weaning weight ($P < 0·05$) than pure red deer calves, whilst male calves had significantly higher initial weight ($P < 0·05$), LWG ($P < 0·05$) and weaning weight ($P < 0·01$) than female calves (Table 7). Liveweight gain was consistently higher for calves grazing chicory than pasture (404 *v*. 351 g/d; $P = 0·07$): there were no interactions between sex, genotype and forage type for liveweight or LWG. All hinds lost weight during lactation, with those grazing chicory losing more weight than those grazing pasture ($P < 0·01$). The significant forage × genotype interaction ($P < 0·05$) was due to large weight losses in hinds grazing chicory that reared pure red deer calves.

In Expt 2, LWG of stag calves was higher than that of hind calves in all three seasons (autumn, winter and spring; $P < 0·01$; Table 8), whilst the growth of hybrid deer was consistently greater than that of pure red deer both during autumn and spring ($P < 0·01$). During autumn, LWG of weaners grazing chicory was significantly higher than that of weaners grazing perennial ryegrass/white clover pasture ($P < 0·001$), and the forage × sex interaction was significant ($P < 0·05$), indicating a greater LWG response to

Table 6. *Expt 2. Chemical composition (% DM ± S.E.) of forage on offer and diet selected by red and hybrid weaner deer grazing either perennial ryegrass/white clover pasture or chicory during autumn, winter and spring in 1993*

	Pasture ($n = 7$)	Chicory ($n = 6$)
	Forage on offer	
Total N		
Autumn	3·32 ± 0·18	3·63 ± 0·18
Winter	4·08 ± 0·12	—
Spring	3·36 ± 0·08	3·13 ± 0·19
OMD		
Autumn	76·3 ± 1·26 (12·5)*	83·4 ± 0·91 (14·6)
Winter	87·2 ± 0·82 (12·0)	—
Spring	83·5 ± 0·53 (10·2)	86·4 ± 0·49 (13·7)
	Diet selected	
Total N		
Autumn	4·28 ± 0·24	3·19 ± 0·24
Winter	4·05 ± 0·08	—
Spring	3·61 ± 0·20	3·11 ± 0·10
Water-soluble	8·5 ± 1·45	14·4 ± 1·45
carbohydrate (*a*)		
Autumn	7·3 ± 2·16	14·6 ± 1·15
Winter	8·9 ± 1·63	—
Spring	8·1 ± 0·40	11·5 ± 1·06
Pectin (*a*)		
Autumn	1·4 ± 0·42	7·0 ± 0·50
Winter	1·1 ± 0·28	—
Spring	1·9 ± 0·26	6·0 ± 2·13
Cellulose (*b*)		
Autumn	20·4 ± 1·95	11·8 ± 1·34
Winter	21·4 ± 3·17	—
Spring	20·7 ± 0·57	12·8 ± 2·62
Hemicellulose (*b*)		
Autumn	20·5 ± 5·96	4·4 ± 2·47
Winter	16·0 ± 1·24	—
Spring	16·2 ± 3·22	5·7 ± 1·44
Ratio (*a*:*b*)		
Autumn	0·21 ± 0·10	1·39 ± 0·12
Spring	0·27 ± 0·12	0·95 ± 0·13
Lignin		
Autumn	1·3 ± 0·32	1·6 ± 0·41
Winter	1·1 ± 0·19	—
Spring	1·1 ± 0·16	1·8 ± 0·48
OMD		
Autumn	77·6 ± 1·25 (11·9)	85·8 ± 0·29 (15·5)
Winter	85·2 ± 0·45 (17·6)	—
Spring	84·8 ± 0·53 (12·6)	86·5 ± 0·58 (13·9)

* Ash content. 100 − ash content = OM content.
D.F. = 11.

grazing chicory in stags (especially hybrids) than hinds. In spring, LWG was similar for weaners grazing chicory or pasture, but there was some indication of a forage × genotype interaction, with the growth advantage of hybrid deer over red deer being greatest on chicory.

The effects of sex ($P = 0·06$) and genotype ($P < 0·01$) on age at weaning were significant, with hybrids being on average 8 days younger than pure red deer and stags on average 4 days younger than hinds. All liveweight data in Expt 2 was therefore adjusted to constant age (Table 8). These age effects were probably due to differences in gestation length.

The interaction between sex and genotype was significant ($P < 0·05$) for initial liveweight, with red deer stags and hybrid hinds being heaviest. Weaner

Table 7. *Expt 1. Growth of red (R) and elk red hybrid (H) deer calves grazing on perennial ryegrass/white clover pasture and chicory during lactation in summer 1994*

Forage…	Pasture				Chicory				
Sex…	Stag		Hind		Stag		Hind		S.E.
Genotype…	R	H	R	H	R	H	R	H	(D.F. = 31)
Number of animals	4	2	6	7	5	3	6	6	4
Calves									
Initial weight (kg)	29·6	35·3	25·8	28·7	29·5	29·7	26·1	29·4	2·0
Weight change (g/day)	358	375	314	356	402	490	332	391	36·0
Weaning weight (kg)	48·3	54·8	42·1	47·2	50·4	55·2	43·3	49·8	3·0
Hinds									
Weight change (g/day)	−17	−43	−27	−48	−139	−32	−106	−85	29·6

DM allowance was 12 kg DM/hind/day.

Table 8. *Expt 2. Liveweight and liveweight gain of red (R) and hybrid (H) weaner deer grazed on either perennial ryegrass/white clover pasture or chicory during autumn, winter and spring of 1993*

Forage…	Pasture				Chicory				
Sex…	Stag		Hind		Stag		Hind		S.E.
Genotype…	R	H	R	H	R	H	R	H	(D.F. = 39)
Number of animals	7	8	6	4	6	8	5	4	6
Mean initial age (days) (1.3.93)	97·0	88·6	100·2	94·1	97·0	88·6	100·2	94·1	3·1
Mean liveweight (kg)*									
Initial (1.3.93)	50·4	47·4	44·8	49·1	50·4	47·4	44·8	49·1	2·3
End autumn (8.6.93)	68·4	67·6	60·8	65·5	74·3	78·8	63·5	70·8	3·2
End winter (20.9.93)	87·4	83·3	71·8	77·4	88·4	99·6	75·1	81·4	4·0
End spring (12.12.93)	108·5	105·3	86·1	96·1	110·8	124·9	85·8	100·0	4·7
Liveweight gain (g/d)									
Autumn (99 days)	178	203	157	264	246	318	193	220	17·2
Winter (100 days)	171	146	98	113	127	193	103	93	13·6
Spring (79 days)	260	271	174	223	255	310	141	232	21·1

* Adjusted to equal age.

Table 9. *Expt 2. Carcass production from stags and hinds grazing either perennial ryegrass/white clover pasture or chicory and attaining slaughter liveweight (92 kg) by one year of age*

Sex...	Stags					Hinds		
Forage...	Pasture		Chicory		S.E.	Pasture	Chicory	S.E.
Genotype...	R	H	R	H	(D.F. = 24)	H	H	(D.F. = 6)
Number of animals	7	8	6	8	7	4	4	4
Number of animals attaining target slaughter LW (%)	7 (100)	7 (88)	6 (100)	8 (100)	—	3 (75)	2 (50)	—
Carcass weight (kg)	56·6	57·0	63·2	73·0	2·34	56·2	58·6	3·77
Dressing percentage (%)	54·1	54·1	58·4	58·6	0·45	54·4	58·6	0·25
GR tissue depth (mm)	3·2	3·1	5·7	7·1	0·70	5·7	8·3	0·83
Rump fat cover (mm)	109·1	105·9	105·7	125·7	3·95	115·7	118·8	1·94

R = pure red deer. H = hybrid (0·25 elk; 0·75 red).

deer that had grazed on chicory tended to have heavier liveweight than those that had grazed pasture at the end of autumn, at the end of winter and at the end of spring. Hybrid deer were heavier than pure red deer at the end of all three seasons ($P < 0·05$). The genotype × forage interaction was significant at the end of both autumn and spring ($P = 0·07$), explained by hybrid deer (especially stags) being heavier when grazed on chicory compared with pasture. Stags were significantly heavier than hinds at the end of all three seasons ($P < 0·01$) and there were no interactions involving sex, genotype and forage.

Effects of treatments on carcass production

Most stags and at least 50% of the hinds grazing either forage attained the target slaughter liveweight of 92 kg (Table 9). Stags grazing chicory had significantly higher carcass weight ($P < 0·001$) and dressing out percentage ($P < 0·001$) than those grazing perennial ryegrass/white clover pasture, whilst hybrid stags had a significantly higher carcass weight ($P <$ 0·05) than pure red deer stags. The interaction between forage and genotype was significant ($P = 0·06$) for carcass weight, with hybrid stags showing a much bigger response on chicory than on pasture. There was no interaction between forage and genotype for dressing out percentage. After being adjusted to equal carcass weight, carcass subcutaneous fat depth (GR) was higher ($P = 0·09$) for stags grazing chicory than for stags grazing perennial ryegrass/white clover pasture; there was no interaction between genotype and forage. The interaction between genotype and forage for rump fat cover was significant ($P < 0·05$), with hybrid stags grazing chicory having higher rump fat cover compared to the other groups.

Hybrid hinds grazing chicory had a significantly higher dressing out percentage ($P < 0·01$) than those grazing perennial ryegrass/white clover pasture. Although hinds grazing chicory tended to have greater carcass weight, GR and rump fat cover than those grazing perennial ryegrass/white clover pasture, none of the effects attained significance.

Effects of treatments on stomach characteristics

Stags grazing chicory had similar weights of digesta-free rumen and abomasal tissue, but reduced omasal weights ($P < 0·01$) relative to stags grazing pasture; stags grazing chicory also had reduced volume (i.e. capacity) of the emptied rumen ($P < 0·01$), reduced omasal volume ($P = 0·07$) and reduced weight and volume of rumen contents ($P < 0·01$; Table 10). Similar trends were evident in the hinds, with the weights of digesta-free rumen and omasal tissue ($P <$ 0·05) and the weight and volume of rumen contents ($P < 0·01$) being lower for deer fed chicory than those

Table 10. *Expt 2. Volume (l) and weight (kg) of the emptied rumen, omasum and abomasum organs, together with the weight and volume of rumen contents in deer grazing either perennial ryegrass/white clover pasture or chicory. All data are expressed per 100 kg liveweight*

Sex...	Stags		S.E.	Hinds		S.E.
Forage...	Pasture	Chicory	(D.F. = 22)	Pasture	Chicory	(D.F. = 6)
Number of animals	14	13	14	4	4	4
Rumen						
Volume (*A*)	10·38	7·26	0·760	9·13	6·78	1·812
Weight	1·96	1·98	0·063	2·27	1·93	0·085
Omasum						
Volume	0·30	0·14	0·057	0·18	0·12	0·029
Weight	0·18	0·13	0·090	0·18	0·11	0·016
Abomasum						
Volume	1·15	1·03	0·087	1·19	0·91	0·106
Weight	0·33	0·33	0·011	0·29	0·31	0·012
Rumen contents						
Volume	6·13	3·57	0·254	6·48	3·53	0·608
Weight (*B*)	5·86	3·48	0·492	5·31	3·15	0·195
Ratio (*B*:*A*)	0·57	0·48	0·055	0·64	0·51	0·121

Table 11. *Expt 2. Mean values for the length and width of rumen papillae in stags and hinds grazing either perennial ryegrass/white clover pasture or chicory*

Sex...	Stags		S.E.	Hinds		S.E.
Forage...	Pasture	Chicory	(D.F. = 22)	Pasture	Chicory	(D.F. = 6)
Number of animals	14	13	14	4	4	4
Roof (mm)						
Length	0·25	0·39	0·014	0·25	0·43	0·032
Width	0·08	0·16	0·006	0·08	0·14	0·006
Blindsac (mm)						
Length	0·82	0·85	0·048	0·85	0·81	0·013
Width	0·18	0·21	0·008	0·16	0·18	0·015
Atrium (mm)						
Length	0·84	1·06	0·025	0·93	0·86	0·225
Width	0·17	0·20	0·007	0·16	0·19	0·004

fed perennial ryegrass/white clover pasture. Rumen contents as a proportion of rumen capacity (ratio *B*:*A*; Table 10) was also consistently lower for stags and hinds grazing chicory than perennial ryegrass/white clover pasture.

Stags grazing chicory had significantly longer and wider rumen papillae in the roof ($P < 0.01$), and wider ($P < 0.01$) rumen papillae in the blindsac than those grazing perennial ryegrass/white clover pasture (Table 11). Similar trends were again evident in the hinds, with rumen papillae length and width in the roof and width in the atrium of hinds grazing chicory being significantly greater ($P < 0.01$) than those grazing perennial ryegrass/white clover pasture.

Voluntary feed intake (VFI) and grazing behaviour

Voluntary feed intake (VFI) of hinds grazing chicory in Expt 1 was significantly higher than those grazing pasture ($P < 0.01$; Table 12), whilst in Expt 2 VFI of deer weaners grazing chicory was significantly higher than those grazing pasture both in autumn ($P < 0.05$) and in spring ($P < 0.05$). For the deer grazing chicory, VFI tended to be higher for hinds suckling hybrid than red deer calves in Expt 1 (6147 *v.* 4609 g OM/day) and for growing hybrid than red deer in Expt 2, in both autumn (1562 *v.* 1396 g OM/day) and in spring (4439 *v.* 3633 g OM/day), but the effects did not attain significance.

Table 12. *Expts 1 and 2. Organic matter intake (OMI), eating and ruminating times of deer grazing either perennial ryegrass/white clover pasture or chicory during summer 1994 (lactating hinds) and during autumn and spring 1993 (weaner deer). Data are mean values for red and hybrid deer of both sexes grazing each forage*

	Pasture	Chicory	S.E. (D.F. = 40)
Expt 1 (lactating hinds)		Summer	
OMI (g/day)	3448	5378	428·9
Eating time (h/24 h)*	11·2	11·2	0·04
Rate of biting (bites/min)*	51·7	46·7	1·40
Bite weight (mg OM/bite)*	101	180	16·7
Ruminating time (h/24 h)*	6·1	2·6	0·03
Expt 2 (weaner deer)		Autumn	
OMI (g/day)	1170	1479	77·6
Eating time (h/24 h)*	10·9	8·7	0·51
Rate of biting (bites/min)*	52·1	34·1	2·06
Bite weight (mg OM/bite)*	35	86	3·0
Ruminating time (h/24 h)*	3·5	1·6	0·41
		Spring	
OMI (g/day)	3501	4038	180·0
Eating time (h/24 h)*	10·3	8·6	0·12
Rate of biting (bites/min)*	46·7	32·6	0·82
Bite weight (mg OM/bite)*	127	243	9·3
Ruminating time (h/24 h)*	3·3	2·0	0·11

* Error D.F. = 8.

Table 13. *Expt 2. Velvet antler production from red and hybrid yearling stags grazing either perennial ryegrass/white clover pasture or chicory during 1993*

Feed ...	Pasture		Chicory		
Genotype ...	Red	Hybrid	Red	Hybrid	S.E. (D.F. = 22)
Total number of stags	7	8	6	8	7
Stags producing velvet (%)	100	75	83	100	
First cut (g)	280 (7)*	269 (6)	349 (5)	399 (8)	58·2
Regrowth (g)	368 (3)	160 (1)	379 (5)	438 (7)	67·2
First cut and regrowth (g)	438 (7)	296 (6)	727 (5)	783 (8)	103·7
Mean date of first cut					
Uncorrected	29 Oct	15 Nov	4 Oct	14 Oct	8·28
Corrected†	23 Oct	10 Nov	3 Oct	23 Oct	8·25

* Number of stags per group.
† Corrected by covariate to equal liveweight at the end of winter.

Eating time of hinds grazing chicory or pasture was not significantly different (Table 12) in Expt 1, but hinds grazing chicory had a significantly lower rumination time ($P < 0·01$) and bite rate ($P < 0·05$) than those grazing perennial ryegrass/white clover pasture. In Expt 2, weaner deer grazing chicory spent significantly less time eating in autumn ($P < 0·05$), and in spring ($P < 0·01$) than those grazing pasture. Deer grazing chicory in Expt 2 spent less time ruminating in autumn ($P < 0·01$) and in spring ($P < 0·01$) compared to those grazing perennial ryegrass/white clover pasture. Bite rate of deer weaners grazing chicory was lower in autumn ($P < 0·001$) and in spring ($P < 0·001$). Calculated bite weight was significantly higher for deer grazing chicory than pasture, for lactating hinds in Expt 1 ($P < 0·001$) and for weaner deer in autumn ($P < 0·001$) and in spring ($P < 0·05$).

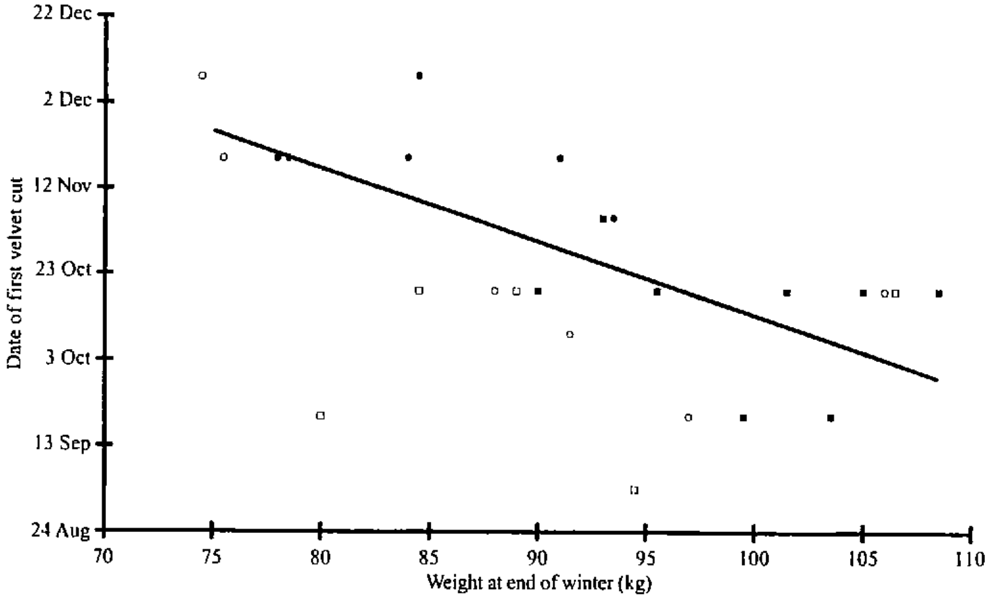

Fig. 1. The relationship between date of first-cut velvet antler and liveweight at the end of winter of red deer on pasture (○), hybrid deer on pasture (●), red deer on chicory (□) and hybrid deer on chicory (■).

Velvet antler production

Relative to grazing on pasture, grazing on chicory tended to increase the weight of first cut velvet ($P = 0{\cdot}12$) and significantly increased the combined weight of first cut and regrowth velvet ($P < 0{\cdot}01$; Table 13). Grazing deer on chicory advanced the mean date of first cut velvet antler by 28 days ($P < 0{\cdot}01$). A number of liveweight (W) relationships were examined, and the date of first velvet cut (D) was found to be best correlated with liveweight at the end of winter (Fig. 1; Eqn (6)). Each 10 kg increase in liveweight (W) at the end of winter advanced the date of first velvet cut by an average of 9·3 days. When liveweight at the end of winter was used as a covariate (Table 13), grazing on chicory still advanced the date of first velvet cut ($P < 0{\cdot}05$), but the advancement was reduced to 16 days. First-cut velvet was on average 14 days later for hybrid than for pure red deer stags ($P = 0{\cdot}13$); there were no forage × genotype interactions for any of the velvet measurements.

$$D = 151 - 0{\cdot}93W$$
$$\text{S.E.} = \pm 0{\cdot}47 \qquad (6)$$

DISCUSSION

The most important results in the present study were the greater carcass weight of deer grazing chicory compared to those grazing pasture, and the greater carcass weight responses of hybrid deer on chicory than on pasture, indicating that the superior genetic potential of hybrid stags for growth can best be expressed when grazing a high nutritive value forage. Components of the superior carcass weight on chicory included a greater carcass dressing out percentage than for deer grazing pasture and superior growth rates relative to pasture-fed deer during summer and autumn. Studies with red clover (Niezen *et al.* 1993; Semiadi *et al.* 1993) have shown that inputs of this plant increased deer carcass production through increasing carcass dressing out percentage and by increasing LWG, mainly during summer and autumn. Relative to the perennial ryegrass-based pastures, the chicory used in Expts 1 and 2 was of higher OMD and VFI was higher during summer, autumn and spring (Tables 5, 6 and 12). Hence grazing chicory promoted greater levels of deer production than grazing pasture in terms of deer calf and weaner growth, especially for hybrid stags. The higher ratio of readily fermentable CHO: structural CHO must be associated with the higher OMD value of chicory compared to pasture, as total N of chicory was lower than that of pasture. The CHO composition and OMD of chicory showed little change between seasons, but pasture changed with season, being of lowest OMD in summer and highest OMD in spring. Adam (1988) stated that moisture stress during summer leads to higher contents of structural CHO in pasture, lowering its digestibility. These observations indicated that pasture is of lowest feeding value during summer and autumn, and the nutritional advantages of chicory over pasture are likely to be greatest over these periods, thus explaining the LWG responses of chicory-fed deer over this period. As grazing time was either similar (Expt 1) or less (Expt 2) for deer grazing chicory than those on pasture and as bite rate was consistently lower for deer grazing chicory, it is evident that the principal means by which deer grazing chicory increased their VFI relative to deer grazing pasture was through increased bite weight.

Data from grazing behaviour observations showed that deer grazing chicory spent only slightly less time eating but substantially less time ruminating than those grazing pasture. This result agreed with that of Hoskin *et al.* (1995) that deer fed freshly-cut pure chicory indoors spent a similar time eating (361 *v.* 379 min/24 h) but markedly less time ruminating (33 *v.* 270 min/24 h) than those fed perennial ryegrass. The function of the rumination process is to reduce particle size until the critical size is reached which allows a high probability of leaving the rumen (Ulyatt *et al.* 1986) and for deer this has been defined as passage through a 1 mm sieve (Domingue *et al.* 1991). The shorter ruminating time in deer fed chicory suggests that particles of this feed can be broken down to the critical particle size and passed out of the rumen faster than perennial ryegrass, and this is supported by the reduced weight and volume of rumen digesta in the deer fed chicory. This, together with the reduced volume of the emptied rumen in deer fed chicory, suggests that digestion of this plant caused less distension of the rumen than digestion of perennial ryegrass/white clover pasture, offering a further reason for the increased VFI on chicory. Deer grazing chicory had longer and wider rumen papillae compared to those grazing perennial ryegrass/white clover pasture (Table 11). The mean length and width of rumen papillae in calves increased in response to feeding grain or intraruminally administered volatile fatty acid (VFA) solutions, with butyrate being more potent than propionate and acetate (Sander *et al.* 1959; Tamate *et al.* 1962). The higher values of rumen papillae of deer grazing chicory compared to those grazing perennial ryegrass/white clover pasture can therefore be explained from the higher butyrate proportions found from the digestion of chicory (Hoskin *et al.* 1995).

The higher carcass subcutaneous fat depth (GR) of deer grazing chicory compared to those grazing pasture was probably related to the difference in the end products of rumen fermentation and efficiency of their utilization, as Hoskin *et al.* (1995) reported that chicory produced a rumen fermentation with a higher acetate:propionate ratio and greater *n*-butyrate proportions than perennial ryegrass. This finding contrasts with the generally accepted hypothesis that diets with a higher ratio of readily fermentable CHO:structural CHO produce rumen fermentations with a lower acetate:propionate ratio (Ulyatt 1973). Higher production of acetic and *n*-butyric acids in chicory compared to perennial ryegrass pasture probably contributed to the GR value being higher grazing chicory than in those grazing pasture, as the excess of acetic acid production in the rumen can be incorporated directly into adipose tissue (Butler-Hogg & Cruickshank 1989).

Stags grazing chicory had higher total velvet weight and earlier first velvet cut compared to those grazing pasture (Table 13). Fennessy & Suttie (1985) stated that pedicle initiation is highly correlated with body weight and is dependent on the level of nutrition. Suttie & Kay (1983) reported that stags fed to appetite advanced pedicle initiation by 12 weeks compared to those under restricted feeding. P. F. Fennessy (unpublished, cited by Fennessy & Suttie (1985)) reported that feeding pelleted feed (barley-lucerne-linseed) *ad libitum* advanced pedicle initiation of stags by 6 weeks compared to those given meadow hay. That stags grazing chicory in this study had an earlier first velvet cut than those grazing pasture suggests that chicory is able to advance pedicle initiation; hence total velvet weight was higher. It seems that grazing chicory advanced the date of first velvet cut in the yearling stags by two mechanisms; first by increasing liveweight and second by a nutritional effect independent of liveweight. Semiadi *et al.* (1993) found that yearling stags grazing red clover had superior LWG but similar spiker velvet antler production as that of young stags grazing pasture. The cause of the independent nutritional effect in stags grazing chicory is unknown and warrants further investigation.

If chicory is to be included in deer production systems under grazing conditions, it is very important to maintain a high proportion of leaf relative to stem, because an increase in the proportion of reproductive stem leads to a decrease in forage quality. Li *et al.* (1994) reported that the primary reproductive stem of chicory was controlled by hard grazing (50 mm stem height), and that this maximized leaf mass. Light grazing of chicory with sheep resulted in a lower leaf:stem ratio compared to medium, hard and very hard grazing (Li *et al.* 1994). Chicory continues to produce relatively less vigorous secondary reproductive stems once the primary stems are controlled, but these are less detrimental to leaf growth and forage quality than the primary stems.

In conclusion, carcass weights of 50–65 kg can be achieved by < 1 year of age by grazing stags on chicory, and hybrid stags showed greater growth and carcass weights than pure red stags when they were grazed on chicory. Higher VFI and OMD, coupled with lower ruminating times of deer grazing chicory compared to those grazing pasture suggested faster rumen particle breakdown occurring on chicory relative to pasture. Further research is needed to determine the efficiency of rumination on particle size breakdown in deer fed chicory. Also, an experiment to investigate outflow rate of digesta needs to be done to explain the high VFI and high levels of production in deer grazing chicory.

The authors are grateful for the assistance of G. S. Purchas, W. C. L. Howell, W. L. Wong and G. Semiadi, who assisted with data collection. R. W. Purchas is acknowledged for his guidance in carcass measurements. The skilled assistance of Nutrition Laboratory staff, Massey University, is also acknowledged. Massey University acknowledges financial assistance from AgVax Developments, Aspiring Animal Services, Bayer, Farmers Mutual Group, Gallagher Electronics, Merck Sharp & Dohme, Mitchpine, Ravensdown, Petrochem, Wiremakers and Wrightson.

REFERENCES

ADAM, J. L. (1988). Pasture for deer production. *Proceedings of the New Zealand Grassland Association* **49**, 37–40.

ATAJA, A. M., WILSON, P. R., BARRY, T. N., HODGSON, J., HOSKINSON, R. M., PARKER, W. J. & PURCHAS, R. W. (1992). Early venison production from red deer (*Cervus elaphus*) as affected by grazing perennial or annual ryegrass pastures, pasture surface height and immunization against melatonin. *Journal of Agricultural Science, Cambridge* **118**, 353–369.

BAILEY, R. W. (1967). Quantitative studies of ruminant digestion. II. Loss of ingested plant carbohydrates from the reticulo-rumen. *New Zealand Journal of Agricultural Research* **10**, 15–32.

BUTLER-HOGG, B. W. & CRUICKSHANK, G. J. (1989). The effect of environmental factors on growth and development. In *Meat Production and Processing* (Eds R. W. Purchas, B. W. Butler-Hogg & A. S. Davies), pp. 87–101. *New Zealand Society of Animal Production Occasional Publication No. 11*.

COSTIGAN, P. & ELLIS, K. J. (1987). Analysis of faecal chromium from controlled released devices. *New Zealand Journal of Technology* **3**, 89–92.

DOMINGUE, B. M. F., DELLOW, D. W., WILSON, P. R. & BARRY, T. N. (1991). Comparative digestion in deer, goats and sheep. *New Zealand Journal of Agricultural Research* **34**, 45–53.

FENNESSY, P. F. & SUTTIE, J. M. (1985). Antler growth: nutrition and endocrine factors. In *Biology of Deer Production* (Eds P. F. Fennessy & K. R. Drew), pp. 239–250. *Royal Society of New Zealand Bulletin 22*.

HODGSON, J. (1982). Ingestive behaviour. In *Herbage Intake Handbook* (Ed. J. D. Leaver), pp. 113–138. Maidenhead: The British Grassland Society.

HOSKIN, S. O., STAFFORD, K. J. & BARRY, T. N. (1995). Digestion, rumen fermentation and chewing behaviour of red deer fed fresh chicory and perennial ryegrass. *Journal of Agricultural Science, Cambridge* **124**, 289–295.

HUNT, J. F. & HAY, R. J. M. (1990). A photographic technique for assessing the pasture species performance of grazing animals. *Proceedings of the New Zealand Grassland Association* **51**, 151–196.

HUNT, W. F. (1993). Maximising red deer venison production through high quality pasture. In *Proceedings of the XVII International Grassland Congress* (Eds M. J. Baker, J. R. Crush & L. R. Humphreys), pp. 1497–1500. Palmerston North: Keeling and Mundy Ltd.

JAMIESON, W. S. & HODGSON, J. (1979). The effect of daily herbage allowance and sward characteristics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. *Grass and Forage Science* **34**, 261–271.

KIRTON, A. J. (1989). Principles of classification and grading. In *Meat Production and Processing* (Eds R. W. Purchas, B. W. Butler-Hogg & A. S. Davies), pp. 143–157. *New Zealand Society of Animal Production Occasional Publication No. 11*.

LI, G., KEMP, P. D. & HODGSON, J. (1994). Control of reproductive growth in puna chicory by grazing management. *Proceedings of the New Zealand Grassland Association* **56**, 213–217.

NIEZEN, J. H., BARRY, T. N., HODGSON, J., WILSON, P. R., ATAJA, A. M., PARKER, W. J. & HOLMES, C. W. (1993). Growth responses in red deer calves and hinds grazing red clover, chicory or perennial ryegrass/white clover swards during lactation. *Journal of Agricultural Science, Cambridge* **121**, 255–263.

PARKER, W. J., MCCUTCHEON, S. N. & CARR, D. H. (1989). Effect of herbage type and level of intake on the release of chromic oxide from intraruminal controlled release capsules in sheep. *New Zealand Journal of Agricultural Research* **32**, 537–546.

ROUGHAN, P. G. & HOLLAND, R. (1977). Predicting in-vivo digestibilities of herbages by exhaustive enzyme hydrolysis of cell walls. *Journal of the Science of Food and Agriculture* **28**, 1057–1064.

SANDER, E. G., WARNER, R. G., HARRISON, H. N. & LOOSLI, J. K. (1959). The stimulatory effect of sodium butyrate and sodium propionate on the development of rumen mucosa in the young calf. *Journal of Dairy Science* **42**, 1600–1605.

SEMIADI, G., BARRY, T. N., WILSON, P. R., HODGSON, J. & PURCHAS, R. W. (1993). Growth and venison production from red deer (*Cervus elaphus*) grazing red clover (*Trifolium pratense*) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture. *Journal of Agricultural Science, Cambridge* **121**, 265–271.

SOETRISNO, E., BARRY, T. N., WILSON, P. R., HODGSON, J. & PURCHAS, R. W. (1994). Effects of grazing red clover (*Trifolium pratense*) or perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pastures upon growth and venison production from weaner red deer (*Cervus elaphus*). *New Zealand Journal of Agricultural Research* **37**, 19–27.

STAFFORD, K. J. (1995). The stomach of the sambar deer (*Cervus unicolor*). *Anatomia, Histologia, Embryologia* **24**, 241–250.

STATISTICAL ANALYSIS SYSTEM (1987). *SAS/STAT Guide for Personal Computers, Version 6*. Cary, US: SAS Institute.

SUTTIE, J. M. & KAY, R. N. B. (1983). The influence of nutrition and photoperiod on the growth of antlers of young red deer. In *Antler Development in Cervidae* (Ed.

R. D. Brown). pp. 61–71. Texas A and M University Press.

TAMATE, H., MCGILLIARD, A. D., JACOBSON, N. L. & GETTY, R. (1962). Effect of various dietaries on the anatomical development of the stomach in the calf. *Journal of Dairy Science* 45, 408–420.

ULYATT, M. J. (1973). The feeding value of herbage. In *Chemistry and Biochemistry of Herbage, Vol. 3* (Eds G. W. Butler & R. W. Bailey), pp. 131–178. London: Academic Press.

ULYATT, M. J., DELLOW, D. W., JOHN, A., REID, C. S. W. & WAGHORN, G. C. (1986). Contribution of chewing during eating and rumination to the clearance of digesta from the reticulorumen. In *The Control of Digestion and Metabolism in Ruminants: Proceedings of the Fourth International Symposium on Ruminant Physiology* (Eds L. P. Milligan, W. L. Grovum & A. Dobson), pp. 488–517. New Jersey: Reston Books.

VAN SOEST, P. J. (1994). *Nutritional Ecology of the Ruminant*. Ithaca & London: Cornell University Press.