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Early venison production from red deer (*Cervus elaphus*) as affected by grazing perennial or annual ryegrass pastures, pasture surface height and immunization against melatonin

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SUMMARY

Two grazing experiments in New Zealand, using newly weaned red deer stags, assessed methods of maximizing growth over winter and spring, with the objective of attaining a slaughter weight of 92 kg liveweight (> 50 kg carcass) at the end of spring, by 12 months of age. Perennial ryegrass/white clover pastures, and the same direct-drilled with an annual ryegrass, were grazed at two surface heights (5 cm and 10 cm; Experiment 1; 1988) or at similar pasture mass (Experiment 2; 1989). Balanced groups of stags grazing each forage were immunized against melatonin, commencing at 3 months of age (Expt 1) or at birth (Expt 2). Moata annual ryegrass comprised 19–46% of the feed on offer in Expt 1 and 65–82% in Expt 2. Perennial ryegrass comprised 79–89% of control pastures and white clover generally comprised < 10% of all pastures. Organic matter digestibility of both the feed on offer and diet selected, determined with deer fistulated in the rumen or oesophagus, was 75–80%.

In Expt 1, rates of body growth during winter were greater for stags grazing at 10 cm than at 5 cm pasture height, with no effect due to the inclusion of annual ryegrass. During spring, growth rates were similar for stags grazing 10 cm pastures and the 5 cm pasture containing annual ryegrass, but were lower on 5 cm pasture based on perennial ryegrass. Inclusion of annual ryegrass slightly increased winter rates of herbage dry matter accumulation, animal carrying capacity and the proportion of stags attaining target slaughter weight.

In Expt 2, annual ryegrass pastures were of higher organic matter digestibility than perennial pastures during winter, and supported greater rates of liveweight gain (LWG) and voluntary feed intake (VFI) than the perennial ryegrass. During spring, LWG increased in both groups of stags although the difference between the two groups ceased to be significant. More of the animals grazing annual ryegrass pastures attained target slaughter weight than those grazing perennial pasture. Rumen acetate:propionate ratio, measured in fistulated stags, was similar for both groups of animals. Relative to perennial ryegrass, pastures containing high proportions of annual ryegrass resulted in similar animal carrying capacity during winter but substantially lower carrying capacity in spring.

Antibodies binding melatonin were detected in 75% of immunized animals, with higher and more persistent titres being obtained using Freund's than using Dextran adjuvant and titre being much higher in stags immunized at birth than at 3 months of age. This was associated with a small and variable increase in plasma prolactin concentration, but had no effect upon plasma concentrations of LH or testosterone or upon LWG.

It was concluded that the small increase in deer production attributable to annual ryegrass was mainly due to higher VFI, and that grazing perennial ryegrass/white clover pastures at 10 cm surface height resulted in higher levels of deer production than grazing at 5 cm surface height. These studies emphasise the feasibility of early venison production from grazed pastures in New Zealand, and show that the young deer were growing close to their genetic potential under this system.

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INTRODUCTION

Deer farming (mainly of the red deer, *Cervus elaphus*) has now been practised in New Zealand (NZ) for 21 years, with the population of farmed deer now being 1·1m and predicted to be 2·9m by 1996 (NZ Game Industry Board, personal communication). However, there have been few investigations on applied nutrition of grazing deer. In order to meet the requirements of Northern Hemisphere markets it is desirable to produce venison in NZ of > 50 kg carcass weight (92 kg liveweight) in the August–November period (spring). Since red deer in NZ calve during November and December (late spring/early summer), the most economic means of achieving this objective is to develop a venison production system which achieves the above criteria by 12 months of age or less, using grazed forages as the sole diet.

Young deer are normally weaned in NZ during March (autumn). Hence, to meet the above requirements, rapid rates of liveweight gain (LWG) are needed in both winter and spring. Winter growth presents problems, as both pasture production (Korte *et al.* 1987) and deer growth rates (Kay 1985) are low at this time. Pastures in NZ are based on perennial ryegrass, which is of lower nutritive value to sheep than annual or short rotational ryegrasses (Ulyatt 1971, 1981). Annual ryegrass (e.g. 'Grasslands Moata') also has better winter dry matter (DM) production (Armstrong 1981) and is a tetraploid plant. The objective of this investigation was to study the feasibility of a 12-month venison production system from red deer, based solely upon grazed pastures, and to investigate factors that could improve its efficiency. Hence, pastures based upon perennial ryegrass were compared with the same direct-drilled with Moata annual ryegrass in two experiments, the first using two pasture heights and the second maintaining a constant pasture mass. To gain an understanding of the factors contributing to deer growth, measurements were made of herbage accumulation rate, botanical composition and nutritive value of both the feed on offer and of the diet selected, voluntary feed intake and the end-products of rumen digestion. Carcass weight and indirect measures of carcass fatness were measured at slaughter, to assess the effects of stimulating growth upon venison yield and composition.

As the cycles of both voluntary feed intake (VFI) and growth in seasonal breeds of deer are probably entrained to photoperiod by secretion of melatonin from the pineal gland (Barry *et al.* 1991; Domingue *et al.* 1992), a second objective was to evaluate active immunization against melatonin as a possible means of increasing LWG during winter and early spring.

MATERIALS AND METHODS

Experiment 1

Experimental design

Weaner red deer stags (*Cervus elaphus*) were grazed under continuous set stocking at two sward heights (5 and 10 cm) on either perennial ryegrass/white clover pasture or the same direct-drilled with Moata annual ryegrass during 1988. Half of the animals within each grazing treatment group were immunized against melatonin.

Animals

Fifty-two weaner red deer stags *c.* 4·5 months old were purchased and transported to Massey University in April 1988. The stags were exposed to electric fences and were herded into the handling yards at intervals in the pre-experimental period, to accustom them to the handling routine. They were also offered supplements of barley grain to get them used to contact with people.

On 15 April, the stags were divided into four groups. Two groups of 14 stags were randomly allocated to the two annual ryegrass treatments (5 and 10 cm), whilst the other two groups of 12 stags were randomly allocated to the two perennial pasture treatments (5 and 10 cm). Each group was further subdivided at random into two subgroups of seven (annual treatments) and six (perennial treatments) for immunization against melatonin. All 14 or 12 stags in each treatment grazed together as a single group. Mean liveweight (kg) at the time of allocation to grazing treatments was 55·2 ± 3·63 (S.D.).

Rumen fistulated stags

Eight 3·5-year-old, castrated, hand-reared, rumen-fistulated red deer stags of mean liveweight 99 ± 9·1 kg (S.D.) were randomly allocated to the four grazing groups (2 stags/group) for study of diet selection. In June and November, the fistulated stags were allowed to graze with their respective groups for 4 days and then were sedated, using 20 mg xylazine (Rompun; Bayer NZ Ltd) intramuscularly. Under mild sedation, the entire rumen digesta was removed and maintained at 40 °C. One litre of artificial saliva (Baumgardt *et al.* 1962) was introduced into the rumen and the cannula replaced. The stags were each given 0·25 mg/kg yohimbine hydrochloride (Recervyl; Aspiring Animal Services, Wanaka, NZ) intravenously, to reverse the sedation. After 45 min they were returned to their respective grazing groups for 2 h. The freshly eaten ingesta was then bailed out of the rumen without further sedation and the warmed rumen digesta replaced. Bailing was carried out over a period of 3 days, using two or three stags per day.

Pasture management

The stags were grazed under a continuous stocking system at two different sward heights (5 and 10 cm), on either perennial ryegrass/white clover pastures (hereafter referred to as 'perennial') or the same direct-drilled with Moata annual ryegrass (hereafter referred to as 'annual'). Paddocks comprised 1 ha each maintained at 5 cm height of both perennial and annual ryegrass and 1·50 ha each maintained at 10 cm height of both perennial and annual ryegrass.

The annual paddocks were direct-drilled with band spraying on 1 March 1988 at 20 kg seed/ha, using a cross-pass drilling technique (Baker 1976) at 10 kg seed/pass. A molluscicide, metaldehyde (Blitzem pellets; Yates NZ Ltd, Auckland) was applied to the direct-drilled paddocks at 12 kg/ha on 2 March 1988. All paddocks were top-dressed with urea on 15 May, at 100 kg urea (46 kg N)/ha, and on 29 June and 19 July with 50 kg urea (23 kg N)/ha. On 20 October 1988, the four main paddocks were top-dressed with 100 kg urea (46 kg N)/ha.

The target sward heights of *c.* 5 and 10 cm were established on the annual treatments at the same time as the perennial 5 cm treatment (6 May) and these paddocks were stocked with stags. The target sward height of 10 cm was achieved on the perennial treatment on 23 May, and it was stocked with stags on the same day. The experiment commenced on 30 May 1988. Sward heights were monitored thrice weekly (Monday, Wednesday and Friday), using a rising plate meter (Hammond Doyle Co Pty Ltd, Australia). Fifty random plate meter readings were recorded for each paddock and the mean sward height for each paddock calculated. Stocking rate adjustments to compensate for sward height changes were made as described by Hodgson *et al.* (1986), with non-experimental stock being introduced as required to maintain target herbage surface heights.

Pasture production and composition

Pasture accumulation rates (kg DM/day) and herbage mass on offer (kg DM/ha) were measured during winter and spring. Five quadrat (0·2 m^2) herbage sample cuts made to soil level were taken from areas corresponding to the target sward heights (5 or 10 cm) in each main paddock. The herbage samples were then washed, oven dried at 90 °C for 17 h and weighted to determine the herbage mass (kg DM/ha). Five adjacent areas of similar sward height were protected by metal cages (90 × 46 × 33 cm). Three weeks later, five quadrat sample cuts, made to soil level, were taken from inside the cages. The herbage samples were washed, oven dried and weighed. Pasture accumulation rate over the 3-week period was obtained from the difference between the mean herbage mass (kg DM) of the two sampling dates. Rates of pasture accumulation were measured every 3 weeks, with the cages being moved to new areas.

Five random herbage sample cuts made just above soil level were also taken from each main paddock every month for laboratory *in vitro* digestibility analyses, total nitrogen determination and botanical dissection. The herbage samples were not washed.

Experiment 2

Experimental design

Weaner red deer stags were grazed under a rotational grazing system on either perennial ryegrass/white clover pasture ($n = 18$) or the same direct-drilled with Moata annual ryegrass ($n = 18$) during 1989, with equal numbers of animals grazing each pasture type being given different vaccination treatments to immunize against melatonin.

Animals

Thirty-six weaner red deer stags of mean liveweight 52·9 ± 5·85 kg (S.D.) were assigned to two mixed pasture sward types (perennial ryegrass/white clover and the same direct-drilled with 'Grasslands Moata' annual ryegrass) on 15 May 1989.

To estimate faeces output, all stags were orally dosed with sheep-type intraruminal chromium controlled release devices (CRC; 3·0 cm core, 65 % Cr_2O_3 Matrix, 9·00 mm orifice diameter), on 14 June and 2 November 1989 (Captec Ltd, Auckland, NZ). All estimations of faecal output were made 8–21 days post-CRC dosing, during the period of linear Cr release (Parker *et al.* 1989). Faecal output was estimated either directly from the sward, from within marked sites of 2 m radius (ring sampling; Raymond & Minson 1955) in both winter and spring, or by rectal sampling of individual animals (spring only). Ten sites per paddock were used for ring sampling, with pooled samples for annual and perennial ryegrass pastures taken daily from days 9 to 18. Rectal samples were taken from individual animals (spring only) on days 17, 19 and 21 post-CRC dosing. During the period of ring sampling, the deer grazing each pasture type were separated into the three vaccination groups, to provide replicates.

Oesophageal fistulated (OF) stags

Five 5-month-old, castrated, hand-reared OF red deer stags of mean liveweight 50 ± 3·5 kg (S.D.) were randomly allocated to the two grazing groups (2 or 3 stags/group) for diet selection studies. From June 1989, the OF stags were allowed to graze with their respective groups for 4 days, after which they were brought into the yard and fasted for 3 h. Their fistula plugs were then removed, plastic sample collection bags were fitted around their necks and they were

then allowed to graze for 40 min, after which the extrusa samples were collected. The stags were then sedated, using 20 mg xylazine (Rompun; Bayer, NZ) intramuscularly, and the plugs replaced. The stags were then given yohimbine hydrochloride (Recervyl; Aspiring Veterinary Services, NZ) intramuscularly at 0·25 mg/kg for the reversal of sedation and were returned to their paddock. Extrusa samples were collected twice monthly until November, with animals being changed to the other sward type after each sampling.

Rumen fistulated stags

Seven 4·5-year-old, castrated, hand-reared, rumen-fistulated red deer stags of mean liveweight 115 ± 8·5 kg (S.D.) were randomly allocated to the two grazing groups (3 or 4 stags/group) for rumen fluid sampling for volatile fatty acid (VFA) and NH_3 determination.

In September 1989, the fistulated stags were allowed to graze with their respective groups for 4–5 days. After the initial grazing period, a metal probe encased in polyester fibre, which acted as a filter, with a pore size of 80 μm (Estal Mono; Swiss Screens Ltd, Australia) was inserted into the rumen of each stag. The probes were attached to plastic tubes drilled through holes in rubber fistula-bungs for ease of rumen fluid sampling. The stags were allowed to graze until the next day, when rumen fluid samples were taken from each animal via the plastic tubes using 20 ml syringes. Rumen fluid samples were taken thrice monthly at 13.00 h (September–November), with animals being changed to the other sward type after each sampling in order to avoid any animal effects.

Pasture management

The stags were grazed under a rotational grazing system, with 5- and 3-week periods in between grazing during winter and spring respectively. The animals grazed either perennial ryegrass/white clover swards ('perennial') or pasture direct-drilled with Moata annual ryegrass ('annual'), at levels of herbage DM mass of 2100 reducing to 1600 kg DM/ha (pre- and post-grazing). The perennial swards were grazed from 10 cm (initial) to 8 cm (final) height measured by rising plate meter during winter and spring; the annual swards were grazed from 16 to 12 cm during early winter and, as the tiller density of the sward increased, they were grazed from 12 to 10 cm from late winter through spring. The sward heights were based on 6-weekly calibration curves produced from herbage cuts. The different initial heights were selected so that perennial and annual pasture swards of the same mass (2100 kg DM/ha) were offered pre-grazing.

Each sward type comprised 2·75 ha areas divided into five plots. The annual pasture paddocks were direct-drilled (blanket-sprayed with herbicide) using the cross-pass technique (Baker 1976) on 23 March 1989 at 24 kg seed/ha (12 kg seed/pass), together with an molluscicide (Thimet 20G (200 g/kg phorate granules; ICI, NZ Ltd)) at 5 kg/ha. Superphosphate fertilizer was applied to all paddocks on 14 April 1989 at 250 kg/ha. All annual pasture swards were grazed by the weaner stags in a group between 28 April and 14 May, in order to encourage the annual ryegrass to tiller. The target sward heights (10 cm for perennial and 16 cm for annual sward) were achieved on 15 May 1989, when the stags were allocated to their respective groups and the experiment commenced. All paddocks were top-dressed with urea on 23 May and 25 July at 80 kg/ha (36·8 kg N/ha). The sward heights were monitored thrice weekly and maintained at the target heights as described for Expt 1. Occasionally, non-experimental animals were introduced into the paddocks to clean up post-grazing residues in order to ensure clean swards and to maintain target pasture heights.

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

Animal health

All animals were given 0·4% w/v ivermectin at 200 μg/kg LW (Ivomec; Merck Sharpe and Dohme, NZ) orally and were vaccinated against clostridial infections (Convax 5; Pitman Moore, NZ) at the start of the experiment. Thereafter, they were weighed at 3-weekly intervals, and further drenched with Ivomec at monthly intervals.

Vaccination procedures and blood sampling

The anti-melatonin vaccine was prepared in two different adjuvants; Freund's and diethylaminoethyl dextran (DEAE-dextran), hereafter referred to as the Freund's and Dextran groups. A single dose of the anti-melatonin vaccine comprised 1 mg antigen (5-methoxy-tryptamine hemisuccinamide conjugated to human serum albumin (HSA)), 1 ml physiological saline (9 g NaCl/l), and 1 ml Freund's or Dextran adjuvant. Vaccine for the primary immunization of animals in the Freund's groups was prepared using Freund's complete adjuvant, while Freund's incomplete adjuvant was used for the subsequent booster injections.

In Expt 1, vaccinated stags received primary subcutaneous injections at weaning in March 1988, 1 ml at two separate sites either side of the neck (1 mg antigen/stag) using Freund's adjuvant. First and second booster injections were given in the same

manner on 9 June and 7 July. Control stags were not vaccinated.

In each grazing group ($n = 18$) in Expt 2, the stags were randomly assigned to the three treatments (none, Freund's and Dextran) within 2 days of birth (November/December 1988). The primary subcutaneous injection comprised 1 ml at two separate sites either side of the neck at the rate of 1 mg antigen/stag. First and second booster injections were given in the same manner on 28 February (at weaning) and on 15 May 1989.

Blood (10 ml) was taken from the jugular vein of all animals by venipuncture on the day of the first booster injection (bleeding before booster vaccination given), 7 days post-booster, 4 weeks post-booster and at monthly intervals thereafter until November. The blood samples were collected in 10 ml vacutainers (Nipro Medical Industries Ltd, Japan), using Na heparin as an anticoagulant. The blood samples were centrifuged at 4 °C, at 1850 *g* for 20 min to obtain plasma for measuring melatonin antibodies (titre) and for hormone determinations. Each plasma sample was stored at −20 °C in five 1 ml portions.

Slaughter and carcass data

All stags that attained or exceeded the target weight of 92 kg LW were sent for slaughter at the Deer Slaughter Premises of Venison New Zealand at the end of November in both years. Rump fat width (from the carcass dorsal midline to the lateral margin of the rump subcutaneous fat depot), carcass weights and GR tissue depth were recorded for both left and right sides of all carcasses and the testes were weighed. GR is an indirect measure of carcass fatness, and in deer is defined as the soft tissue depth (mm) over the 12th rib measured 16 cm from the carcass midline (Kirton 1989).

Laboratory methods

Herbage and extrusa samples were stored at −20 °C and freeze-dried and ground (1 mm sieve) before analysis. *In vitro* digestibility was determined by the method of Roughan & Holland (1977), total nitrogen (N) by the Kjeldahl method and VFA by gas liquid chromatography as described by Domingue *et al.* (1991). Faecal samples were stored at −20 °C, and oven dried at 60 °C for 48 h to constant weight. 1·0 g faeces DM/animal of the individual rectal samples were ashed overnight at 500 °C. The group faecal samples were bulked across days (5 days/bulk) and ground (1 mm sieve). The samples were thoroughly mixed and a 1·0 g faecal sample in duplicate for each treatment was ashed overnight at 500 °C. Chromium analysis was done as described by Parker *et al.* (1989).

Fresh herbage samples were stored at 4 °C, sorted into individual plant species, and dried at 100 °C for 16 h. Extrusa samples were analysed using a flotation technique (D. A. Clark, personal communication). The samples were separated into perennial ryegrass, Moata annual ryegrass, white clover, other species and dead matter. Results were expressed as percentages.

The anti-melatonin antibody titre was measured by the method of Abraham (1974), as described by Ataja *et al.* (1992). Plasma lutcinizing hormone (LH) was determined using the procedure of Scaramuzzi *et al.* (1970) for sheep plasma and validated for fallow deer plasma by Asher *et al.* (1986); plasma testosterone by the method of Peterson *et al.* (1978) and plasma prolactin by the method of van Landeghem & van der Weil (1978) as adapted for deer plasma (Ataja *et al.* 1992).

Statistical analyses and calculations

The experimental data was analysed using General Linear Models (GLM), as factorial designs, with sward types (perennial and annual), sward height and types of vaccination (none, Freund's and Dextran) being factors. Rump fat width and GR data were analysed using carcass weight as a covariate. Pasture M/D values (MJ metabolizable energy/kg DM) were calculated as DOMD (g digestible organic matter/100 g DM) × 16·3. As there was no interaction between effects of pasture type and immunization treatment ($P > 0{\cdot}05$), main effects only (pasture and immunization) are presented in the results.

Voluntary food intake (VFI) was calculated from faecal output (F) and *in vitro* digestibility (D) using the relationship:

$$\text{VFI} = \frac{\text{F}}{1-\text{D}}$$

RESULTS

Experiment 1

Herbage mass and botanical composition

Moata annual ryegrass content in the direct-drilled areas was 33–46% of the total DM during winter and 19–22% during spring, with the lower values being in the 10 cm paddocks (Table 1). Perennial ryegrass comprised 81–89% DM in perennial (control) pastures and 30–59% DM in annual (Moata) paddocks, with the higher values occurring during spring. White clover comprised < 7% of the DM available in all pastures during winter and in 10 cm pasture during spring; 5 cm and annual pastures contained 9–14% white clover in spring. Dead matter was very low in all pastures during winter and in 5 cm pastures during spring (< 6% total) but rose to 11% in 10 cm pastures during spring.

Botanical composition of herbage and rumen ingesta

Table 2 shows the botanical composition of the

Table 1. *Expt 1. Mass and botanical composition (% DM) of the swards during winter (May–August) and during spring (September–November) 1988, in New Zealand*

Sward height	Sward type		Herbage mass (kg DM/ha)	Perennial ryegrass	Moata annual ryegrass	White clover	Other species	Dead matter
				Winter*				
10 cm	Perennial	Mean	1840	89	0	5	2	4
		S.E.	55·3	2·5	—	1·1	0·6	1·0
	Annual	Mean	1694	45	33	7	9	6
		S.E.	24·2	3·5	0·7	1·8	1·0	1·3
5 cm	Perennial	Mean	1236	88	0	6	4	3
		S.E.	62·3	0·3	—	0·6	0·4	0·6
	Annual	Mean	1148	30	46	5	16	4
		S.E.	7·0	10·1	6·0	1·1	4·2	0·8
				Spring†				
10 cm	Perennial	Mean	2251	81	0	6	1	11
		S.E.	45·9	2·5	—	0·6	0·5	2·1
	Annual	Mean	2022	59	19	6	5	11
		S.E.	32·9	0·3	1·5	1·3	0·5	2·0
5 cm	Perennial	Mean	1731	84	0	9	2	5
		S.E.	73·1	2·5	—	2·2	0·3	0·8
	Annual	Mean	1690	50	22	14	11	3
		S.E.	44·3	1·6	1·6	0·8	4·2	1·0

*20 samples/sward type.
†15 samples/sward type.

herbage on offer (% DM) and the diet selected by the grazing stags (ingesta; %) in June and November. The perennial ryegrass and 'other species' component in the ingesta was greater than in the herbage on offer ($P < 0·001$) during both months, whereas the ingesta values for both white clover and Moata annual ryegrass were lower than their proportions in the herbage ($P < 0·001$).

Nutritive values of herbage and ingesta

Tables 3 and 4 show high total N, organic matter digestibility (OMD) and M/D (MJ metabolizable energy/kg DM) values during both seasons, as a result of pastures being kept in a permanent vegetative state. Herbage nitrogen concentration was similar for all swards, but tended to be greater during winter than in spring. OMD was higher in winter than in spring, and the herbage maintained at 5 cm sward height had slightly greater OMD than that at 10 cm ($P < 0·10$). The total N concentration, OMD and M/D values for the ingesta were similar to those for the herbage for both months.

Seasonal herbage accumulation rates and carrying capacity

Fig. 1 shows the seasonal herbage accumulation rates for the two pasture types at 5 and 10 cm sward heights. Annual swards had slightly higher accumulation rates than perennial swards during winter ($P < 0·10$) and therefore had a slightly greater carrying capacity (10 cm, 13·1 *v.* 10·5 animals/ha; 5 cm, 15·4 *v.* 12·4 animals/ha). During spring, herbage accumulation rate from the 10 cm annual sward decreased markedly with a corresponding fall in carrying capacity (9·4 *v.* 12·4 animals/ha).

Liveweight gain (LWG) and carcass characteristics

During winter, LWG was much greater in stags grazing the 10 cm swards than those grazing the 5 cm swards ($P < 0·001$; Table 5), with the introduction of annual ryegrass having no effect. During spring, there was a significant interaction ($P < 0·001$) between sward height and the presence of annual ryegrass; although LWG was high on all 10 cm swards regardless of herbage type, it was much lower in stags grazing the 5 cm perennial pasture and was significantly increased by the addition of annual ryegrass ($P < 0·01$), so that the LWG of the stags grazing 5 cm annual sward was similar to that of the stags grazing 10 cm swards. Around 46% of the stags grazing 10 cm sward height and 21% of those grazing the 5 cm annual pasture reached the target liveweight (92 kg) by the end of November, whereas none of those grazing the 5 cm perennial pasture attained the target liveweight by this date. There were no significant differences in carcass data between stags grazing the two pasture types.

Table 2. *Expt 1. Botanical composition of herbage (% DM) and rumen ingesta (%) of stags grazing different sward types during June and November 1988 in New Zealand*

Sward height	Sample type	Sward type	Perennial ryegrass + other species	White clover	Moata annual ryegrass
			June		
10 cm	Herbage*	Perennial	95·2	4·8	—
		S.E.	1·08	1·08	
		Annual	51·3	10·7	38·0
		S.E.	0·81	0·89	1·33
	Ingesta†	Perennial	99·1	0·9	—
		S.E.	0·28	0·28	
		Annual	81·3	3·5	15·2
		S.E.	0·91	0·37	1·05
5 cm	Herbage	Perennial	95·1	4·9	—
		S.E.	1·41	1·41	
		Annual	40·3	5·0	54·7
		S.E.	0·95	0·30	2·42
	Ingesta	Perennial	96·4	3·6	—
		S.E.	0·53	0·53	
		Annual	90·1	4·6	5·3
		S.E.	2·63	0·66	1·14
			November		
5 cm	Herbage	Perennial	85·8	14·2	—
		S.E.	0·63	0·63	
		Annual	59·8	16·2	24·0
		S.E.	1·48	0·48	0·89
	Ingesta	Perennial	96·8	3·2	—
		S.E.	0·28	0·28	
		Annual	77·8	6·9	15·4
		S.E.	2·29	1·43	2·80

* 5 samples/herbage type per month.
† 10 samples per month.

Melatonin antibody titre and hormone concentrations

There was a slight decline in mean melatonin antibody titre following the first booster injection in June from 1:72±36 to 1:34±16 (mean±S.E.) in July (Fig. 2). The titre increased following the second booster injection and was highest at 1:613±256 in November 1988, about 8 months after the primary injection was given. The mean titre reported was for 19 animals (73%; responders) out of 26 antigen vaccinated stags. Seven animals (27%; non-responders) did not develop any detectable melatonin antibodies.

Plasma LH (0·85±0·25: 0·59±0·10 ng/ml) and testosterone (3·18±0·59; 1·42±0·15 ng/ml) concentrations were higher in October than in November, with the vaccination treatment having no effect ($P > 0·10$) during both months. Plasma prolactin concentrations (Fig. 3) showed similar patterns for both control and immunized groups with low values during winter (June–August) and higher values during spring (September–November). Plasma prolactin levels in the immunized group tended to be numerically higher than those of the control group during both seasons, with the difference being greatest during October ($P < 0·10$).

Vaccination against melatonin at 3 months had no statistically significant effect upon LWG or carcass data (Table 6).

Experiment 2

Herbage mass and botanical composition of swards

Herbage mass on offer and residue (kg DM/ha) during winter and spring for stags grazing perennial and annual ryegrass pastures are shown in Table 7. The two sward types were grazed at different heights but had similar herbage mass before and after grazing in both seasons.

Comparison of the botanical composition of the two sward types for the winter and spring seasons show that annual ryegrass swards contained less perennial ryegrass than the perennial pasture swards during both seasons (Table 8). Moata ryegrass content of the annual pasture was very high during winter

Table 3. *Expt 1. Organic matter digestibility (OMD), total nitrogen (N) concentration and estimated concentrations of metabolizable energy (M/D values) of herbage and rumen ingesta of stags grazing different sward types during winter (June–August) 1988 in New Zealand*

Sward height	Sward type		OMD (%)	Total N (%)	M/D (MJ ME/kg DM)
		Herbage*			
10 cm	Perennial	Mean	81·4	4·4	11·6
		S.E.	0·55	0·09	0·22
	Annual	Mean	81·6	4·5	11·3
		S.E.	0·27	0·11	0·23
5 cm	Perennial	Mean	81·9	3·9	10·7
		S.E.	0·23	0·24	0·54
	Annual	Mean	82·5	4·3	10·9
		S.E.	0·81	0·30	0·65
		Rumen ingesta†			
5 cm	Perennial	Mean	77·1	4·1	10·6
		S.E.	1·00	0·17	0·16
	Annual	Mean	79·8	4·1	10·3
		S.E.	0·18	0·09	0·07

* 3 samples/herbage type taken monthly.
† 17 samples taken in June.

Table 4. *Expt 1. Organic matter digestibility (OMD), total nitrogen (N) concentration and estimated concentrations of metabolizable energy (M/D values) of herbage and rumen ingesta of stags grazing different sward types during spring (September–December) 1988 in New Zealand*

Sward height	Sward type		OMD (%)	Total N (%)	M/D (MJ ME/kg DM)
		Herbage*			
10 cm	Perennial	Mean	76·4	2·5	10·5
		S.E.	1·57	0·31	0·24
	Annual	Mean	77·8	2·6	10·7
		S.E.	1·19	0·23	0·18
5 cm	Perennial	Mean	79·1	2·8	10·9
		S.E.	1·61	0·30	0·26
	Annual	Mean	79·0	2·9	11·0
		S.E.	2·07	0·36	0·27
		Rumen ingesta†			
5 cm	Perennial	Mean	80·0	4·4	11·2
		S.E.	0·18	0·17	0·10
	Annual	Mean	81·0	3·4	11·4
		S.E.	0·69	0·16	0·17

* 4 samples/herbage type taken monthly.
† 15 samples taken in November.

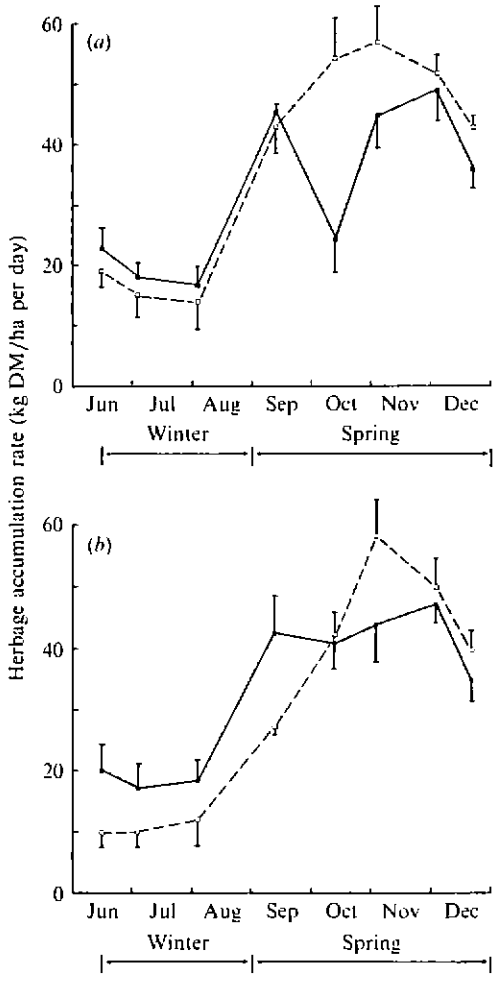

Fig. 1. (Expt 1). Herbage accumulation rate (kg DM/ha per day). (*a*) perennial ryegrass based pasture, 10 cm height (□); with Moata annual ryegrass introduced, 10 cm height (■); (*b*) perennial ryegrass based pasture, 5 cm height (○); with Moata annual ryegrass introduced, 5 cm height (●). Bars represent S.E.

(82%), declining to 65% during spring; the direct-drilling was thus successful in replacing perennial ryegrass almost completely with annual ryegrass. White clover content was low in all swards, especially in the annual ryegrass pastures. The 'other species' and dead matter components of both swards increased during spring.

Botanical composition of herbage and extrusa

Table 9 shows the botanical composition of the herbage on offer (% DM) and of oesophageal extrusa (%) of grazing stags during winter and spring. There was consistently a larger proportion of perennial

Table 5. *Expt 1. Effect of sward type on liveweight gain (LWG) of grazing stags during winter and spring 1988; percentage of stags attaining target liveweight and carcass measurements*

	Sward height				
	10 cm		5 cm		
Sward type...	Perennial	Annual	Perennial	Annual	S.E.
Number of stags	12	14	12	14	—
Initial weight (kg)	56·9	60·7	59·8	60·2	—
Liveweight gain (g/day)					
Winter*	153	131	74	79	9·0
Spring†	234	209	147	211	10·1
Stags attaining 92 kg liveweight by end of November (% total)	42	50	0	21	—
Carcass data					
Dressing out %	54·6	55·2	—	—	0·46
Rump fat width (mm)	107·5	99·6	—	—	3·28
GR tissue depth (mm)	5·8	5·0	—	—	0·45
Testes weight (g)	43·1	40·2	—	—	3·84

* 30 May–30 August.
† 31 August–30 November.

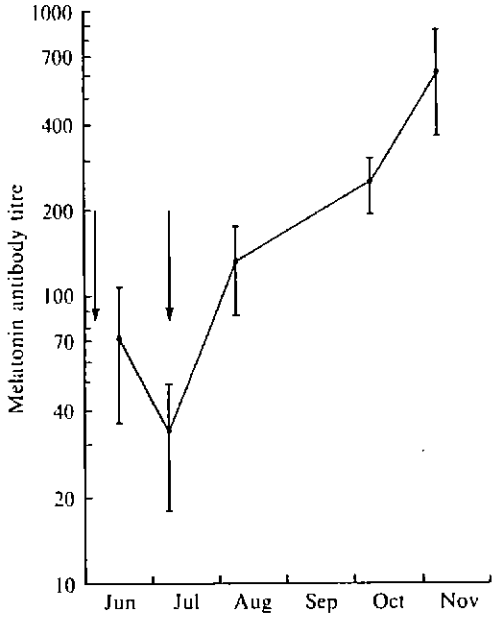

Fig. 2. (Expt 1). Melatonin antibody titre development in red deer given a primary injection at 3 months of age (March 1988). Arrows (↓) indicate first and second booster vaccinations; data are for only those 19 animals showing an antibody response. Bars represent S.E.

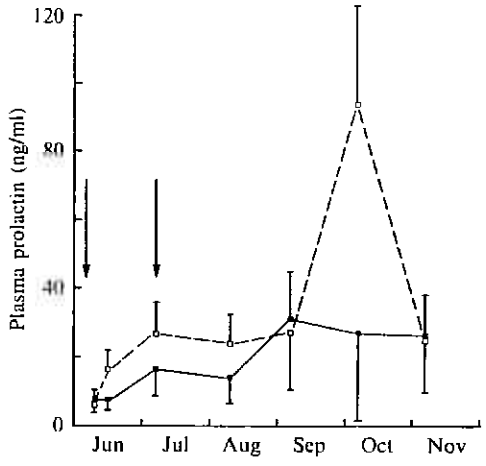

Fig. 3. (Expt 1). Effect of immunization against melatonin at 3 months of age on plasma prolactin concentration (ng/ml) in weaner red deer stags. Non-immunized (control) ($n = 26$) (■) and immunized (melatonin antigen) ($n = 26$) (□). Arrows (↓) indicate first and second booster vaccinations; data are for all animals. Bars represent S.E.

ryegrass in the extrusa than in the swards on offer during both seasons, whilst the white clover and dead matter proportions in the extrusa were consistently smaller than in the swards during winter and spring.

Nutritive values of herbage and extrusa

The organic matter digestibility (OMD), organic matter (OM), total N and M/D values for the herbage on offer were generally high during the winter (Table 10). Annual pasture had numerically greater OMD and M/D values ($P < 0·10$) than the perennial pasture over this period. OMD and M/D values for the extrusa were higher than those of the herbage on

Table 6. *Expt 1. Effect of immunization against melatonin at 3 months of age upon liveweight gain (g/day) of red deer stags during winter and spring 1988; percentage of stags attaining target liveweight and carcass measurements*

	Control stags	Vaccinated stags	S.E.
Live weight gain			
Winter*	108	96	10·3
Spring†	209	193	9·4
Stags attaining 92 kg liveweight by end of November (% total)	34	23	—
Carcass data			
Dressing-out (%)	54·6	55·4	0·29
Carcass weight (kg)	51·5	52·5	0·44
Rump fat width (mm)	103·1	105·7	2·06
GR tissue depth (mm)	4·9	5·2	0·31
Testes weight (g)	41·2	41·8	2·51

*30 May–30 August.
†31 August–30 November.

offer, and OM values were lower for extrusa, due to saliva contamination.

There was a slight decline in OMD and total N contents of the herbage on offer during spring, with both sward types having similar nutritive values ($P > 0·10$). OMD and M/D values for the extrusa were higher than those for herbage on offer. Whilst the total N for the extrusa was generally higher than that for the herbage, the OM value was lower for extrusa, both probably due to saliva contamination. Overall, Table 10 shows that both pasture types maintained a very high nutritive value during the experimental period.

Carrying capacity

During winter, annual and perennial pasture swards supported a similar number of animals/ha (8·8 *v.* 8·7/ha). The number of animals/ha increased for both swards in spring, less so for annual than for perennial pastures (16·6 *v.* 23·0/ha).

Growth patterns, LWG and carcass characteristics

Winter and spring LWG (g/day), VFI (g DM/day)

Table 7. *Expt 2. Surface height (cm) and herbage mass (kg DM/ha) (with S.E.) of two types of swards during winter (June–August) and spring (September–November) 1989 in New Zealand*

		Sward type	
		Perennial	Annual
	Winter		
Surface height (cm)	Before grazing	10 (0·4)	16 (0·8)
	After grazing	8 (0·3)	12 (0·8)
Herbage mass (kg DM/ha)	Before grazing	2105 (50·5)	2012 (57·0)
	After grazing	1600 (44·1)	1587 (28·0)
	Spring		
Surface height (cm)	Before grazing	10 (0·5)	12 (0·5)
	After grazing	8 (0·3)	10 (0·5)
Herbage mass (kg DM/ha)	Before grazing	2235 (52·7)	2190 (44·4)
	After grazing	1576 (64·2)	1665 (68·0)

Table 8. *Expt 2. Botanical composition (% DM) of the swards during winter (June–August) and spring (September–November) 1989 in New Zealand; 15 samples taken per season*

Sward type		Perennial ryegrass	Moata annual ryegrass	White clover	Other species	Dead matter
		Winter				
Perennial	Mean	87·0	0	3·2	1·1	8·6
	S.E.	1·52	—	0·55	0·20	1·09
Annual	Mean	9·3	81·9	0·2	5·0	3·6
	S.E.	1·59	1·28	0·03	0·72	1·12
		Spring				
Perennial	Mean	78·9	0	4·2	3·8	13·1
	S.E.	3·51	—	0·23	0·77	2·72
Annual	Mean	12·0	65·1	2·3	6·4	14·1
	S.E.	3·19	5·25	0·29	0·88	2·22

Table 9. *Expt 2. Botanical composition of herbage (% DM) and oesophageal extrusa (%) (with* S.E.*) of stags grazing different sward types during winter and spring 1989 in New Zealand*

Sample type and number	Sward type	Perennial ryegrass + other species	Perennial ryegrass, Moata annual ryegrass + other species	White clover	Dead matter
		Winter			
Herbage (n = 15)	Perennial	88·1 (1·50)	—	3·2 (0·55)	8·6 (1·09)
	Annual	—	96·2 (1·10)	0·2 (0·03)	3·6 (1·12)
Extrusa (n = 19)	Perennial	95·6 (0·55)	—	1·4 (0·20)	3·0 (0·56)
(n = 25)	Annual	—	99·2 (0·21)	0·1 (0·04)	0·7 (0·19)
		Spring			
Herbage (n = 15)	Perennial	82·7 (2·96)	—	4·2 (0·23)	13·1 (1·17)
	Annual	—	83·5 (2·47)	2·3 (0·29)	14·1 (1·70)
Extrusa (n = 5)	Perennial	98·0 (0·66)	—	1·5 (0·66)	0·5 (0·03)
(n = 14)	Annual	—	97·8 (0·51)	1·2 (0·46)	1·0 (0·23)

Table 10. *Expt 2. Organic matter digestibility (OMD), organic matter (OM), total nitrogen (N) concentration and estimated concentrations of metabolizable energy (M/D values) (with* S.E.*) of herbage and oesophageal extrusa of stags grazing different sward types during winter (June–August) and spring (September–November) 1989 in New Zealand*

Sample type	Sward type	OMD (%)	OM (g/100 g dry matter)	Total N (g/100 g dry matter)	M/D (MJ ME/kg DM)
			Winter		
Herbage*	Perennial	80·3 (0·62)	84·0 (1·45)	3·95 (0·28)	11·0 (0·28)
	Annual	86·1 (1·19)	86·7 (0·28)	4·40 (0·26)	12·2 (0·21)
Extrusa†	Perennial	89·2 (0·42)	61·9 (4·12)	4·03 (0·13)	12·4 (0·06)
	Annual	89·6 (0·15)	73·0 (2·36)	4·12 (0·13)	12·7 (0·02)
			Spring		
Herbage	Perennial	78·9 (2·68)	86·1 (0·49)	2·83 (0·61)	11·1 (0·42)
	Annual	80·4 (2·12)	86·6 (1·41)	2·70 (0·32)	11·3 (0·47)
Extrusa	Perennial	88·0 (0·30)	77·0 (1·53)	4·09 (0·16)	12·2 (0·04)
	Annual	88·9 (0·40)	69·1 (4·13)	3·65 (0·15)	12·6 (0·06)

* 3 samples/herbage type.
† 9 samples.

and the percentage of stags attaining slaughter weight (92 kg) by the end of November for the perennial and annual ryegrass groups are shown in Table 11. Winter LWG ($P < 0·05$) and VFI ($P < 0·001$) of the annual group were significantly greater than for the perennial group. Spring LWG and VFI also tended to be higher for stags grazing annual pastures, but neither attained significance ($P > 0·05$). During spring, VFI estimated from ring samples was higher than that estimated from rectal samples. During late August and late November, deer grazing annual pasture were significantly heavier ($P < 0·01$) than those grazing perennial pasture. A larger proportion of animals grazing annual ryegrass than of those grazing perennial ryegrass reached the target liveweight (92 kg LW) by November 30 (60 *v.* 41%). Carcass dressing out percentage was slightly higher for stags grazing annual than perennial pastures ($P = 0·052$), but there were no significant differences in measures of subcutaneous fatness.

Table 11. *Expt 2. Effect of sward type on liveweight gain (LWG) and voluntary feed intake (VFI) of grazing stags during winter and spring 1989; percentage of stags attaining and target liveweight and carcass measurements*

	Sward type		
	Perennial	Annual	S.E.
Number of stags	17	15	—
Liveweight gain (g/day)			
Winter*	140	165	6·6
Spring†	226	235	5·4
Voluntary feed intake (g DM/day)			
Winter (ring samples)	1185	1615	100
Spring (individual samples)	1762	1719	50
Spring (ring samples)	2318	2570	107
Stags attaining 92 kg liveweight by end of November (% total)	41	60	—
Carcass data			
Dressing out (%)	52·6	53·8	0·38
Rump fat width (mm)	116·5	113·6	1·59
GR tissue depth (mm)	2·9	3·6	0·30
Testes weight (g)	46·9	47·0	2·27

* 15 May–28 August.
† 29 August–30 November.

Rumen VFA and NH_3 concentrations

There was no significant difference ($P > 0{\cdot}10$) in the acetate:propionate ratio in the rumen fluid of stags grazing annual (3·56:1·00) or perennial ryegrass (3·70:1·00) in spring. Ammonia concentration was lower ($P < 0{\cdot}001$) in the rumen fluid of deer grazing annual than perennial pastures (134 *v.* 188 mg N/l).

Melatonin antibody titre and hormone concentrations

The patterns of melatonin antibody development in both vaccinated groups (Freund's and Dextran) are shown in Fig. 4. Fifteen (75%) of the vaccinated animals gave a detectable antibody titre response. The antibody titres of the Freund's group were much higher (1:3545 ± 1059 to 1:15215 ± 5551) than those of the Dextran group (1:48 ± 31 to 1:1941 ± 423) and peaked in October, *c.* 11 months after the primary vaccination. The titre level of the Dextran group peaked in May at 1:1941 ± 423, about 6 months after the primary vaccination, and rapidly declined to undetectable levels by September. The antibody titre level of the Freund's group rose above 1:5000 shortly after the second booster injection in May and remained high until the end of the experiment in November.

Plasma LH (0·55 ± 0·02; 0·47 ± 0·02 ng/ml) and testosterone (2·27 ± 0·04; 1·49 ± 0·10 ng/ml) concentrations were higher in October than November and were not affected by immunization ($P > 0{\cdot}10$). Plasma prolactin concentrations in the control group were slightly above the baseline level during the winter (Fig. 5), with a tendency to increase during spring. Plasma prolactin levels of the immunized groups were generally higher during winter, and the spring rise in concentration occurred earlier and was greater than in the control group. These attained significance for the Dextran group in mid May ($P < 0{\cdot}05$).

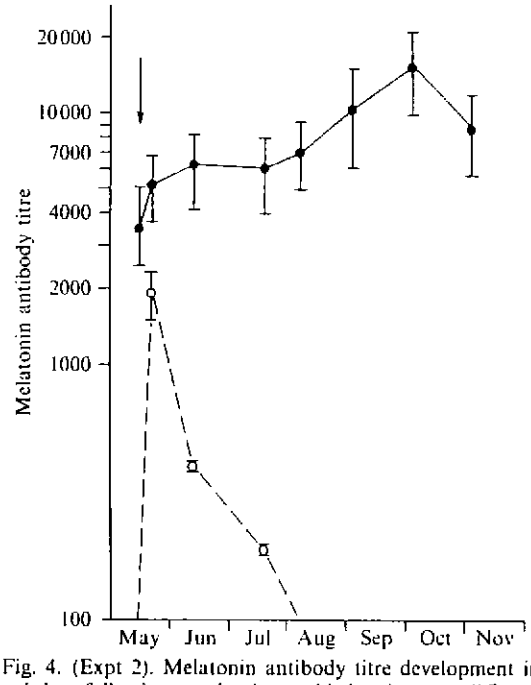

Fig. 4. (Expt 2). Melatonin antibody titre development in red deer following vaccination at birth using two different adjuvants; Freund's (●) and Dextran (○). Arrow (↓) indicates second booster vaccination; data are only for animals showing an antibody response. Bars represent S.E.

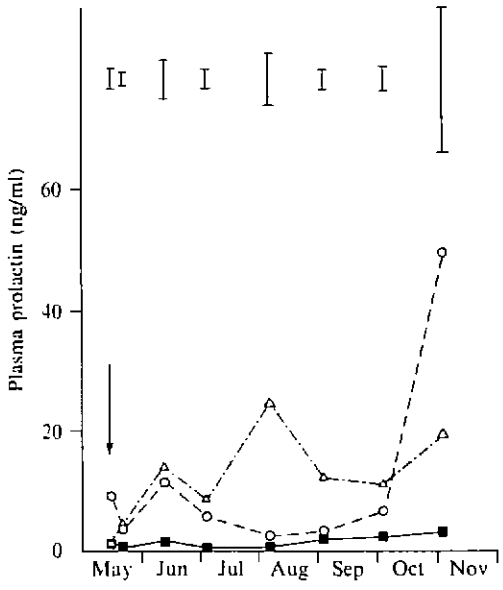

Fig. 5. (Expt 2). Effect of immunization against melatonin at birth on plasma prolactin concentration (ng/ml) in weaner red deer stags. Non-immunised (control) (■); Freund's adjuvant (△) and Dextran adjuvant (○). Arrow (↓) indicates second booster vaccination; data are for all animals. Bars represent S.E.

Effect of vaccination on weaning weight, LWG and carcass data

Stags vaccinated at birth with antigen in Freund's adjuvant had lower weaning weight (47·7 ± 1·25 kg) than control animals (51·8 ± 2·12 kg; $P < 0·05$) or those vaccinated with antigen in Dextran adjuvant (52·2 ± 1·38 kg; $P < 0·05$) and the depressed growth rate continued until end of autumn. Table 12 shows that all groups grew at similar rates during winter and spring ($P > 0·10$). Whilst 73% of the Dextran group and 67% of the control group attained the target slaughter weight (92 kg LW) by the end of November, no animals from the Freund's group attained the target weight at this date. Carcass data were similar for all groups ($P > 0·10$; Table 12). The Freund's group had heavier testes than the control group ($P < 0·10$).

DISCUSSION

Seasonal pattern of sward components

The marked decrease in the Moata annual ryegrass component of the direct-drilled pastures in Expt 1 from an average of 39·5% during winter to 20·5% during spring could be due to the sensitivity of the annual ryegrass to continuous defoliation through grazing (R. J. M. Hay, personal communication).

Table 12. *Expt 2. Effect of immunization against melatonin at birth, using two different types of adjuvant on liveweight gain (LWG) and voluntary food intake (VFI) of yearling red deer stags during winter and spring (1989) and on carcass measurements*

	Vaccination treatment				
	Control (not immunized)	Freund's adjuvant	DEAE-dextran adjuvant	Freund's + DEAE-dextran adjuvant	S.E.
Number of stags	12	9	11	20 (15)*	—
Initial weight (kg)	50·9	50·9	50·9	50·9 (50·7)	—
Liveweight gain (g/day)					
Winter†	149	142	163	154 (153)	—
S.E.	8·38	9·68	8·76	6·63	
Spring‡	230	222	229	231 (225)	—
S.E	6·06	7·00	6·33	4·88	
Voluntary feed intake (g/day)					
Spring	1792	1672	1745	—	74·2
Carcass data					
Number of stags	9	3	8	—	—
Dressing-out (%)	53·5	53·2	53·2	53·4 (53·7)	0·38
Rump fat width (mm)	114·7	107·1	117·3	114·7 (112·0)	1·66
Testes weight (g)	43·4	55·8	47·2	49·5 (51·1)	2·06
GR tissue depth (mm)	3·1	4·2	3·3	3·4 (3·3)	0·31

* Responders to anti-melatonin vaccination only (i.e. 5 non-responders deleted).
† 15 May–28 August.
‡ 29 August–30 November.

However, the double-pass drilling plus band spraying produced a pasture that outyielded perennial ryegrass during winter and increased winter carrying capacity by 3 animals/ha. Although the double-pass direct-drilling and blanket herbicide spraying used in Expt 2 produced a pasture containing 82% annual ryegrass during winter, this did not increase winter carrying capacity relative to perennial ryegrass pasture. The number of animals carried/ha increased during spring for both swards, with the annual ryegrass pastures supporting fewer animals than the perennial ryegrass pastures, in both the Expt 1 (10 cm pastures) and in Expt 2, due to Moata annual ryegrass dying off in spring, creating swards with an open structure and reduced tiller density which resulted in increased invasion by weeds. White clover content of the swards showed a seasonal spring increase as reported by Widdup & Williams (1982) and Chapman (1983), with the white clover component of the 5 cm swards being greater during the spring than during winter. There was also a seasonal trend in the increase of the dead matter component of the swards, being greater during the spring than during winter, especially in the 10 cm swards. This could be due to the rate of herbage production during spring being greater than the rate of herbage utilization by the animals, leading to a greater incidence of herbage senescence and death (Bircham & Korte 1984).

Diet selection by grazing stags

The comparison of herbage on offer and extrusa in Expt 1 suggests that the grazing animals selected perennial ryegrass and other species over white clover and Moata annual ryegrass. Hunt & Hay (1989) reported that grazing yearling red deer stags showed distinct preference for white clover 'Grasslands Kopu' over both high and low endophyte ryegrasses 'Grasslands Nui'. The low content of white clover in ingesta may be due to its low height in the grazing canopy, in addition to its very low overall content in the herbage on offer.

In Expt 2 the deer consumed mainly green plant material and avoided dead matter. This is in agreement with the results of L'Huillier *et al.* (1984) on diet selection by sheep, and by Hughes *et al.* (1984) on diet selection by kids, lambs and calves during late spring. Content of white clover in both extrusa and feed on offer was low and no selection for this component was evident. Conversely, the perennial pasture and annual pasture diets eaten contained greater proportions of perennial ryegrass, annual ryegrass (where available) and 'other species' than the proportions found in the swards during both seasons. There was also evidence that the animals ate a diet higher in OMD and ME than the feed on offer in both experiments, which can be partly explained by their selection against dead material.

Voluntary feed intake (VFI) of grazing deer

The stags grazing annual ryegrass swards had greater estimated VFI than those grazing perennial ryegrass swards during winter, corresponding to 2·8 and 2·0% of liveweight and 20·5 and 14·7 MJ ME/head daily respectively. However, VFI during winter was low, compared to the results of Fennessy & Milligan (1987). A contributing factor could be an outbreak of yersiniosis (*Yersinia pseudotuberculosis*), which occurred in Expt 2 when winter VFI was being measured, and was controlled with oral administration of neomycin sulphate (11 mg/kg; Neomix, Upjohn Laboratories) for 3 consecutive days in late June and early July. During spring the VFI determined using individual faecal samples was lower than that determined using group faecal samples, but there was no difference in the VFI of animals grazing either annual of perennial pasture. Hence, the energy intake determined using individual rectal faecal samples (21·7 and 21·5 MJ ME/head daily) for annual and perennial pasture groups during spring, respectively, were lower than the estimated daily requirement (27 MJ ME; Fennessy & Milligan 1987), whilst the MEI calculated using the group faecal samples were marginally higher (32·4 and 28·3 MJ ME). Thus further experimentation is necessary to validate the CRC technique for use with deer. The difference between sampling methods could perhaps be due to a diurnal pattern in faeces Cr concentration, caused by a diurnal pattern in feed intake, or to rectal sampling itself reducing VFI in deer. Both methods of sampling should be further compared in future experiments, to determine which method is better.

Liveweight gain (LWG)

The 131–153 g/day LWG recorded for animals grazing the 10 cm swards in Expt 1 and the perennial ryegrass pasture in Expt 2 is the same as the upper limit of 100–150 g/day suggested as a suitable target value for young stags fed a high quality diet (Fennessy & Milligan 1987). It also showed that providing high quality pasture at high feed allowance (10 cm sward height) can greatly improve the growth rate of the stags during winter, compared with grazing 5 cm swards. This contrasts with deer production systems in the UK, where indoor feeding is recommended during the first winter (5 months), followed by grazing pastures maintained at 4–6 cm surface height (Milne *et al.* 1987).

Relative to perennial ryegrass/white clover pasture, inclusion of annual ryegrass by direct-drilling produced only small additional increases in winter carrying capacity and in the proportion of stags attaining target slaughter weight in Expt 1, perhaps due to annual ryegrass forming a relatively low proportion of the sward. The greater VFI and winter

Table 13. *Comparison of liveweight gain in weaner red deer stags over their first winter and spring to estimate the genetic potential for growth, and the extent to which this can be met from grazed forages*

Reference	Year	No. of animals	Liveweight gain (g/day) Winter (W)	Spring/early summer (S)	W/S	Location	Latitude
Pelleted concentrate diet							
Suttie *et al.* (1989)	1989	6	180	240	0·75	Mosgiel (NZ)	45° 5′ S
Perennial ryegrass/white clover temperate pasture							
Moore *et al.* (1988)	1974	10	6	250	0·02	Mosgiel (NZ)	45° 5′ S
	1975	26	41	251	0·16		
	1976	13	41	243	0·17		
	1977	6	122	236	0·52		
	1978	38	102	239	0·43		
	1979	18	103	256	0·40		
	1982	33	60	218	0·28		
This paper							
Expt 1	1988	12	153	234	0·65	Palmerston North (NZ)	40° 2′ S
Expt 2	1989	17	140	226	0·62		
Annual ryegrass/perennial ryegrass/white clover temperate pasture							
This paper							
Expt 1	1988	12	131	209	0·63	Palmerston North (NZ)	40° 2′ S
Expt 2	1989	17	165	235	0·70		
Sub-tropical pasture with grain supplement							
Woodford *et al.* (1990)	1985/88	32	179	219	0·82	Brisbane (Aust.)	27° 4′ S

LWG of stags grazing annual ryegrass pastures in Expt 2 resulted in 60% attaining the slaughter weight by 30 November. This is consistent with the superior LWG of sheep grazing annual and short rotation ryegrass varieties compared with perennial ryegrass varieties (Rae *et al.* 1964; Ulyatt 1971). Better deer production than was attained in previous experiments (25–45% attaining target slaughter weight; Ataja *et al.* 1989; Ataja 1990) could be due to the greater VFI of animals grazing the annual ryegrass swards than those grazing the perennial pasture swards, the consequence of a higher proportion (82%) of Moata ryegrass in the annual ryegrass swards during winter.

Suttie *et al.* (1989) fed a high energy (11 MJ ME/kg DM) pelleted ration, and their data can be used to estimate the genetic potential of weaner red deer stags for growth (Table 13), giving a ratio of winter (W) to spring/early summer (S) growth of 0·75. Early attempts at deer farming from grazed pastures in NZ (Moore *et al.* 1988) produced comparable growth during spring/early summer, but much lower values during winter, giving a mean W/S ratio of 0·28 (Table 13). A major part of the present study has been the development of systems to increase the growth of young deer from grazed pastures during winter, whilst retaining high spring/early summer growth, giving a W/S ratio of 0·62–0·70, thus showing that the young deer were growing close to their genetic potential.

A higher W/S ratio is recorded for red deer grazing closer to the equator (0·82; Woodford *et al.* 1990), due to reduced seasonal changes in photoperiod, with growth during winter being almost as high as during spring/summer. Thus it is possible that the genetic potential of weaner red deer stags for growth during winter may be greater at latitudes closer to the equator.

Melatonin antibody titre and its effects on growth and plasma hormones

The present experiments have shown that active immunization against melatonin at birth produced higher antibody titres than immunization at 3 or 6 months of age (see also Ataja *et al.* 1989). The highest mean titre in both experiments was recorded in October/November (8–12 months after the primary vaccination), showing firstly that antibodies against melatonin can be raised in 73% of the animals

vaccinated and secondly, that a long lag phase is involved in melatonin antibody titre development.

The Freund's group experienced reduced growth until autumn (6 months of age) which could be due to the adverse effect of the Freund's complete adjuvant used at birth. Although Ataja *et al.* (1989) showed that Freund's adjuvant alone did not influence stags' growth when immunization was commenced at 6 months of age, it seems this is not the case when immunization is commenced at birth. Duckworth & Barrell (1989) reported that immunization against melatonin increased liveweight of young stags by 7–10% between 9–11 and 16–20 months of age. However, no such response was obtained in the present work.

Active immunization against melatonin tended to result in higher plasma prolactin concentrations during winter and an earlier onset of the spring rise in prolactin. Ryg & Jacobsen (1982) reported that injections of prolactin to yearling male reindeer during winter were associated with increases in VFI and LWG. It might therefore be expected that immunization against melatonin, with its associated elevation of plasma prolactin concentration, should also have increased winter LWG. Further work is needed on this aspect, using larger numbers of animals and reformulated vaccines of the DEAE-dextran type that produce larger and longer acting antibody responses.

The heavier testes of the vaccinated group suggests that this treatment may have advanced the seasonal cycle of testes size in red deer, which normally peaks in the rut (Lincoln & Kay 1979). In future experiments, testes diameter should be determined before, during and after the rut.

Early venison production

The more rapid growth in deer grazing perennial ryegrass pastures at 10 cm compared with 5 cm surface height increased the proportion of animals attaining the target slaughter weight by the end of spring (30 November) from 0 to 40%. This substantially increases the efficiency of venison production at very low cost to the producer. Whilst the inclusion of annual ryegrass increased winter carrying capacity in Expt 1, responses in LWG tended to be small, although in Expt 2 this treatment did increase the proportion of animals attaining target slaughter weight to 60%. As deer grazing annual or perennial ryegrass pastures selected diets of similar OMD and had similar rumen acetate:propionate ratios, it seems likely that the additional winter growth on annual ryegrass was due mainly to increased VFI.

These studies demonstrate the feasibility of early venison production from grazed pastures and indicate that more research is needed to get a greater proportion of stags to slaughter weight by 1 year of age or less. This could include the development of specialist forages for deer production, such as red clover, which increases hind lactation performance and increased fawn weaning weight by 7–10 kg (Niezen *et al.* 1991), and also increases autumn growth of weaners (G. Semiadi, personal communication). Such pastures would give heavier animals at the onset of winter, when the treatments developed in the present investigation could be applied.

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REFERENCES

ABRAHAM, G. E. (1974). Radioimmunoassay of steroids in biological materials. *Acta Endocrinologica* **183** (Supplement), 7-42.

ARMSTRONG, C. S. (1981). 'Grassland Moata' tetraploid Italian ryegrass (*Lolium multiflorum* Lam.). *New Zealand Journal of Experimental Agriculture* **9**, 337–341.

ASHER, G. W., BARRELL, G. K. & PETERSON, A. J. (1986). Hormonal changes around oestrus of farmed fallow deer, *Dama dama*. *Journal of Reproduction and Fertility* **78**, 487–496.

ATAJA, A. M. (1990). *Venison production from weaner red deer stags grazing Moata annual ryegrass or perennial ryegrass pastures*. PhD thesis, Massey University, New Zealand.

ATAJA, A. M., WILSON, P. R., PURCHAS, R. W., HODGSON, J., BARRY, T. N. & HAY, R. J. M. (1989). A study of early venison production from grazing red deer (*Cervus elaphus*). *Proceedings of the New Zealand Society of Animal Production* **49**, 25–27.

ATAJA, A. M., BARRY, T. N., HOSKINSON, R. M. & WILSON, P. R. (1992). Effects of active immunization against LHRH and melatonin on growth and plasma hormone concentrations in red deer stags during their second year. *Journal of Agricultural Science, Cambridge* **118**, 371–377.

BAKER, C. J. (1976). Experiments relating to techniques for direct drilling of seeds into untilled dead turf. *Journal of Agricultural Engineering Research* **21**, 133–144.

BARRY, T. N., SUTTIE, J. M., MILNE, J. A. & KAY, R. N. B. (1991). Control of food intake in domesticated deer. In *Physiological Aspects of Digestion and Metabolism in Ruminants. Proceedings of the VII International Symposium on Ruminant Physiology* (Eds T. Tsuda, Y. Sasaki & R. Kawashima), pp 385–401. San Diego, USA: Academic Press.

BAUMGARDT, B. R., TAYLOR, M. W. & CASON, J. L. (1962). Evaluation of forages in the laboratory. II. Simplified artificial rumen procedure for obtaining repeatable estimates of forage nutritive value. *Journal of Dairy Science* **45**, 62–68.

BIRCHAM, J. S. & KORTE, C. J. (1984). Principles of herbage production. *New Zealand Agricultural Science* **18**, 123–126.

CHAPMAN, D. F. (1983). Growth and demography of *Trifolium repens* stolons in grazed hill pastures. *Journal of Applied Ecology* **20**, 597–608.

DOMINGUE, B. M. F., DELLOW, D. W. & BARRY, T. N. (1991). Voluntary intake and rumen digestion of a low quality roughage by goats and sheep. *Journal of Agricultural Science, Cambridge* **117**, 111–120.

DOMINGUE, B. M. F., WILSON, P. R., DELLOW, D. W. & BARRY, T. N. (1992). Effects of subcutaneous melatonin implants during long daylength on voluntary feed intake, rumen capacity and heart rate of red deer fed a forage diet. *British Journal of Nutrition* **68**.

DUCKWORTH, J. A. & BARRELL, G. K. (1989). Effect of melatonin immunisation on the liveweight gain of red deer. *Proceedings of the New Zealand Society of Animal Production* **49**, 29–34.

FENNESSY, P. F. & MILLIGAN, K. E. (1987). Grazing management of red deer. In *Livestock Feeding on Pasture* (Ed. A. M. Nicol), pp. 111–118. Occasional Publication 10. The New Zealand Society of Animal Production.

HODGSON, J., MACKIE, C. K. & PARKER, J. W. G. (1986). Sward surface heights for effective grazing. *Grass Farmer. A British Grassland Society Publication* **24**, 5–10.

HUGHES, T. P., SYKES, A. R. & POPPI, D. P. (1984). Diet selection of young ruminants in late spring. *Proceedings of the New Zealand Society of Animal Production* **44**, 109–112.

HUNT, W. F. & HAY, R. J. M. (1989). Alternative pasture species for deer production in the Waikato. In *Proceedings of the Ruakura Deer Industry Conference*. (Eds G. Asher & J. Squire), pp. 31–33. Ruakura Research Centre, Hamilton, New Zealand: MAF Technology.

KAY, R. N. B. (1985). Body size, patterns of growth, and efficiency of production in red deer. In *Biology of Deer Production* (Eds P. F. Fennessy & K. R. Drew), pp. 7–20. Bulletin 22. Wellington, New Zealand: The Royal Society of New Zealand.

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. 143–158. Occasional Publication No. 11. Ruakura Research Centre, Hamilton, New Zealand: New Zealand Society of Animal Production.

KORTE, C. J., CHU, A. C. P. & FIELD, T. R. O. (1987). Pasture production. In *Livestock Feeding on Pasture* (Ed. A. M. Nicol), pp. 7–20. Occasional Publication 10. The New Zealand Society of Animal Production.

L'HUILLIER, P. J., POPPI, D. P. & FRASER, T. J. (1984). Influence of green leaf distribution on diet selection by sheep and the implications for animal performance. *Proceedings of the New Zealand Society of Animal Production* **44**, 105–107.

LINCOLN, G. A. & KAY, R. N. B. (1979). Effect of season on the secretion of LH and testosterone in intact and castrate red deer stags (*Cervus elaphus*). *Journal of Reproduction and Fertility* **55**, 75–80.

MILNE, J. A., SIBBALD, A. M., MCCORMACK, H. A. & LOUDON, A. S. I. (1987). The influences of nutrition and management on the growth of red deer calves from weaning to 16 months of age. *Animal Production* **45**, 511–522.

MOORE, G. H., LITTLEJOHN, R. P. & COWIE, G. M. (1988). Factors affecting liveweight gain in red deer calves from birth to weaning. *New Zealand Journal of Agricultural Research* **31**, 279–283.

NIEZEN, J. H., WILSON, P. R., HOLMES, C. W., HODGSON, J. & BARRY, T. N. (1991). Lactation performance of red deer hinds grazing red clover and perennial ryegrass/white clover pastures. *Proceedings of the New Zealand Society of Animal Production* **51**, 185–187.

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.

PETERSON, A. J., FAIRCLOUGH, R. J. & SMITH, J. F. (1978). Radioimmunoassay of androstenedione and testosterone in cow plasma at the time of luteolysis and oestrus. *Journal of Reproduction and Fertility* **52**, 127–129.

RAE, A. L., BROUGHAM, R. W. & BARTON, R. A. (1964). A note on liveweight gains of sheep grazing different ryegrass pastures. *New Zealand Journal of Agricultural Research* **7**, 491–495.

RAYMOND, W. F. & MINSON, D. J. (1955). The use of chromic oxide for estimating the faecal production of grazing animals. *Journal of the British Grassland Society* **10**, 282–296.

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

RYG, M. & JACOBSEN, E. (1982). Effects of thyroid hormones and prolactin on food intake and weight changes in young male reindeer (*Rangifer tarandus tarandus*). *Canadian Journal of Zoology* **60**, 1562–1567.

SCARAMUZZI, R. J., CALDWELL, B. V. & MOOR, R. M. (1970). Radioimmunoassay of LH and estrogen during the estrous cycle of the ewe. *Biology of Reproduction* **3**, 110–119.

SUTTIE, J. M., FENNESSY, R. F., CORSON, I. D., LAAS, F. J., CROSBIE, S. F., BUTLER, J. H. & GLUCKMAN, P. D. (1989). Pulsatile growth hormone, insulin-like growth factors and antler development in red deer. *Journal of Endocrinology* **121**, 351–360.

ULYATT, M. J. (1971). Studies on the causes of the differences in pasture quality between perennial ryegrass, short-rotation ryegrass and white clover. *New Zealand Journal of Agricultural Research* **14**, 352–367.

ULYATT, M. J. (1981). The feeding value of herbage: Can it be improved. *New Zealand Agricultural Science* **15**, 200–205.

VAN LANDEGHEM, A. A. J. & VAN DER WEIL, D. F. M. (1978). Radioimmunoassay for porcine prolactin: Plasma levels during lactation, suckling and weaning, and after TRH administration. *Acta Endocrinologica* **88**, 653–667.

WIDDUP, K. H. & WILLIAMS, W. M. (1982). Evaluation of white clover (*Trifolium repens* L.) populations at Gore. *New Zealand Journal of Experimental Agriculture* **10**, 43–47.

WOODFORD, K. B., DUNNING, A. & WINCH, J. B. (1990). Production of red deer in a subtropical environment. *Proceedings of the Australian Society of Animal Production* **18**, 436–429.