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

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SUMMARY

A rotational grazing experiment using weaner deer was conducted at Palmerston North, New Zealand, during the autumn, winter and spring, to compare the voluntary feed intake (VFI), liveweight gain (LWG) and carcass production of deer grazing chicory with those grazing perennial ryegrass/white clover pasture. Deer were either treated with anthelmintic at 3-weekly intervals (T) or anthelmintic was withheld until trigger-treatment (TT) criteria were attained. Pure red and 0·75 red:0·25 elk hybrid stags and hinds were given forage allowances of 5 kg DM/deer/day in autumn and early-mid winter, 6 kg DM/deer/day in late winter and 7 kg DM/deer/day in spring. Deer grazed chicory or pasture in autumn and spring, with all deer combined on pasture during winter when chicory was dormant. Organic matter digestibility of diet selected was greater for chicory than for pasture in both autumn and spring.

Anthelmintic-treated deer grazing pasture in autumn had significantly higher VFI and LWG, contributing to higher carcass weights, than TT deer. Anthelmintic treatment had no effect on these measures for deer grazing chicory in autumn. Clinical signs of lungworm infection were evident in pasture TT deer during autumn and winter, and in chicory TT deer grazing pasture during winter. Faecal egg counts (FEC) were significantly greater for pasture TT deer during autumn and early winter than all other groups. Faecal lungworm larval counts (FLC) were significantly greater for chicory TT deer following transfer to pasture, than for all other groups in early winter, although both FEC and FLC were low. Faecal larval counts were poorly related to clinical signs of lungworm infection during autumn, but were a better guide in winter. Plasma pepsinogen concentrations appeared unrelated to gastrointestinal parasite infection. Trigger-treated deer grazing pasture required five anthelmintic treatments during autumn and winter. The chicory TT group required no anthelmintic treatment when grazing chicory during autumn, but required two treatments after transfer from chicory to pasture during winter.

There was no effect of anthelmintic regime on VFI and LWG in spring, and LWG was greater for deer grazing chicory than those grazing pasture. Hybrid deer had greater spring LWG and carcass weights than red deer when grazing chicory, but similar LWG and carcass weights when grazing pasture.

It was concluded that grazing chicory offers the potential for reducing anthelmintic use in farmed weaner deer, particularly during autumn.

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INTRODUCTION

One of the aims of the New Zealand (NZ) deer industry is to produce quality-assured, natural, tender, farm-raised venison (CERVENA®) from young deer all year round. A premium is paid for carcasses in the range 50–65 kg. Most NZ farmers produce red deer for slaughter at an age of 15–24 months (Drew 1985; Barry & Wilson 1994), through grazing perennial ryegrass (*Lolium perenne*/white clover (*Trifolium repens*) (PRG/WC) pastures, with the regular use of anthelmintics to control internal parasites. However, it is preferable to produce carcass weights of 50–65 kg before 12 months of age, during August–November (spring), which attract a seasonal premium. It is also desirable to minimize anthelmintic usage, to lower costs and to reduce the risk of the development of anthelmintic resistance and carcass chemical residues.

Young deer in their first autumn and early winter are highly susceptible to internal parasites (Audige *et al*. 1998). Lungworm (*Dictyocaulus viviparus*) is considered to pose the greatest risk (Wilson 1984), followed by gastrointestinal nematodes, especially deer-specific abomasal *Ostertagia*-type nematodes (such as *Spciulopteragia* sp., *Skrjabinagia* sp.) (Connan 1991; Waldrup & Mackintosh 1992). Audige *et al*. (1998) observed that frequency of anthelmintic treatment and the interval between treatments varied markedly between NZ red deer farms, with a significant liveweight increase being associated with each autumn anthelmintic treatment for calves grazing conventional ryegrass-based pasture. Deer calves treated after mid-June exhibited higher winter and spring growth rates (Audige *et al*. 1998).

Red deer exhibit seasonal patterns of VFI and LWG (Kay 1979; Suttie *et al*. 1987), making the achievement of optimum carcass weights before 12 months of age difficult (Audige 1995). Most PRG/WC pastures are unable to produce the quantity of feed required for high deer growth rates during the summer–autumn period of inherent maximum potential VFI and LWG in deer.

Special purpose forages such as red clover (*Trifolium pratense*; Niezen *et al*. 1993*a*; Semiadi *et al*. 1993) and chicory (*Cichorium intybus*; Kusmartono *et al*. 1996), which produce high dry matter (DM) yields of high nutritive value particularly during summer and autumn, enable 100% of red deer stags to reach 92 kg liveweight (50 kg carcass weight) by 1 year of age, compared with 73% (range 25–90%) of those grazing PRG/WC pasture of 10 cm surface weight. Three-weekly anthelmintic treatments were administered during autumn and winter to prevent a confounding effect of parasitism in those trials.

Moss & Vlassoff (1993) and Scales *et al*. (1995) observed fewer sheep parasite larvae on chicory compared with several different grass-based swards, suggesting that conditions in a chicory sward caused by the different plant morphology may be less suitable for larval development and migration. Scales *et al*. (1995) suggested that the higher soluble carbohydrate and mineral content and presence of condensed tannins (CT) in chicory may have enabled lambs grazing chicory to cope better with parasitism than lambs grazing grass-based swards. There are no reports on the effect of chicory on parasitism in deer.

The objective of this study was to determine the growth, VFI, carcass weight, FEC and FLC in young red and hybrid (0·75 red : 0·25 elk) deer calves grazing chicory or PRG/WC pasture from weaning to slaughter at 1 year of age, with and without regular anthelmintic treatment to control internal parasites. This study was conducted at the same time and on the same experimental area as the nutritional study reported by Hoskin *et al*. (1998) and the same chicory and pasture grazed by treated (but not trigger-treated) deer were used in both investigations.

MATERIALS AND METHODS

Experimental design

A rotational grazing experiment was conducted with 44 weaner deer (initially 3–4 months old) grazed on either PRG/WC pasture ($n = 22$) or chicory ($n = 22$). Deer grazing each forage were balanced for genotype (red deer or 0·75 red : 0·25 elk hybrid), liveweight and sex. Half the deer were regularly treated at 3-weekly intervals with an oral anthelmintic to control internal nematode parasites. Half remained untreated until pre-defined trigger concentrations of faecal gastrointestinal parasite eggs of lungworm larvae were reached or deer exhibited clinical signs of parasitism. Treated (T) and trigger-treated (TT) deer were grazed as separate groups and each was rotated around different halves of the eight paddocks of each forage used.

Factors investigated included LWG, VFI, faecal gastrointestinal nematode egg (FEC) and lungworm larval counts (FLC), serum pepsinogen concentration and carcass characteristics at slaughter. The experiment was carried out at the Massey University Deer Research Unit (DRU), Palmerston North, for 255 days from 15 March 1994 to 27 November 1994, and was divided into autumn (71 days), winter (116 days) and spring (68 days) periods.

Forages

The forages grazed were established perennial ryegrass (cv. Grasslands Niu)/white clover (cv. Grasslands Huia) pasture and chicory (cv. Grasslands Puna), sown December 1992. Both forages were grazed by hinds and calves and yearling deer in the 6 months prior to the start of the trial. Potassic superphosphate (9%P : 10%:S : 7% K) was applied to both forages in late April 1994 at 250 kg/ha. Nitrogen fertilizer

(urea; 46% N) was applied to both forages in late March (chicory 76 kg N/ha; pasture 56 kg N/ha) and early August (chicory 76 kg N/ha; pasture 60 kg N/ha). In autumn, chicory paddocks were mechanically topped following initial grazing to remove reproductive stem material in order to maintain the vegetative state and in winter were sprayed with herbicide (Galant; Dow-Elanco, NZ Ltd; 3 litres/ha) to control grasses.

Animals

Nine red hinds, ten red stags, 13 hybrid hinds (0·75 red:0·25 elk) and 12 hybrid stags were used. Mean initial liveweight (±S.D.) was 50·6 (±6·23) kg. On 28 February 1994, the fawns were weaned, weighed and vaccinated against clostridial infections (Clostridial 5 in 1; Ultravac CSL Ltd, NZ) and yersiniosis ('Yersiniavax; AgVax, AgResearch, NZ) by subcutaneous injection into the front of the neck, and treated orally with ivermectin (Ivomec oral, 0·4% w/v at 200 μ/kg liveweight; Merck, Sharp and Dohme, NZ). Booster vaccinations were given 30 days later. On 15 March the weaners were ear-tagged and reweighed. On 17 March they were randomly assigned to the four treatment groups based on liveweight, and balanced as far as possible for sex and genotype. On 3 October all deer were given 12 g cupric oxide/animal orally (Copper Needles; Bayer NZ Ltd) and a 3 ml injection of vitamin B12 (Project 1 mg vitB12/ml; Bomac Laboratories Ltd, NZ) subcutaneously in the front of the neck.

Deer were weighed and a rectal faecal sample was taken for FEC and FLC at 3-weekly intervals. Blood samples (10 ml) for serum pepsinogen analysis were taken 6-weekly by jugular venipuncture using plain vacutainers (Hemogard; Becton-Dickinson, New Jersey, USA). Samples stood at room temperature for 2 h before being centrifuged (20 min; Minifuge-T; Heraeus, Separationstechnik, Gispsmuhlenweg, Germany). Sera were stored at −20 °C. Spiker velvet antler was removed when 20 cm in length by the method described by Semiadi *et al.* (1993) and weight and date of removal were recorded.

Treated animals (T) were administered oral anthelmintic 3-weekly, until 6 weeks before slaughter. All deer in a trigger-treated (TT) group were given anthelmintic (Ivomec oral, 0·4% w/v at 200 μg/kg liveweight; Merck, Sharp and Dohme, NZ) when one or more of the following conditions were met: (i) one or more animals in the group exhibited clinical signs of parasitism; (ii) the group mean average for lungworm larvae exceeded 150 larvae/g faeces, with 100% prevalence; (iii) an individual animal in the group exceeded 500 lungworm larvae/g faeces, or (iv) eggs of strongylid nematodes exceeded a group mean average of 1000/g faeces. Anthelmintic usage was recorded.

Grazing management

Deer were rotationally grazed throughout the trial, with allowances (excluding dead matter) for all animals being set at 5 kg DM/hd/day from 17 March until 1 September (autumn and winter), 6 kg DM/hd/day from 1 to 19 September (late winter), and 7 kg DM/hd/day from 19 September to slaughter on 28 November (spring). Rotation length was 4–7 weeks, with grazing periods of 4–7 days for chicory and 5–10 days for pasture. Each paddock was bisected with an electric fence (5-strand, Gallagher Electronics, Hamilton, NZ), and the T and TT groups were randomly allocated to one half each. Treatment groups were rotated to the same side of each paddock, so that no cross-grazing occurred.

In autumn and spring, the deer grazed either chicory (2·39 ha), or pasture (2·46 ha). In winter, the chicory and pasture groups were combined on pasture (3·66 ha) due to chicory becoming dormant, with the two anthelmintic treatment groups continuing to graze separately.

Forage sampling and measurements

Pre- and post-grazing herbage mass was measured by taking cuts to soil level from six quadrats ($0{\cdot}1^2$) per each half paddock for DM determination, enabling the calculation of grazing days (Semiadi *et al.* 1993) according to the allowance set. Samples of herbage on offer were taken from each whole paddock at the start of grazing, mixed and divided into two 200 g portions and stored at −20 °C. Samples for botanical composition were dissected into grasses, clover (red and white), dead matter and weed (for PRG/WC pasture); and chicory stem and leaf separately, clover, dead matter and weed (for chicory). Each component was separately oven-dried (100 °C for 18 h) and weighed. During autumn and spring, hand-plucked samples for estimating deer diet selected were taken daily (Kusmartono *et al.* 1996), pooled per paddock and stored at −20 °C for chemical analysis.

Voluntary feed intake

In autumn and in spring, intra-ruminal, slow-release chromium capsules (CRDC, Cr_2O_3 matrix; Nufarm, NZ) were administered to all deer to estimate faecal organic matter output (Parker *et al.* 1989). Rectal faecal samples were collected at 2-day intervals during days 8–22 post-CRDC insertion. Samples were oven-dried at 100 °C for 36 h (minimum 2 g dry weight/animal), pooled per animal, and ground for chromium analysis. Faecal output and VFI were calculated as described by Kusmartono *et al.* (1996).

Slaughter procedure

Thirty-five deer were slaughtered at the Feilding Deer

Table 1. *Seasonal pre- and post-grazing herbage mass (kgDM/ha ± S.E.) of perennial ryegrass/white clover pasture or chicory*

	Pasture			Chicory		
	n	Pre-grazing	Post-grazing	*n*	Pre-grazing	Post-grazing
Autumn						
Treated	6	2960 ± 352·9	1852 ± 128·4	8	2852 ± 160·1	1777 ± 79·4
Trigger-treated	6	2879 ± 236·1	1909 ± 169·2	8	2813 ± 189·3	1799 ± 114·7
Winter						
Treated	14	2377 ± 80·8	1413 ± 40·3	—	—	—
Trigger-treated	14	2310 ± 110·5	1377 ± 50·1	—	—	—
Spring						
Treated	6	3130 ± 332·6	2185 ± 413·0	6	2819 ± 95·4	1801 ± 62·8
Trigger-treated	6	3219 ± 401·9	2105 ± 447	6	3011 ± 126·4	1771 ± 144·8

Slaughter Premises (Venison Packers NZ Ltd) on 28 November, with nine red hinds remaining at Massey University Deer Research Unit as breeding replacements. Final liveweight was measured before transport. Hot carcass weight, carcass grade and carcass GR (an indirect measure of subcutaneous fat depth measured as soft tissue depth over the 12th rib, 16 cm from the dorsal midline) were recorded for each animal.

Laboratory analyses

Samples of diet selected were freeze-dried and then ground to pass a 1 mm sieve (Wiley Mill, USA). Organic matter (OM) content was determined by ashing overnight at 555 °C. *In vitro* organic matter digestibility (OMD) was determined by incubation with fungal cellulase and hemicellulase enzymes (Roughan & Holland 1977) and total nitrogen (N) was determined by the Kjeldahl method (Kjeltec Auto 1030 Analyzer, Tectator, Sweden). Total condensed tannins were determined by the modified butanol/HCl procedure of Terrill *et al.* (1992). Faecal chromium concentration was determined by atomic absorption spectrometry, as described by Costigan & Ellis (1987). Serum pepsinogen concentrations were assayed to the method described by Pomroy & Charleston (1989).

Faecal samples for FEC were refrigerated within 2 h of sampling (4 °C) and FEC were determined using a modified McMaster technique (Stafford *et al.* 1994), where a count of one egg was equivalent to 50 eggs/g faeces. Faecal lungworm larval counts were determined using a modified Baermann technique (Hendriksen 1965).

Data analysis

Liveweight gain, faecal eggs and larval counts, serum pepsinogen concentration and VFI were compared within each season using Generalized Linear Models (GLM; SAS 6·11; 1996, SAS Institute Inc, USA), with forage type, anthelmintic treatment, animal genotype, sex and interactions as factors. Liveweight gain at 3-weekly intervals throughout the experiment was also analysed using repeat measures analysis. Other factors analysed at the end of the experiment were final live-weight and carcass weight. Initial liveweight was used as a covariate in the analysis for live-weight and carcass weight, and carcass weight was used as covariate for carcass GR.

RESULTS

Herbage mass and botanical composition

Pre- and post-grazing herbage masses were similar for both chicory and pasture swards in autumn (Table 1). In spring the pre- and post-grazing herbage mass of chicory was lower than for pasture. There was no difference ($P = 0{\cdot}10$) in pre- and post-grazing herbage mass between areas grazed by T and TT deer for both forages.

Detailed seasonal botanical composition of chicory and pasture has been presented by Hoskin *et al.* (1998), and only a brief summary is given here. Perennial ryegrass constituted 59 ± 3·5 (S.E.)% of the pasture sward in autumn, and 82 ± 1·9% in spring. The white clover component of pasture ranged from 28 ± 2·0% in autumn to 7 ± 0·3% in winter and spring, whilst dead matter comprised 10–14%. Chicory content of feed on offer ranged from 71 ± 4·0% in autumn to 56 ± 2·1% in spring. The ratio of chicory leaf:stem was 1·9:1 in autumn and 20:1 in spring. The white and red clover content of the chicory sward was 4 ± 1·2% in autumn, increasing to 24 ± 2·2% in spring. The dead matter content of chicory was 20 ± 2·8% in autumn and 11 ± 2·7% in spring. The weed component of chicory increased from 6 ± 1·6% in autumn to 9 ± 2·4% in spring, while the weed component of pasture was consistently lower than for chicory and was similar in autumn and spring (3 ± 1·1%).

Nutritive value and chemical composition of the diet selected

Chicory diet selected had a significantly lower OM content than pasture in autumn ($P < 0{\cdot}01$) and spring ($P < 0{\cdot}01$) (Table 2). Organic matter digestibility of diet selected for chicory was higher than pasture in both autumn ($P = 0{\cdot}08$) and spring ($P = 0{\cdot}05$). There was no difference in total nitrogen (N) content between chicory and pasture diet selected in autumn or spring ($P = 0{\cdot}10$). Low concentrations of condensed tannins (CT) were measured in both pasture and chicory selected. The total CT content of both forages was very similar in both seasons, with total CT concentration being higher in autumn than in spring.

Table 2. *Seasonal chemical composition* (% *DM* ± *S.E.*) *of diet selected by deer grazing either perennial ryegrass/white clover pasture or chicory*

	Season	Pasture	Chicory
Total N	Autumn	4·16 ± 0·17	3·79 ± 0·11
	Spring	3·08 ± 0·11	3·36 ± 0·23
OM	Autumn	90·1 ± 0·55	82·1 ± 0·55
	Spring	91·6 ± 0·38	87·0 ± 0·38
OMD (% OM)	Autumn	82·7 ± 0·54	85·2 ± 1·05
	Spring	83·8 ± 2·34	88·4 ± 0·03
Total CT	Autumn	0·26 ± 0·020	0·26 ± 0·015
	Spring	0·14 ± 0·005	0·17 ± 0·025

$n = 4$ for each forage in each season.

Liveweight gain and anthelmintic treatment

Figure 1 shows the times of trigger treatment in the TT groups and LWG at 3-weekly intervals throughout the trial. Treated deer on both forages received anthelmintic on 11 occasions, at 3-weekly intervals. Repeat measures analysis showed a significant effect of time on LWG ($P < 0{\cdot}01$) and a significant forage × anthelmintic treatment × time interaction ($P < 0{\cdot}01$). The latter can be explained by LWG decreasing in the TT pasture group during late autumn and in the chicory TT group grazing PRG/WC pasture during early winter. Trigger-treated deer grazing pasture were first treated with anthelmintic on 17 May (late autumn) because of liveweight loss of some animals, bouts of coughing and laboured breathing and reduced VFI. Treatment was repeated on 20 June (early winter) after further reduced liveweight gain and coughing. Following this, it was decided to treat the pasture-fed TT group at three

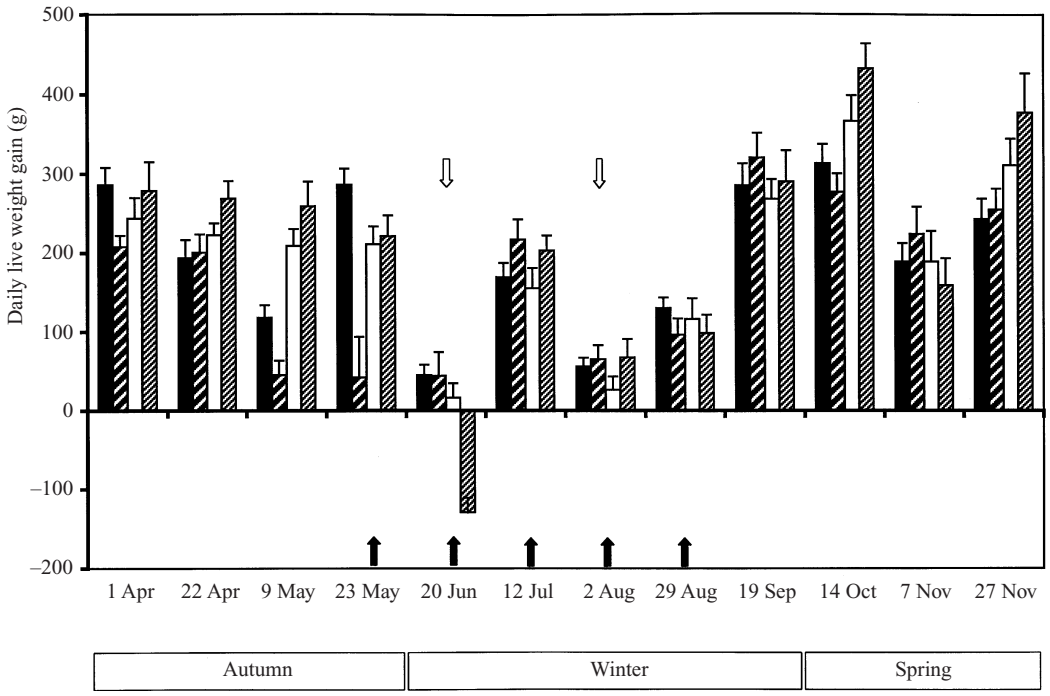

Fig. 1. Three-weekly mean (±S.E.) daily liveweight gain (LWG; g/d) of deer grazing perennial ryegrass/white clover pasture (P) or chicory (C) and treated three-weekly (T) or trigger-treated (TT) with anthelmintic. ■, P (T); ▨, P (TT); □, C (T); ▨, C (TT). (⇑, P, ⇩, C: Administration of anthelmintic in the TT groups). (Dates of liveweight measurement and anthelmintic treatment of T-groups on *x*-axis.)

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

	Pasture		Chicory		
	Treated	Trigger-treated	Treated	Trigger-treated	S.E.
Number of deer	11	11	11	11	—
Voluntary feed intake					
Autumn	1920	835◆	1015	1150◆	127·3
Spring	1539	1739	1765	1631	55·2
Mean liveweight					
Initial (15/3/94)	50·4	49·8	51·1	49·2	0·95
End autumn (25/5/94)	63·8	57·2	62·0	64·0	1·20
End winter (19/9/94)	80·0	74·5	77·0	76·7	1·94
End spring (27/11/94)	96·4	90·0	94·7	94·5	1·42
Autumn (71 days)	217	125	184	212	8·7
Winter (116 days)	133	138	115	95	7·4
Spring (68 days)	249	238	288	291	12·4

D.F. = 40. ◆ VFI was measured prior to anthelmintic treatment being given to these groups.

Table 4. *Carcass measurements of stags and hinds, treated (T) or trigger-treated (TT) with anthelmintic and grazed on perennial ryegrass/white clover pasture or chicory*

	Stags					Hinds				
	Pasture		Chicory		S.E.	Pasture		Chicory		S.E.
	T	*TT*	*T*	*TT*	(D.F. = 20)	*T*	*TT*	*T*	*TT*	(D.F. = 12)
Number of deer	5	6	5	6		4	3	3	3	—
Number reaching target CW	5	4	4	6		2	1	3	1	—
Carcass weight (kg)	57·9	51·3	57·1	57·0	1·52	50·0	46·5	50·1	47·3	0·90
Dressing percentage (%)*	54·2	52·9	54·9	55·3	0·49	55·1	54·0	56·0	54·1	0·32
GR tissue depth (mm)†	5·4	6·2	6·0	5·9	0·33	3·4	5·9	3·7	5·9	0·50

* Dressing percentage calculated using final liveweight off pasture prior to being trucked.
† Adjusted to equal carcass weight.

further 3-weekly intervals during the winter period (Fig. 1). The TT chicory group received two anthelmintic treatments, both during winter when they were grazing PRG/WC pasture, when clinical signs were observed as in the pasture TT group.

The average autumn LWG and final autumn liveweight of the TT pasture group was lower than that of the other three groups ($P < 0{\cdot}01$) (Table 3). The winter final liveweight of the pasture TT group remained significantly lower than the pasture T group ($P < 0{\cdot}01$). During spring, the mean LWG of deer grazing chicory was greater than for deer grazing pasture ($P < 0{\cdot}05$), with no effect of anthelmintic regime. The final spring liveweight of the pasture TT group was significantly lower than the pasture T group ($P < 0{\cdot}05$) only, with no significant differences between the two chicory groups.

During autumn, hybrid deer gained $200 \pm 9{\cdot}1$ (S.E.) g/day compared with red deer, which gained $170 \pm 9{\cdot}9$ g/day ($P < 0{\cdot}05$) and during spring, hybrid deer gained $296 \pm 10{\cdot}1$ g/day, compared with red deer, which gained $237 \pm 11{\cdot}6$ g/day ($P < 0{\cdot}001$). A significant forage × genotype interaction for spring LWG ($P < 0{\cdot}05$) was found, where hybrid deer on chicory gained $331 \pm 13{\cdot}0$ g/day, red deer on chicory gained $238 \pm 14{\cdot}5$ g/day, hybrid deer on pasture gained $260 \pm 13{\cdot}0$ g/day and red deer on pasture gained $233 \pm 15{\cdot}2$ g/day. Stags gained liveweight significantly faster than hinds during winter ($159 \pm 5{\cdot}7$ *v.* 81 ± 59/day) and during spring ($323 \pm 10{\cdot}8$ *v.* $209 \pm 10{\cdot}9$ g/day, $P < 0{\cdot}001$). Final liveweight was significantly greater for stags than for hinds ($P < 0{\cdot}001$) at the end of winter ($81 \pm 0{\cdot}9$ *v.* $73 \pm 0{\cdot}9$ kg) and spring ($102 \pm 1{\cdot}3$ *v.* $86 \pm 1{\cdot}3$ kg). There were no interactions

Table 5. *Serum pepsinogen concentration (mU tyrosine/l ± S.E.) from deer grazing either perennial ryegrass/white clover pasture or chicory and treated with anthelmintic 3-weekly (T) or trigger-treated (TT)*

	Pasture		Chicory	
	T	TT	T	TT
Autumn				
26 April	301 ± 28·6	274 ± 28·8	194 ± 28·6	246 ± 28·6
Winter				
30 May	302 ± 30·0	269 ± 30·3	257 ± 30·0	263 ± 30·0
12 July	321 ± 31·9	283 ± 32·2	308 ± 31·9	355 ± 31·9
29 August	335 ± 31·9	346 ± 32·2	330 ± 31·9	439 ± 31·9

D.F. = 40.

involving sex, genotype, forage or anthelmintic treatment for final liveweight for any season, or for LWG during autumn and winter.

Voluntary feed intake

Voluntary feed intake (Table 3) of deer grazing chicory was similar for both anthelmintic treatments during autumn and spring. The VFI of the pasture TT group was lower than the pasture T group in autumn ($P < 0{\cdot}01$), but not spring. During autumn, the VFI of both chicory TT ($P < 0{\cdot}05$) and treated ($P < 0{\cdot}01$) groups was lower than the pasture T group, but in spring VFI of all groups was similar.

There was a trend towards higher VFI of hybrid deer than red deer in autumn (1443 ± 150·7 *v.* 997 ± 167/8 g/day; $P = 0{\cdot}06$) and spring (1748 ± 56·6 *v.* 1588 ± 66·0 g/day; $P = 0{\cdot}07$. Stags exhibited significantly higher VFI than hinds in spring (1884 ± 62·0 *v.* 1453 ± 59·9 g/day; $P < 0{\cdot}001$), but not autumn (1366 ± 158·5 *v.* 1073 ± 158·6 g/day; $P = 0{\cdot}20$). There were no interactions involving sex, genotype, forage or anthelmintic treatment for VFI during autumn or spring.

Carcass production

For deer grazing chicory, 88% of both T and TT deer reached the target of 92 kg liveweight (50 kg carcass weight) by one year of age, whilst for pasture, 56% of TT and 78% of T deer reached this target (Table 4). An initial analysis of carcass weight (CW) data revealed no treatment effects, despite treatment effects on final liveweight. The statistical analysis was repeated with initial liveweight as a covariate, when a

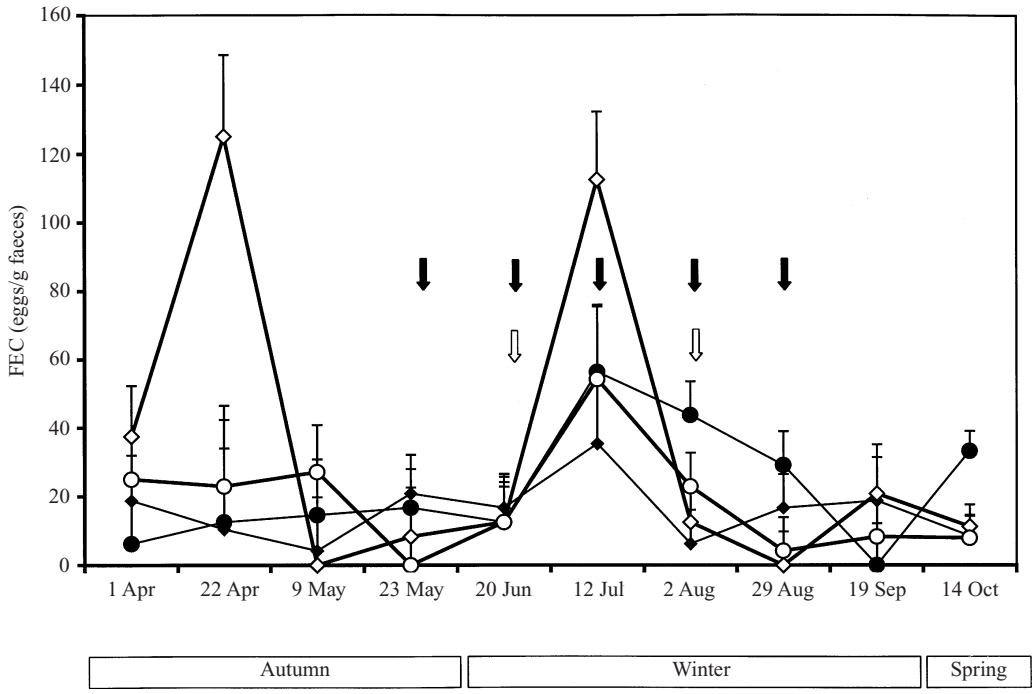

Fig. 2. Mean (± S.E.) faecal egg counts (FEC; epg) of deer grazing perennial ryegrass/white clover pasture (P) or chicory (C) and treated three-weekly (T) or trigger-treated (TT) with anthelmintic. ◆, P (T); ◇, P (TT); ●, C (T); ○, C (TT). (⬇, P, ⇩, C: Administration of anthelmintic in the TT groups.) (Faeces sampling dates and anthelmintic treatment dates for T-groups on *x*-axis.)

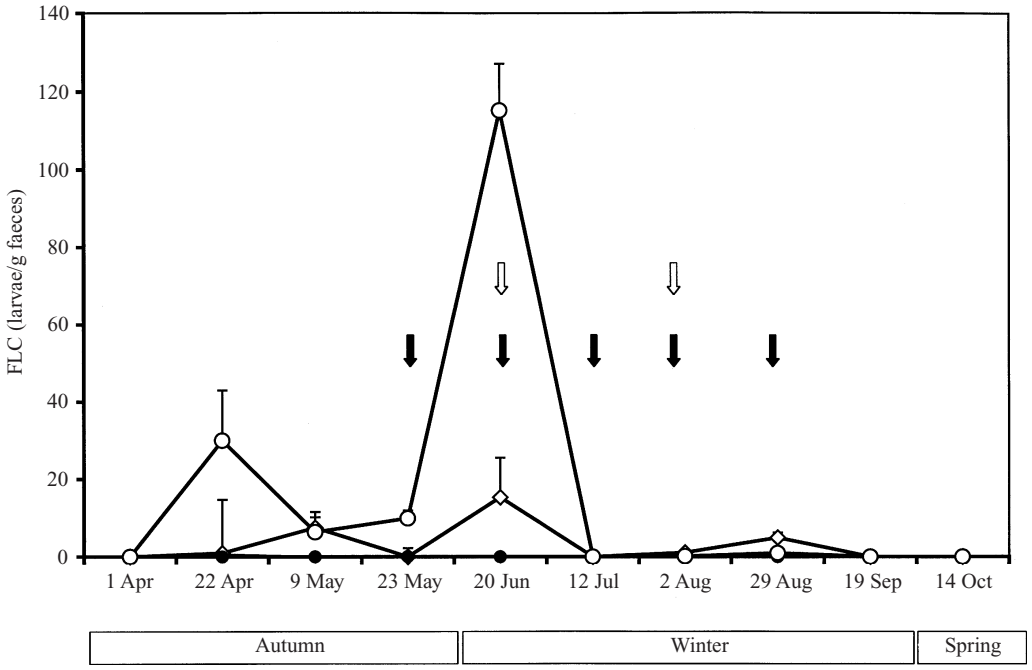

Fig. 3. Mean (±S.E.) faecal lungworm larval counts (FLC; lpg) of red deer grazing perennial ryegrass/white clover pasture (P) or chicory (C) and treated three-weekly (T) or trigger-treated (TT) with anthelmintic. ◆, P (T); ◇, P (TT); ●, C (T); ○, C (TT). (⇓, P, ⇩, C: Administration of anthelmintic in the TT groups). (Faeces sampling dates and anthelmintic treatment dates for T-groups on X axis).

significant forage × anthelmintic interaction was found ($P = 0{\cdot}011$), with CW of the pasture TT group being significantly lower than the pasture T group ($P < 0{\cdot}01$), but there was a difference between chicory groups. Carcass weight was significantly greater for hybrid stags than red stags ($59{\cdot}5 \pm 1{\cdot}89$ *v.* $52{\cdot}2 \pm 2{\cdot}05$ kg; $P < 0{\cdot}001$), and was greater for hybrid stags than hybrid hinds ($48{\cdot}5 \pm 1{\cdot}30$ kg; $P < 0{\cdot}001$). A significant forage × genotype interaction was found for CW ($P < 0{\cdot}05$), with hybrid deer on chicory having a greater carcass weight than red deer (54·5 *v.* $47{\cdot}9 \pm 1{\cdot}58$ kg; $P < 0{\cdot}01$), whilst CW of hybrid and red deer grazing pasture was similar (51·1 *v.* $51{\cdot}9 \pm 1{\cdot}70$ kg). There were no significant differences in carcass subcutaneous fat depth (GR; adjusted to equal CW) due to forage grazed or anthelmintic treatment. The dressing out percentage (DR) of the pasture TT group was significantly lower than that of the other three groups ($P < 0{\cdot}05$). There was no effect of sex or genotype on GR or carcass DR.

Serum pepsinogen

The serum pepsinogen concentration (Table 5) of both T and TT pasture groups was higher than the chicory-T group in mid-autumn ($P = 0{\cdot}07$), but there was no difference in mean pepsinogen concentration between groups during early and mid-winter. However, in late winter there was a tendency for serum pepsinogen concentration of the chicory TT group to be greater than all other groups ($P = 0{\cdot}07$).

Faecal egg and larval counts

Regular anthelmintic administration to treated deer grazing both forages maintained FEC at low values and maintained FLC at values close to zero. Faecal egg counts (Fig. 2) from the pasture TT group were significantly higher than all other groups in early autumn ($P < 0{\cdot}01$). The pasture TT group had higher FEC than both chicory groups ($P = 0{\cdot}06$) in early winter. FEC did not differ significantly between chicory groups at any time during the experiment. Faecal lungworm larval counts (Fig. 3) of the chicory TT group grazing pasture during early winter were significantly higher than all other groups at this time ($P < 0{\cdot}001$), with no differences found in FLC between pasture groups.

DISCUSSION

This study has shown that venison production from young deer by 1 year of age can be achieved with reduced anthelmintic input when deer are grazed on

chicory in autumn, but not when they are grazed on PRG/WC pasture. This is the first such observation for deer and suggests that the use of different herbage species may play an important role in parasite control on deer farms. Withholding anthelmintic treatment resulted in clinical parasitism in deer grazing pasture during autumn, associated with reductions in LWG, VFI, carcass weight and a 22% reduction in the number of deer reaching 92 kg liveweight (50 kg CW) by 1 year of age, despite trigger treatment.

There was no effect of withholding anthelmintic treatment on autumn LWG, VFI on carcass weight of deer grazing chicory, but clinical parasitism became apparent once these deer were transferred to pasture for the winter period. This may have been due to the parasite larval challenge on pasture, but may also have been a result of failure to develop resistance in autumn because of low exposure to parasite larvae on chicory. These results are similar to those of Scales *et al*. (1995) who found that lambs grazing chicory in autumn were unaffected by gastrointestinal nematodes, whilst parasitized lambs grazing grass pastures exhibited lower carcass weights than anthelmintic-treated lambs. Chicory therefore may offer the potential for reduced anthelmintic use in autumn, whilst simultaneously increasing LWG in autumn and spring when fed under higher herbage allowance (7 kg DM/deer/day) and higher post-grazing herbage mass ($>$ 2100 kg DM/ha; Kusmartono *et al*. 1996) than used here. The similarity in LWG, and VFI of deer on both anthelmintic treatment regimes in spring indicates that deer were unaffected by internal parasites by this time, probably due to the development of host resistance or the effect that treatment of all groups during late winter had on parasite life-cycles.

No studies have been performed to investigate the relationship between potentially diagnostic parameters such as FEC and FLC or serum pepsinogen concentration and nematode burdens, or the likelihood of clinical or sub-clinical effects of parasites in deer. Therefore, the trigger treatment criteria chosen were based on first principles clinical judgement. During autumn in the pasture TT group, a combination of liveweight loss, reduced VFI and clinical signs of coughing occurred in the absence of significant FEC and FLC. The decision to treat was followed by a rapid reduction of coughing and return to expected LWG. That FEC and FLC were low at that time could indicate that the majority of nematodes were immature, yet were of sufficient numbers to cause clinical signs, or that the fecundity of adult nematodes was low. This can only be determined post-mortem, and it is clear that future experiments of this type will need to include slaughter of sub-groups at defined time intervals or when clinical symptoms are observed.

Thus, FEC and FLC appeared not to be of diagnostic or prognostic value during autumn, when larval challenge may be high and host resistance low. Counts appeared to be more useful during winter, particularly for FLC in the chicory TT group that grazed pasture over this period. However, some animals exhibited severe clinical signs of lungworm, despite FLCs of $<$ 10 larvae/g faeces. The extent to which gastrointestinal nematode burdens were contributing to the clinical signs observed is not known. Hypobiotic larvae of deer *Ostertagia*-type nematodes have been found in the abomasal walls of red (Connan 1991, 1997) and white-tailed deer (Baker & Anderson 1975) similar to pre- type-II ostertagiasis in cattle and it is possible that hypobiotic larvae could have caused or contributed to the clinical signs seen in this trial.

Attempts to correlate FEC with associated adult nematode burdens in deer have been complicated by low or zero FEC in infected animals (Wilson 1981), low nematode populations associated with high FEC and high variability of results (Anderson 1985; Schultz *et al*. 1993). Similar problems exist for FLC. Serum pepsinogen measurement has been used to attempt to confirm *H. contortus* (Johnston *et al*. 1984) and mixed abomasal nematode infections in red deer (Wagner & Mackintosh 1993) and elk (Mason 1984). In this study serum pepsinogen concentrations were inconclusive as a diagnostic aid. More research is needed to evaluate the use of both individual deer and herd mean serum pepsinogen concentrations as indicators of parasitism (Audige *et al*. 1998).

There was some evidence that gastrointestinal nematodes contributed to the reduced production of pasture TT deer in autumn and early winter (Fig. 2). However, clinical signs, especially coughing in the absence of diarrhoea, suggests that lungworm infection, not gastrointestinal nematode infection, was the major factor in the reduced LWG of the chicory TT group in early winter after they were transferred to pasture (Fig. 3). Whilst anthelmintic treatment was completely effective at eliminating lungworm larvae from faeces, it did not completely eliminate the presence of gastrointestinal nematode eggs in faeces.

Differing plant morphology and sward structure and/or effects of plant chemical composition are plant characteristics, which possibly contributed to deer grazing chicory having reduced parasite infection compared with deer grazing pasture. Chicory has a broad-leaved, taller, and more open growth habit than PRG/WC pasture and this may affect the microclimate within the sward and hence larval development, migration and survival (Knapp 1964). This may in turn influence larval intake by grazing animals. Moss & Vlassoff (1993) seeded different herbage species with strongylid eggs and recovered fewer nematode larvae from chicory than from grass swards. Niezen (1996) recovered fewer nematode larvae from chicory than from PRG/WC pasture swards contaminated with sheep faeces. A higher ratio of *trichostongylus : Ostertagia* spp. larvae was found on

chicory than on other herbage species (Moss & Vlassoff 1993; Niezen 1996). Deer-specific *Ostertagia*-type nematodes are the most prevalent gastrointestinal species in NZ red deer (Wilson 1981; Anderson 1985) associated with failure to thrive and/or death (Mason 1977; Connan 1991; Wagner & Mackintosh 1993). An advantage of chicory for deer production with reduced anthelmintic input may therefore be a less suitable micro-climate, particularly for the development and survival of *Ostertagia*-type deer nematodes.

Chicory contains trace concentrations of CT and other phenolic compounds including sesquiterpene lactones, coumarins and caffeic acid derivatives (Rees & Harborn 1985). These are part of the chicory plants' defensive chemistry and deter feeding by insects; they could potentially affect other organisms including perhaps gastrointestinal nematode and lungworm larvae. Cultivars of chicory selected for high and low concentrations of sesquiterpene lactones will be available for research in 1999 (W. Green, personal communication). Larval migration and survival should be studied on these cultivars. Forages containing medium to high concentrations of CT have been shown to increase the production of parasitized lambs compared with non CT-containing forages (Niezen *et al*. 1993*b*, 1995), but it is unlikely that the trace amounts of CT in chicory observed in this study had any effect, because there was no difference in CT content between chicory and pasture.

Research has indicated that young hybrid deer are more susceptible to parasitism than red deer (Mackintosh 1992; Waldrup *et al*. 1994), but the absence of any significant genotype × anthelmintic treatment interactions suggest that in this study hybrid deer with 0·25% elk genes were susceptible to internal parasites to the same extent as red deer. The significant genotype × forage interaction found for carcass weight is similar to that reported by Kusmartono *et al*. (1996), confirming the advantage for venison production of grazing weaner hybrid deer on chicory in autumn and spring to allow best expression of the elk genes for superior growth rate. Other sex and genotype differences on deer production shown in this study are similar to those reported by Kusmartono *et al*. (1996) and Hoskin *et al*. (1998).

This study has shown the potential for reducing anthelmintic input without a reduction in growth and carcass weight with weaner deer grazing chicory during autumn. Withholding anthelmintic treatment from weaner deer grazing PRG/WC pasture during autumn appears to increase the risk of sub-clinical parasitism. Further studies on the epidemiology and pathogenicity of mixed and single species gastrointestinal and lungworm infections in young deer grazing different forage species are required. Further research is also required into methods of diagnosis of internal parasite infections in deer, including FEC, FLC, serum biochemistry and haematology in relation to number of nematodes present and the pathogenicity of such infections. Such studies are essential if deer farmers are to minimize anthelmintic usage, in order to safely monitor the effectiveness of management and the risk of parasitism.

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