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Effect of winter nutrition on antler development in red deer (*Cervus elaphus*): a field study

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Abstract The effects of winter nutrition on date of antler casting and subsequent weight of velvet antler in red deer (*Cervus elaphus*) was investigated in two environments (Farm L, lowland; Farm H, high country). On each property three groups of mature, mixed-age stags were offered a pelleted feed *ad libitum*, half *ad libitum*, or not at all. All groups had access to hay and limited pasture. Both supplemented groups gained weight and the unsupplemented group lost weight on both properties. Only at Farm H was casting date and velvet antler weight affected by treatment and this may have been related to the effect of intake on body condition. Date of antler casting was related to pre-rut bodyweight rather than age; with each 10 kg increase in bodyweight, date of antler casting advanced by 3 - 4 days. Within an age group, velvet antler weight increased by 0.12 kg with each 10 kg increase in pre-rut bodyweight.

Keywords red deer; *Cervus elaphus*; nutrition; animal feeding; velvet antler; antler casting

INTRODUCTION

Antler regeneration in red deer (*Cervus elaphus*) occurs during spring and summer, and culminates in fully mineralised antlers before the breeding season in autumn. Developing antlers are covered by vascular epidermal tissue with sparse and soft epidermal hairs referred to as 'velvet' (Wislocki 1942). Brow, bez, and trez tines are often formed before the main shaft finally branches to form the royal tines. Just before royal tine formation, the antlers are removed in New Zealand for sale and use in traditional Asian medicine. Stage of growth, shape, and weight of antler are important criteria of quality.

Weight of antler is considered to be influenced by age, bodyweight, nutrition, and date of casting of previous 'hard' antler stubs. Casting date is earlier in older stags (Behrend & McDowell 1967; Jacobsen & Griffen 1983) and later in stags in poor condition (Watson 1971). There is a general trend for increase in antler weight with increasing age and bodyweight (Huxley 1926, 1931). Within an age group, weight of hard antler (Hyvärinen et al. 1977) or of 'velvet' antler at the initiation of royal tine development (Fennessy 1982) is positively associated with bodyweight. There is also evidence that, within an age group, velvet antler weight may be related to casting date (Fennessy unpublished data). Thus the hypothesis was developed that an improvement in winter nutrition might advance casting date and increase the yield of velvet antler.

MATERIALS AND METHODS

A winter feeding trial was carried out on two properties in Canterbury and two in Otago, New Zealand in 1979. A summary of data on casting date has been presented by Fennessy & Suttie (1985). This paper describes in detail the results from the two Canterbury properties. Farm L was a border-dyke irrigated lowland property situated 130 m above sea level; latitude 43° 56′S and longitude 172° 36′E. Farm H was a North Canterbury high country station, 600 m above sea level at latitude 42° 36′S and longitude 172° 30′E.

Three nutritional treatments were imposed on both properties; deer pellets were offered either *ad libitum* (Group 1), or at half the rate consumed by Group 1 in the previous week (Group 2), or not at all (Group 3). Table 1 gives the composition of the pellets. They were estimated to contain 11.5 megajoules of metabolisable energy (MJME) per kg of dry matter (DM).

Animals were confined in the smallest fenced areas available to minimise pasture intake. On Farm L each group was confined to 1.0 ha of improved pasture, whereas in Farm H Groups 1, 2, and 3 were restricted to hill paddocks of 4.5, 2.0, and 2.0 ha, respectively, in which matagouri (*Discaria toumatou*), silver tussock (*Poa laevis*),

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Table 1 Ration formulation and chemical analysis of a pelleted ration offered to groups of red deer stags during a winter feeding trial.

Component	Proportion of ration (%)
Ration formulation	
Barley	46.0
Lucerne meal	35.0
Linseed meal	15.0
Dicalciphate	3.5
NaCl	0.25
Vitamins, trace elements	0.25
Analysis	
Crude protein (g/kg DM)	170.0
Calcium (g/kg DM)	16.0
Phosphorus (g/kg DM)	9.0

Table 2 Average individual intake (kg DM/day) of hay, pasture, and pelleted rations by red deer stags during winter on two Canterbury farms.

		Intake		
Farm	Group	Pasture	Hay	Pellets
L	1	0.62	0.80	2.70
	2	0.36	1.58	1.20
	3	0.35	2.19	0
H	1	-	0.26	2.23
	2	-	0.69	1.15
	3	-	1.77	0

and semi-improved hill country pasture species were dominant.

Before the trial the stags were managed as a single mob on each property. Fifty-three stags comprising 23, 10, and 20 within age classes 3, 4, and 5 years were used at Farm L, and 48 comprising 16, 15, 5, 4, and 8 within age classes 3, 4, 5, 6, and 9 years, respectively, on Farm H. They were allocated to treatments such that groups were balanced for age and liveweight. The winter feeding regime began on 27 June and 5 July at Farms L and H, and continued until antler casting was completed, on 15 and 28 October at Farms L and H, respectively.

The pelleted ration was offered to Group 1 in covered hoppers which were refilled each week. Group 2 was offered, each day, one-fourteenth of the weekly DM intake of Group 1 in the previous week. All groups had unrestricted access to lucerne hay on Farm L and to meadow hay on Farm H. Pasture intake was estimated monthly by the difference technique (Lynch 1966). DM was determined on the pelleted feed, hay, and pasture samples by drying to constant weight at 70°C.

Rainfall and daily maximum and minimum temperatures were recorded throughout the period of winter feeding. Liveweight was recorded fortnightly until casting. On Farm L liveweight was also recorded after velveting and again on 5 March in the following year before the rut. The date of casting of the first antler stub was recorded daily at Farm L and weekly on Farm H. All groups were run in a single mob after antler stubs were shed.

The decision to remove individual antlers was made by farm staff as antlers attained the stage of bulbing of the main beam before royal tine formation. Thus antlers were removed at a morphological stage as dictated by commercial requirements, using established techniques for sedation and analgesia. They were subsequently weighed and antler length recorded around the external curvature. At Farm H velvet antler records were available from only 40 of the original 48 stags, from 14, 15, and 11 stags in Groups 1, 2, and 3, respectively.

Data were analysed statistically by analysis of variance, and differences between means were compared by Duncan's Multiple Range Test.

RESULTS

Meteorological data

Normal winters were experienced on both properties, with total rainfall during the 16-week period of winter feeding being 254 mm and 273 mm at Farms L and H, respectively. Mean daily temperatures were slightly higher on Farm L (8.4°C) than on Farm H (6.4°C). A lower incidence of frosts was recorded on Farm L, with 24 frosts out of the 106 days during which recordings were made, compared with 38 frosts out of 100 days on Farm H.

Feed intake

Table 2 gives the mean daily DM intakes of the groups. Supplemented groups consumed similar quantities of pelleted feed on both properties. Hay intake decreased as the level of supplementation increased but was consistently higher at Farm L than in comparable groups at Farm H. Pasture consumption at Farm L was estimated to account for between 11 and 17% of total DM intake. On the other property, the nature of the terrain made sampling difficult. As a consequence, estimates of pasture intake were not reliable and the data were excluded.

Bodyweight changes

Mean bodyweight at the start of the trial was 123.4 ± 1.42 kg at Farm L and 110.2 ± 1.75 kg at Farm H (Fig. 1, Table 3). Supplemented stags (Groups

Table 3 Mean bodyweight, antler casting date, and velvet antler data from red deer stags offered three levels of winter nutrition on two Canterbury farms. Differences between means are indicated by superscripts (Duncan's Multiple Range Test).

Farm	Treatment group	n	Bodyweight (kg) At commencement	At casting	Δ	At antler removal	Mean casting date	Velvet antler Weight (kg)	Growth phase (day)	Growth rate (g/day)
L	1	18	123.7	126.4	+2.7[a]	140.9	15 Sep[a]	2.17[a]	70[a]	31.0[a]
	2	16	122.6	125.5	+2.9[a]	139.0	21 Sep[a]	2.30[a]	70[a]	32.9[a]
	3	18	123.9	118.0	−6.1[b]	136.5	20 Sep[a]	2.28[a]	69[a]	33.0[a]
	SED		3.59	3.86	1.55	3.24	4.32	0.192	2.9	2.20
H	1	16	112.8	118.9	+6.1[a]	-	25 Sep[a]	1.46[a]	51[a]	28.6[a]
	2	16	108.7	113.2	+4.5[a]	-	29 Sep[ab]	1.38[ab]	54[a]	25.6[a]
	3	15	110.1	104.7	−4.6[b]	-	8 Oct[b]	1.22[b]	54[a]	22.6[a]
	SED		4.34	3.70	1.55		5.57	0.100	2.0	1.80

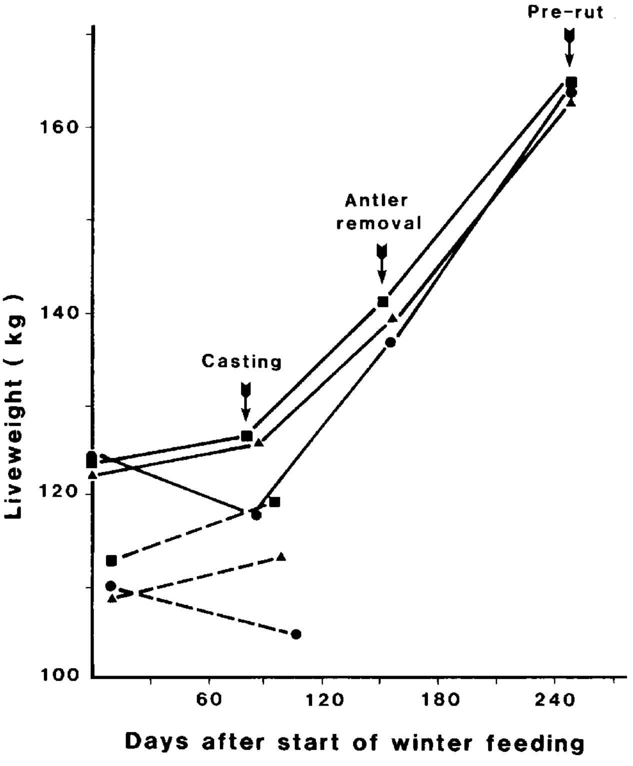

Fig. 1 Changes in liveweight in red deer stags offered three levels of winter feeding on two properties in Canterbury. ■, ▲, and ● represent *ad libitum*, half *ad libitum* pelleted feed, and control and —— and ------ Farms L and H, respectively.

1 and 2) tended to show smaller winter weight gains at Farm L (33 and 41 g/day, respectively) than at Farm H (68 and 54 g/day). On the other hand, the unsupplemented group at Farm L tended to show greater winter liveweight loss than at Farm H (−71 and −49 g/day, respectively). The difference in daily winter liveweight change between Group 3 and Groups 1 and 2 was significant on both properties ($P<0.01$), and so, as a consequence, was liveweight at casting ($P<0.05$ in both instances).

It was only possible to obtain bodyweight data after antler stubs were cast at Farm L. Recovery of pre-rut weight occurred during both spring and summer (Fig. 1). Group 3 stags which lost weight during the winter gained 264 g/day, significantly ($P<0.05$ and <0.01, respectively) faster than Group 1 (204 g/day) or Group 2 (189 g/day). Mean bodyweight at velvet antler removal was similar in all three groups (Table 3).

Casting date

Left and right antler stubs of individual stags were shed within a mean of 1.7 days at Farm L (range, 0 - 6) and there was no effect of treatment. This was not determined at Farm H, because of the low frequency of observations.

There was no effect of nutritional treatment on casting date at Farm L. Mean casting date was 19 September, with a range of 68 days. The pattern of antler casting was normally distributed in each group with a similar modal casting date. The wide spread of casting date was caused by a single stag casting 17 days earlier than the first of its herd-mates.

Mean casting date on Farm H was 30 September with a range of 59 days. Winter nutrition significantly ($P<0.05$) affected mean casting date (Table 3). The pattern of antler casting appeared to change from a normal distribution in Group 1 and, to a lesser extent in Group 2, to a skewed distribution in Group 3 with a delay of 2 weeks in the modal casting date of the latter group (Fig. 2).

At Farm L mean casting date for 5-year-old stags was 11 September, significantly earlier ($P<0.05$) than for either 4- or 3-year-old stags (19 and 25 September, respectively). Relationships were

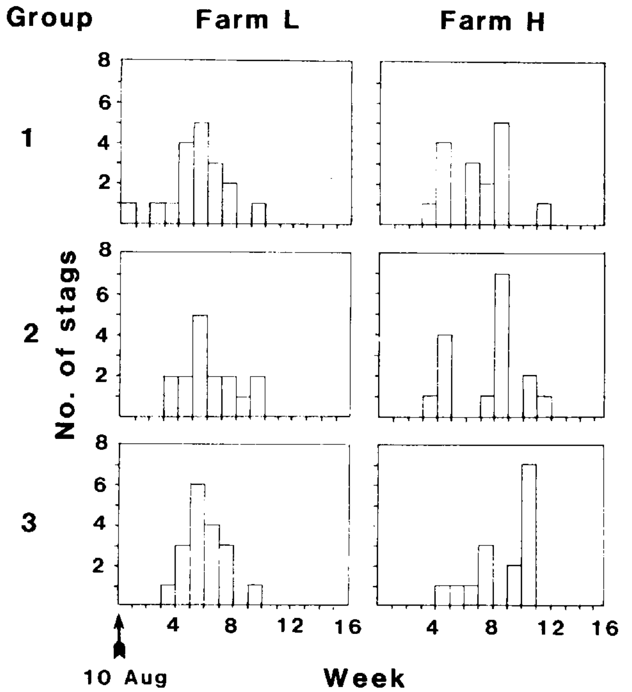

Fig. 2 Distribution of date of casting of hard antler in stags on two Canterbury properties (L and H). Groups 1, 2, and 3 represent stags offered pelleted feed *ad libitum*, half *ad libitum*, or not at all, respectively.

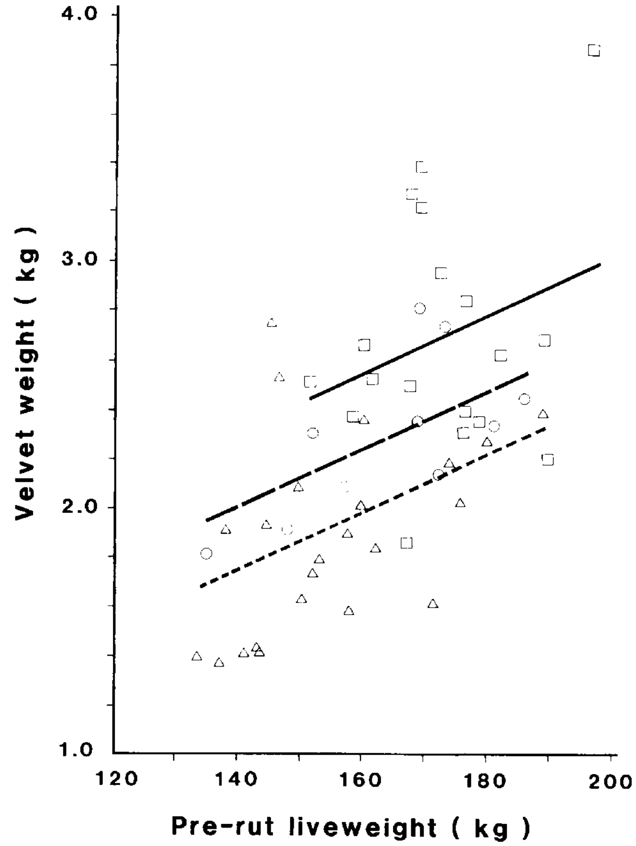

Fig. 3 The relationship between pre-rut liveweight and velvet antler weight in 3- (△), 4- (○), and 5- (□) year-old stags on Farm L. Antlers were removed according to commercial criteria, which was, on average, 69 days after casting.

detected between bodyweight, measured at several times, and date of antler casting, heavier stags tending to cast earlier. Analysis of covariance of the data derived at the different times indicated that the relationships between bodyweight and date of antler casting were similar within age groups; the results were therefore combined to derive common regression equations for each period. Subsequent pre-rut bodyweight (about 6 months after casting) was more closely related with casting date than bodyweight at the start of the trial (mid winter), at antler casting, or at antler removal. This is illustrated in the common regression Equations 1 - 4 where X refers to bodyweight (kg) and Y the date of antler casting (days from winter solstice).

1. $Y = 132.2 - 0.338\,X$ ($r=0.32$*, RSD $= 11.0$): weight at mid winter
2. $Y = 113.2 - 0.184\,X$ ($r=0.19$, RSD $= 11.4$): weight at casting
3. $Y = 126.1 - 0.257\,X$ ($r=0.31$*, RSD $= 11.0$): weight at velvet removal
4. $Y = 146.5 - 0.344\,X$ ($r=0.48$**, RSD $=$ 10.2): weight before subsequent rut

Antler growth rate

Velvet antlers removed from deer at Farm H were smaller at 1.36 ± 0.045 kg weight, and 0.33 ± 0.092 m in length, than from deer at Farm L — 2.25 ± 0.076 kg weight and 0.52 ± 0.140 m length.

Poor winter nutrition was associated with a decrease in velvet antler weight at Farm H, the difference between Groups 3 and 1 being significant ($P<0.05$; Table 2).

The mean time of velvet antler removal from stags at Farm L was similar between age groups — after 69, 68, and 72 days of growth in 3, 4, and 5-year-old stags, respectively. The effects of casting date and liveweight on velvet antler yield could therefore be examined within age groups. There were significant ($P<0.01$) linear relationships (Equations 5 - 7) between date of antler casting (X, days from winter solstice) and weight of velvet antler produced (Y, kg) within 3- and 4-year-old but not 5-year-old stag groups where:

5. $Y = 3.83 - 0.0201\,X \pm 0.34$ ($r=0.54$**, RSD $= 0.34$): 3-year-old stags
6. $Y = 4.24 - 0.0214\,X \pm 0.23$ ($r=0.74$**, RSD $= 0.23$): 4-year-old stags
7. $Y = 4.44 - 0.0208\,X \pm 0.46$ ($r=0.39$, RSD $= 0.46$): 5-year-old stags

Bodyweight and velvet antler weight were also related. Of the bodyweights obtained during the experiment, (mid winter, casting, velvet removal, pre-rut) the linear regression equations relating subsequent pre-rut liveweight (X, kg) with velvet antler weight (Y, kg) explained most variation in the latter and were significant ($P<0.05$) within 3- and 4- but not 5-year-old stags. The slopes were similar between age groups and a common coefficient was fitted, and adjusted for age (Fig. 3, Equations 8 - 10), where:

8. $Y = 0.099 + 0.012\,X \pm 0.36$ ($r=0.44^{**}$, RSD $= 0.36$): 3-year-old stags
9. $Y = 0.361 + 0.012\,X \pm 0.25$ ($r=0.68^{*}$, RSD $= 0.25$): 4-year-old stags
10. $Y = 0.664 + 0.012\,X \pm 0.48$ ($r=0.25$, RSD $= 0.48$): 5-year-old stags

The different constants indicate that at the same liveweight, velvet antler weight was 0.26 kg and 0.56 kg greater in 4- and 5-year-old stags, respectively, compared with 3-year-old stags (Fig. 3).

Multiple regression analysis using casting date, pre-rut liveweight, and spring and summer liveweight gains did not explain significantly more variation in antler weight within age groups than did casting date alone.

DISCUSSION

The pelleted concentrate ration offered to Groups 1 and 2 substituted for hay and forage and prevented bodyweight losses that occurred in groups offered hay only. Thus the winter weight loss that occurs in male red deer (Kay 1980) and reindeer bulls (Ryg & Jacobsen 1982) as a result of the seasonal rhythm of voluntary feed intake may be reduced by the provision of higher quality feed. Bodyweight differences resulting from winter feeding treatments on Farm L had disappeared by the subsequent rut, indicating very rapid realimentation. This contrasts with the findings of Suttie & Hamilton (1983) and Suttie et al. (1983) of persistent effects of feed restrictions during the first and second winters. They concluded that poor winter nutrition, particularly during the first year of life, affected bone growth and might explain the small mature size of wild Scottish stags. In older stags undernutrition would predominantly influence soft tissue (Drew 1985) rather than skeletal size which may explain the rapid compensatory growth in the present study.

Differences between farms in casting date (11 days) and in antler growth rate (6.7 g/day) were large compared with the within-property effects associated with age, liveweight, and nutrition. Timing of antler removal varied by 17 days between properties and was probably caused by differences between operators in assessing the best stage for antler removal for commercial sale. Within-property comparisons for effect of treatment and other variables are still valid.

The delay and change in pattern of casting in stags experiencing the poorest nutrition at Farm H supports similar findings of the effect of poor body condition in Scottish red deer (Watson 1971). Casting in red deer occurs in late winter in association with low plasma testosterone concentrations (Wislocki 1942; Goss 1983) though the precise mechanism is unknown. Suttie et al. (1984) speculated that prolactin may act as an anti-gonadotrophin and Forbes et al. (1979) demonstrated that plasma prolactin concentration can be reduced by poor nutrition in sheep. Therefore in poorly nourished animals, such as those at Farm H, the late winter decline in plasma testosterone (Barrell et al. 1985) may be delayed thus delaying antler casting. Such an effect may well operate through a critical body condition rather than current nutrition *per se* since it did not occur in stags on Farm L despite a similar rate of weight loss to those on Farm H (Fig. 1). Stags on the latter property were lighter at the start of the trial which may reflect differences in body condition.

Casting occurred earlier in older stags, as noted by Behrend & McDowell (1967) and Jacobsen & Griffin (1983). However, older stags are usually heavier and the present data suggest that liveweight may be more important than age in influencing casting date. Furthermore, the improved relationship between casting date and bodyweight before the subsequent rut compared to bodyweight at casting may be explained if casting date is linked to frame size. Hyvärinen et al. (1977) considered that because of the seasonal nature of bodyweight change, values obtained before the rut best represent comparative frame size of individuals. Pre-rut bodyweight is highly repeatable between years ($r=0.89$; Muir unpublished data) and since autumn and winter weight losses, particularly in older, fatter stags are comprised largely of adipose tissue (Drew 1985), the effect is a narrowing of variation in bodyweight at casting. In the present study, values at the start of the trial, at casting, and at the subsequent rut were 123.4 ± 1.42 kg, 123.3 ± 1.62 kg, and 163.7 ± 2.21 kg, respectively, at Farm L.

Within an age group the heaviest stags not only cast earlier but also produced the heaviest antlers. Velvet antler weight increased by 0.12 kg for each 10 kg increase in pre-rut bodyweight, comparable to the value of 0.09 kg derived in 2-year-old stags by Fennessy (1982). Velvet antler weight also increased with age, irrespective of bodyweight, by 0.26 kg between 3- and 4-year-old stags, and by 0.30

kg between 4- and 5-year-old stags at constant bodyweight. This may be attributable to a change in pedicle diameter since Banfield (1960) described an annual deposition of concentric bone rings within caribou pedicles which implies an annual increase in pedicle size.

Within an age group, pre-rut bodyweight provided the best relationship with velvet antler weight which suggests an effect of frame size on antler weight. Thus nutrition during early growth may influence antler weight since, if sufficiently severe, it may affect the rate of attainment and ultimate mature size of the antler (Suttie et al. 1983). There was only a small effect of winter nutrition on antler growth at Farm H which can be largely explained by the later casting date. The 14-day delay in casting as a result of undernutrition on this property would have been predicted, from the data from Farm L, to result in antlers which were 0.28 kg lighter. This compares with the actual reduction of 0.23 kg. This study suggests that though frame size is the greatest determinant of antler weight, poor body condition may influence antler weight through delaying casting date. Further work is required to determine whether poor body condition *per se* influences rate of antler growth after casting.

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