Is there sire variation in seasonal liveweight gain of rising-yearling red deer?

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Abstract

Red deer exhibit the greatest seasonal control of nutritional physiology of farmed ruminants in New Zealand, highlighted by seasonal inappetence during winter, present in all sex and age classes. Four years of data from 2048 DNA-pedigreed mixed-sex progeny of 112 sires and 1069 dams from a red deer breeding stud were interrogated to investigate the hypothesis of sire variation in growth across seasons in rising yearlings. Analysis used 17145 live weights from progeny with ≥ 4 live weights to a minimum of 300 days of age. Estimates of the weights of all animals at the same age were calculated by fitting a restricted maximum likelihood model to adjust for multiple variables and create sire best linear unbiased predictions of rising-yearling growth. Liveweight gain was examined at 11 key seasonal ages. While overall post-weaning variation in liveweight gain was low (CV = 3.6-4.7%), for seasonal periods it was higher (CV 9.2-15.5%), with the greatest variability during the winter period (CV = 15.5%). Ranking sires by the predicted proportion of gained live weight of their offspring over seasonal periods showed sire variation across different seasons. Such variation may be beneficial allowing genetic selection of animals to fit d ferent farm systems.

Keywords: red deer; *Cervus elaphus*; seasonality; growth; live weight

Introduction

Red deer sub-species (*Cervus elaphus*), which originate from temperate Northern Hemisphere latitudes and climates, are ruminant herbivores that are opportunistic grazers and browsers (Kay & Staines 1981). This dietary plasticity, along with seasonal synchronicity of growth, reproduction and activity are key characteristics of cervids (Klein 1984). Kay (1981) characterised four three-monthly periods of growth for young red deer, birth to three months of age, three to six months of age, six to nine months of age and nine to fifteen months of age, noting that appetite falls to low levels during winter (6-9 months). Fennessy et al. (1981b) demonstrated that post-weaning liveweight gain (LWG) was low from 3 to 9 months of age, followed by high LWG from 9 to 15 months of age. Noting different peak weights between progeny of two sires, Fennessy (1981a) speculated that there may be potential for genetic selection for growth rate.

Genotype differences in growth rate of rising-one-year-old (R1) eastern European red deer *vs.* elk-crossbreds during winter and of New Zealand red deer *vs.* eastern European red deer and elk-crossbreds during spring, were described by Stevens et al. (2000). During the Deer Progeny Test (Ward et al. 2014) it was observed that offspring cohorts of individual sires with very similar genetic merit for 12-month live weight followed different pathways of growth to achieve similar sire mean live weights at 11-13 months of age. These pathways were measured at quarterly live weights at approximately 3, 6, and 9 months of age as R1s. If such genetic variation existed, lines of deer could be better fitted to individual farm systems or vice-versa.

It was hypothesised that sire variation in the proportion of liveweight gain of farmed red deer, with equivalent genetic merit for yearling live weight, exists during discrete seasonal periods to twelve months of age.

Methods

Animal data were sourced from a large deer stud breeding company Deer Improvement Limited (now trading as Melior) (Gudex et al. 2013; 2018), from animals born and raised on their breeding farm in Balfour (northern Southland, New Zealand). The progeny represented in these data were born in four different years; 2008, 2009, 2011 and 2012. Date of birth was calculated for all animals using either a known conception date from artificial breeding (either artificial insemination (AI), or embryo transfer (ET)), or estimated based on real-time ultrasonographic fetal ageing (White et al., 1989) if naturally mated (NM). Their pedigrees, (i.e., sire and dam), were determined by DNA methods (Gudex et al., 2013). Live weights of the R1 deer were available from January (approximately 60 days of age) prior to weaning (approximately 100 days of age) and then approximately monthly thereafter until a maximum of 375 days of age. Animals were raised outside on pastures of predominantly perennial ryegrass (*Lolium perenne*), containing white clover (*Trifolium repens*) and herb species including plantain (*Plantago lanceolata*) and chicory (*Cichorium intybus*). During the winter (June-September inclusive) the deer were grazed on fodder crops (forage brassica (e.g., swedes (*Brassica napus napobrassica*), rape (*Brassica napus biennis*) or kale (*Brassica oleracea acephala*) varieties), or fodder beet (*Beta vulgaris mangelwurzel*), and supplemented with ensiled pasture.

Live weights were measured with an electronic scale unit using load cells with precisions of 0.1 kg (<50 kg) and 0.5 kg (>50 kg). All individuals were weighed directly off pasture or crop (i.e., non-fasted live weight). Within the live weight dataset, not all individuals were weighed at all periods, and there were differences in the weighing dates for different mobs, among months and years. Data were excluded for animals with no pedigree, <4 live weights, or no liveweight data beyond 300 days of age (most culling was after this age). The final dataset for analysis contained 17145 live weights on 2048 R1 red deer, from 112 different sires and 1069 different dams. Many sires and most dams were used in more than one year. There were 7731 and 9414 live weights for female and male R1 deer, respectively.

The R1 deer had varying numbers and dates (or age) of weighing. To get valid comparisons of animals, estimates of the weights for all animals at the same age were calculated by fitting a restricted maximum likelihood (REML) model (Genstat v13.2 (VSN International, Hemel Hempstead UK). The model included fixed effects for; year born, sex, age (linear), interactions of these, and a linear correction for birth day (day of year; this latter term effectively gives a correction for the fact that animals reach particular ages at different times of the year), random terms for; sire, dam, animal, sire by linear age (slopes), dam by age, animal by age, and spline (or shape) terms for age, age by year born (different shape for each year), sire by age, dam by age, animal by age (Table 1). A less complex model which excluded fixed effects for sex, and year born interacting with sex, was used to produce growth curves for individual animals which was fitted independently for each sex (Table 2).

The growth curves produced live weights at 11 different ages of R1 deer: being 35, 70, 100, 145, 190, 230, 270, 310, 325 and 345 days of age. These were selected as they align with important developmental and seasonal points in the first year of life of a farmed red deer, including dam peak lactational output at Day 35, weaning at Day 100, end of autumn at Day 190, end of winter at Day 270, early and late spring at Days 310 and 345, respectively. From these 11 age points, four seasonal periods of post-weaning growth to 12 months of age were defined as: autumn between 100-190 days of age, winter between 190-270 days of age, early spring between 270-310 days of age, and late spring between 310-345 days of age. Prior to weaning, a fifth period was defined as summer between 35-100 days. Growth rates were calculated over these periods. Various data from these models were further analysed for the different seasonal growth periods, including live weight, proportional change in live weight (i.e., live weight gained over the period/live weight at the start of the period), and best linear unbiased predictors (BLUP) for the sire. Animals were ranked for each seasonal period by their proportional liveweight change over each season and outlier sires and dams were identified ranked by the proportion of their progeny in the top or bottom 5th percentile for those seasons.

Results

The REML-modelled growth splines for the R1 red deer predicted the average male in this herd to attain 30.6 kg by 35 days of age, 60.6 kg by weaning at 100 days, 78.9 kg at the end of autumn, 88.9 kg at the end of winter (270 days) and 110.2 kg in late spring at 345 days (Fig. 1). The average female was predicted to attain live weights of 28.2 kg, 55.1 kg, 69.1 kg, 75.2 kg, and 92.9 kg at the same times points, which is 8.0%, 9.2%, 12.5%, 15.4% and 15.7% less than those of the males (Figure 1).

Best unbiased linear predictions of R1 offspring live weight were produced for all sires and these are summarised in Table 1. Liveweight gains for the seasonal periods were calculated from the sire BLUP data, along with proportional changes in live weight, deviations from the mean of these seasonal liveweight changes and cumulative live weight from Day 35 (Table 2). Within this herd the overall variation of the sire liveweight BLUP at weaning (i.e., Day

Figure 1 Restricted maximum likelihood modelled mean live weights of male and female rising-yearling red deer born in 2008, 2009, 2011 and 2012 on a deer stud in Southland, New Zealand.

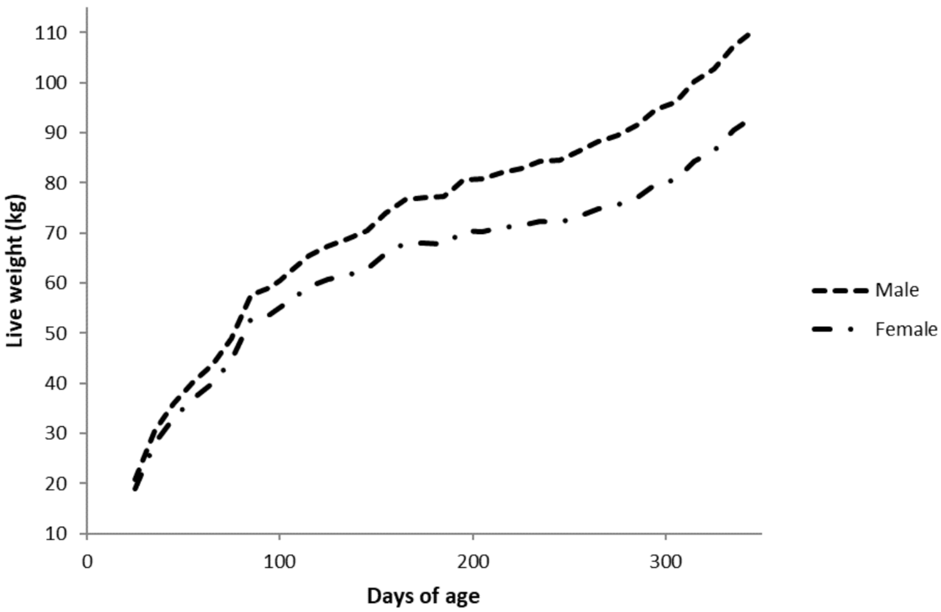

Table 1 Summary statistics, at key seasonal points from 35 to 345 days of age, of best unbiased liner predictions (BLUP) of the live weight (kg) of rising-yearling red deer sired by 112 different stags.

	Day 35	Day 100	Day 190	Day 270	Day 310	Day 345
Mean	29.4	57.5	74.0	82.0	90.2	101.6
Standard deviation	2.6	2.7	3.5	3.3	3.4	3.7
Minimum	19.4	49.7	61.6	71.3	78.9	90.1
Maximum	36.1	63.6	82.3	89.4	98.1	110.9
Coefficient of variatio	8.9%	4.7%	4.7%	4.0%	3.7%	3.6%

Table 2 Summary statistics of seasonal live weight gained (kg) and proportional change in live weight during each seasonal period (in parenthesis) from best linear unbiased predictions of the live weight of rising-yearling red deer by 112 different sires over key seasonal periods from 35 to 345 days of age (D).

	Summer D35-100	Autumn D100-190	Winter D190-270	Early spring D270-310	Late-spring D310-345
Mean	28.1 (0.97)	16.5 (0.38)	8.1 (0.11)	8.2 (0.10)	11.4 (0.13)
Standard deviation	1.8 (0.13)	1.7 (0.05)	1.3 (0.02)	1.0 (0.01)	1.0 (0.01)
Minimum	22.1 (0.73)	11.9 (0.26)	4.4 (0.05)	5.3 (0.07)	8.1 (0.09)
Maximum	31.4 (1.57)	20.1 (0.54)	12.0 (0.18)	10.5 (0.15)	13.3 (0.16)
Coefficient of variatio	6.3% (0.10)	10.2% (0.12)	15.5% (0.18)	12.8% (0.14)	9.2% (0.09)

Table 3 Best linear unbiased prediction of seasonal liveweight change in rising-yearling red deer, absolute change (kg), proportional change (in parenthesis), and seasonal haplotype (where H = high, L= low, and A = average proportional change in live weight, during summer, autumn, winter and spring respectively) for a selection of nine sires whose offspring represent population extremes for one or more season period.

Sire	Summer D35-100	Autumn D100-190	Winter D190-270	Spring D270-345	Seasonal haplotype
Bendigo	31.3 (1.18)	20.1 (0.47)	10.0 (0.13)	13.2 (0.14)	HHAL
Charles	28.1 (0.98)	18.1 (0.42)	5.2 (0.07)	14.2 (0.17)	AALA
Czar	30.1 (0.96)	19.3 (0.41)	8.0 (0.10)	12.7 (0.14)	AAAL
Ivan	27.7 (0.95)	15.4 (0.36)	8.0 (0.11)	18.8 (0.22)	AAAH
Kremlin	22.1 (0.73)	12.6 (0.30)	12.0 (0.18)	15.8 (0.19)	LLHA
Lazio	29.6 (0.95)	19.7 (0.43)	8.4 (0.10)	18.0 (0.19)	AHAA
Luciano	26.6 (0.80)	14.9 (0.32)	10.4 (0.14)	17.4 (0.19)	LLHA
Tundra	31.4 (1.05)	19.2 (0.42)	4.4 (0.05)	14.5 (0.17)	AALA
Tuscany	30.4 (0.92)	18.7 (0.38)	7.1 (0.09)	17.3 (0.18)	AALA

100) and discrete ages post-weaning was low-moderate for (CV 3.6-4.7%, Table 1), but BLUP for live weight gained over seasonal periods were much higher (CV 9.2-15.5%, Table 2) to 12 months of age.

There were sires identified whose data was at the extreme edges relative to the rest of the population for proportional liveweight gain for individual seasonal periods and in some cases for more than one seasonal period. Different representations of growth profiles for a selection of nine such sires with BLUP for proportional change in seasonal live weight over ≥1 season that were more or less than one standard deviation from the population mean, are shown in Table 3. Most of these sires were also extremes for the absolute liveweight gain in those seasonal periods. The average difference between proportional change in seasonal live weight BULP of the two most extreme selected sires, over each period, was 0.45, 0.13, 0.09 and 0.08 of liveweight gain, or 9.3 kg, 7.5 kg, 6.8 kg and 6.1 kg in absolute live weight over the summer, autumn, winter and spring periods respectively (Table 3).

These seasonal variations in growth can be represented as a haplotype to interpret the seasonal growth profile for a given individual in the first year of life as shown for the selected sires (Table 3). For the sires, the live weight BLUP at weaning and start of winter both correlated well (correlation coefficient R=0.77) with Day 345 live weight, while end-winter live weight correlated best (R=0.88) and Day 35 live weight the worst (R=0.44).

Discussion

In this analysis, the mean REML-predicted live weights produced sigmoidal curves, with greatest liveweight gain prior to weaning, lower gains in autumn, the lowest gains in winter and a sharp increase in liveweight gain in spring, as described by Kay (1981). There were BLUP estimated for individual sires that deviated markedly from these mean growth curves, with some much more linear in the post-weaning period and others a much more defined sigmoid with very low liveweight gain over winter. Key to this analysis was the proportional change in live weight over the period (i.e., liveweight gained/starting live weight), as individuals achieve very different live weights at the start of any given seasonal period. To better quantify seasonal growth potential within a herd, it is recommended to weigh R1 deer monthly to produce sufficient definition of seasonal liveweight variability, particularly across years.

While this study has identified sire variation in the seasonal growth of R1 deer, it has not considered possible mechanisms for this or factors contributing to it. These could include efficiency (e.g., digestive or metabolic (i.e., thermoregulation)) or behavioural differences (e.g., grazing behaviours or mob hierarchies). Quantification of some of these is important if genetic selection for seasonality is to be incorporated into a national breeding objective.

Identifying outlier sires within the current analysis reflects normal practice for stud breeders who are looking for freak, or “curve-bending” individuals to increase their genetic merit in particular traits or groups of traits. Within this analysis, the ability to identify sires of differing growth patterns could increase selection sophistication for growth to 12 months of age, by targeting seasonal periods. The deer production year is constrained by the seasonality of both the animal and pastures (Archer & Amer 2009). Variation of these annual cycles may offer opportunities to choose new targets or parts of the seasonal cycle to target either animals or nutrition to better suit both the animal and the farm system, better fitting the cycles of pasture production, or improving resource use efficiency.

At present there are three estimated breeding values (eBV) reported in DEERSelect for R1 live weight. Weaning weight (WWTeBV) is predicted from either a February, March or April live weight, autumn weight (AWTeBV) predicted from a May, June or July live weight, and yearling live weight (W12eBV) from an October, November or December live weight (Archer et. al. 2005). DEERSelect also has an unreported trait of spring live weight from August, September, or October measurements. If the New Zealand deer industry does want to consider selection for R1 seasonal growth, then the time period included in these traits must be more tightly defined, and a spring eBV should be reported. This would allow selection based on eBV for four key seasonal start and end points. It should be acknowledged that for breeders using selection indexes (Archer & Amer 2009), there is already a seasonal component within the indexes accounting for the seasonal variation in the cost of feeding.

Sire variation in R1 red deer growth over discrete seasonal periods offers opportunities for the New Zealand deer industry to better fit animals to farm systems, or farm systems to animals. These seasonal growth differences could be more valuable if they represent individuals that are productively more efficient (i.e., produce more kg product/$ farm system inputs). There is value in the industry further investigating the potential mechanisms of these seasonal differences (e.g., physiological and/or behavioural differences) and preparing DEERSelect to utilise or report on appropriate seasonal traits to select a better deer for future farm systems.

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