A split night photoperiod does not mimic effects of a long-day photoperiod on growth in weaner red deer stags

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ABSTRACT

In sheep, the effects of a long day photoperiod can be mimicked by providing a 'split night' light stimulus during the dark phase of a short-day photoperiod. This study tested the hypothesis that a similar response to a split night photoperiod occurs in deer. From 6 May until 3 September 2003, three groups of weaner red deer stags (n = 10) were subjected to: natural daily photoperiods (short days, experiencing the normal seasonal pattern of daylight), a long day photoperiod (16L:8D, where L = h of light, D = h of darkness) or natural daily photoperiods with a period of 1 h of light (*circa* 370 lux) during the dark phase (split night). For the first 3 months, liveweight gain was similar in all groups (approx. 140 g/day). However, growth of long-day exposed animals began to exceed that of the other treatments so that after 6 August their mean liveweight was significantly (P < 0.01) greater than that of the other groups. From 26 June to 3 September mean liveweight gain was, 324 ± 28.3, 209 ± 23.9 and186 ± 20.6 g/day for long day, split night and short day photoperiod groups, respectively. The long day group had the highest voluntary feed intake and appeared to initiate antler pedicle growth and testicular enlargement earlier than the other groups. Plasma prolactin concentration was elevated (P < 0.01) by the long day treatment (mean for long day group at 9 July = 33.4 ± 4.09 *versus* means of 6.9 ± 3.75 and 2.9 ± 0.99, ng/ml for split night and short day groups, respectively). These results show no stimulatory effect of the split night photoperiod on growth of red deer. It is concluded that some of the photoperiodic signals that can cause physiological changes in sheep are not effective in deer and, hence, there are differences in the underlying mechanisms of photoperiodism between these two species.

Keywords: red deer, growth, photoperiod, liveweight gain, feed intake, prolactin.

INTRODUCTION

Venison production is dependent on growth of weaner deer, however because much of the growth period of these animals is during winter it is limited by constraints on performance of both pastures and animals at that time of the year. Much of the winter-time constraint on feed intake and liveweight gain can be overcome by exposing deer to artificial lighting so that they experience long-day photoperiods (Suttie *et al.*, 1992; Davies *et al.*, 1995; Fisher *et al.*, 1995; Webster *et al.*, 1997,1998; Parkinson, 2001). Male red deer treated with 16 h light per day reached target liveweight for slaughter 7 weeks earlier than others maintained outdoors (Webster *et al.*, 1998), which means that farms where this system is employed benefit from the premium prices paid for early carcasses. Some farmers house deer under 16L:8D lighting systems (where L = h of light, D = h of darkness) to capture these beneficial effects on productivity (Lawrence, 2003).

Although it has become conventional to provide 16 h of light for photoperiodic growth stimulation of deer in winter, studies with sheep have shown that in this species a light duration of 16 h is not necessary for achieving such effects. There is evidence for a 'photosensitive phase' during the period of darkness when 1 h of light is sufficient, in animals on short day (8L) photoperiods, to mimic the growth-stimulating effects of a long day (16L) photoperiod (Schanbacher & Crouse, 1981; Brinklow *et al.*, 1984; Schanbacher *et al.*,

1985). This photosensitive phase seems to occur between 16 and 17 h after the onset of the previous block of light – i.e. the subjective 'dawn'. Although it has been reported that a similar phenomenon occurs in red deer (Suttie & Webster, 1998), that study lacked a control group and the finding could not be substantiated. Because of the potential for use of artificial lighting to achieve high growth rates in deer during winter, the present study was carried out to resolve this uncertainty.

MATERIALS AND METHODS

Animals and management

Thirty weaner red deer stags were housed from 6 May to 3 September, 2003 in a utility shed at the Lincoln University Research Farm in three separate pens. Each pen was 6 x 6.1 metres in area with a concrete floor covered in untreated pine shavings. Animals were offered sufficient pelleted concentrate feed ('All Purpose Ruminant', Western Animal Nutrition, Rangiora, containing 84.9% DM, 91.8% OM, crude protein 15.8% (DM), crude fat 2.5% (DM), DOMD 82.3%, 12.7 MJME/kg/DM - Analytical Services Unit, Lincoln University) daily so that they left approximately 10% (refusals) and water was available *ad libitum*. On 3 September the deer were combined into a single mob and returned to a paddock of ryegrass/white clover pasture. All animal procedures were approved by the Lincoln University Animal Ethics Committee.

Experimental outline

The experimental design consisted of three light treatment groups (n = 10): natural short day photoperiods (*short day*, negative control group), long day photoperiod (*long day*, positive control group) and natural short day photoperiods plus a 1 hour pulse of light at night (*split night*, experimental group). Pens for the long day and split night groups were lined with black polythene sheeting to prevent transmission of light to or from other pens, but were exposed to daylight through windows in the ceiling and upper rear wall. The pen for short day animals was not light proofed. In each pen, artificial lighting was provided by 2 fluorescent tubes (TDL 58W/840, 'cool white', Phillips) that produced an average of 374 lux at 1m above floor level, as measured with a digital light meter (Digital Lux Meter, Tes 1330). The lights were switched on and off by a programmable digital time switch (#808/2, HPM Industries Pty Ltd) that was adjusted according to the schedules outlined below.

Lighting treatment details

Short day treatment

The short day treatment group was exposed to natural daylight that was supplemented with artificial lighting on dull days whenever light intensity within the pen fell below 70 lux (at 1 m above floor level). This group experienced 0.5 h per day of civil twilight. Effectively, this group experienced natural daily photoperiods ranging from approximately 9 to 11 hours per day whilst the deer were indoors.

Long day treatment

For the long day treatment, lights were switched on at 0800 h each morning and off at various times after sunrise to provide 16 hours of light per day. Because this group experienced the natural sunrise, 0.25 h should be added to account for civil twilight, which makes the daily photoperiod effectively 16.25L:7.75D.

Split night treatment

For the split night treatment, the animals were exposed to natural daylight, however lights were switched on at 0800 h each morning and off at 1700 h each evening to ensure adequate light intensity within the pen. This group experienced 0.5 h per day of civil twilight. In addition this group received 1 hour of light (artificial lighting) during the night, approximately 16.5 h after sunrise. Effectively, this group experienced the same daily photoperiod as the short day group (above), but with the additional 1 hour pulse of light occurring approximately 16.5 h after dawn.

Measurements

Liveweight, testis diameter (anterior-posterior width using plate calipers), emergence of visible antler pedicles and length of right antler plus pedicle were measured fortnightly. The weight of feed provided (and refused) was recorded per pen every 2 days. Blood was sampled by jugular venipuncture on 6 May, 2003 immediately prior to the study, and twice more, on 9 July and 10 September 2003, and the plasma harvested for radioimmunoassay of prolactin (performed at Ruakura

Research Centre, Hamilton using ovine prolactin for iodination and standards) and testosterone (Shi & Barrell, 1992).

Statistical analysis

Effects of treatment on liveweight, testis diameter and antler length were determined using repeated measures analysis of variance (ANOVA), other variables were tested by ANOVA. Fisher's LSD (Edelstein-Keshet, 1988) was used to compare between means where there were significant treatment effects.

RESULT

Liveweight

Liveweight increased in all groups throughout the study ($P < 0.001$, Figure 1). During the first 3 months long day, split night and short day groups had an average liveweight gain of 163 ± 23.1, 114 ± 12.6 and 140 ± 9.3 g/day respectively. There was no significant effect of treatment on liveweight until 6 August, 3 months after the start of the trial, when the long day group had a mean liveweight (70.4 ± 1.75 kg) that was significantly heavier ($P < 0.01$) than that of the other groups (65.1 ± 0.96 and 65.9 ± 1.64 kg for split night and short day groups respectively, Figure 1). The difference in liveweight persisted throughout the remainder of the study. Between 26 June and 3 September, the long day group had an average weight gain of 324 ± 28.3 g/day, whereas the split night and short day groups had lower gains of 209 ± 23.9 and 186 ± 20.6 g/day, respectively.

FIGURE 1: Mean liveweight of weaner red deer stags (n = 10) subjected to long day, split night and short day treatments from 6 May to 3 September. Vertical lines indicate S.E.M., asterisks indicate significant differences -*P < 0.05, **P < 0.01.
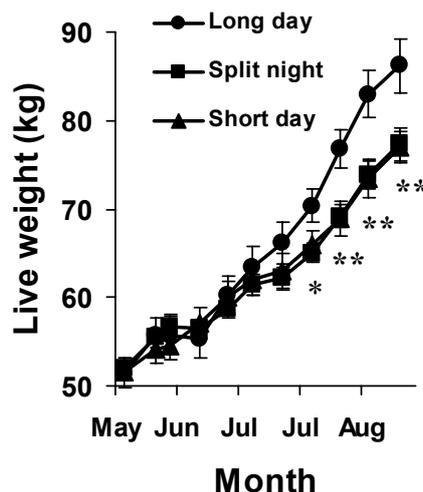

Feed intake

Voluntary feed intake in all groups increased throughout the trial period (Figure 2). It is not possible to perform a statistical comparison of these data. However, the split night and short day groups had a fairly static intake of around 1.5 kg DM/head/day from May until early August after which they showed the typical spring increase in feed intake. In contrast,

animals in the long day group consumed on average more feed (about 0.3 kg DM/head/day more) from late June to late August than those in the other two groups.

FIGURE 2: Average voluntary feed intake (VFI) of weaner red deer stags subjected to long day, split night and short day treatments from 6 May to 3 September. Each value is based on the 2-day intake per pen of 10 animals.
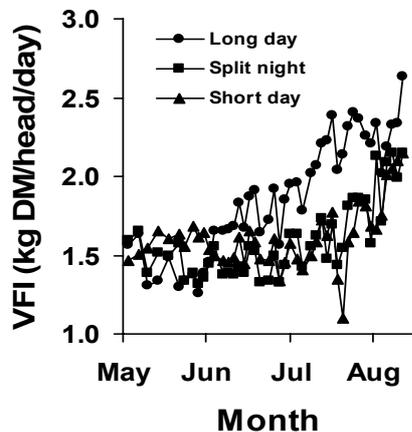
Prolactin

Mean plasma prolactin concentration was not different between groups (overall mean = 2.4 ± 0.42 ng/ml on 6 May, Figure 3) at the start of the study. However, on 9 July shortly after the winter equinox the long day group had an elevated (P < 0.01) mean plasma prolactin concentration (33.4 ± 4.09 ng/ml) compared with 6.9 ± 0.97 and 2.9 ± 3.75 ng/ml for the split night and short day groups, respectively (Figure 3).

FIGURE 3: Mean plasma prolactin concentration on two occasions (6 May, 9 July) of weaner red deer stags (n = 10) subjected to long day, split night and short day treatments from 6 May to 3 September. Vertical lines indicate S.E.M.
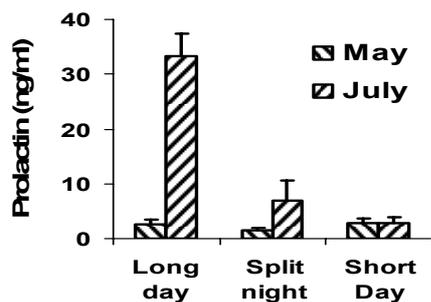
Testis diameter

Mean testis diameter increased throughout the study in all groups and did not differ (P > 0.05) between groups until 18 September when that of the long day group (2.9 ± 0.14 cm) was larger (P < 0.05) than those of the other two groups (2.3 ± 0.17 and 2.2 ± 0.13 cm for split night and short day groups respectively).

Testosterone

At the start of the study, mean plasma testosterone concentration was low (at about the lower limit of

detection in the assay) in all groups. In July and September, the mean concentration was higher (range 0.22 to 0.92 ng/ml) in all groups, but there was no effect of treatment on plasma testosterone concentration.

Antler formation and growth

Antler pedicles were visible on deer of the long day group about 2 weeks earlier than in the other groups and all 10 animals in this group had pedicles by 23 July, about one month before this was achieved in the split night group (Figure 4). The short day group contained one animal that had failed to show visible pedicle emergence by the end of the study period (18 September). In the latter half of the study period, the long day treated animals tended to have longer antlers (mean 11.7 ± 3.45 cm) than the other animals (means 09.1 ± 2.52 and 7.6 ± 1.76 cm for split night and short day groups respectively), but this was never significant.

FIGURE 4: Cumulative number of weaner red deer per treatment that had initiated visible antler pedicles on the dates shown.
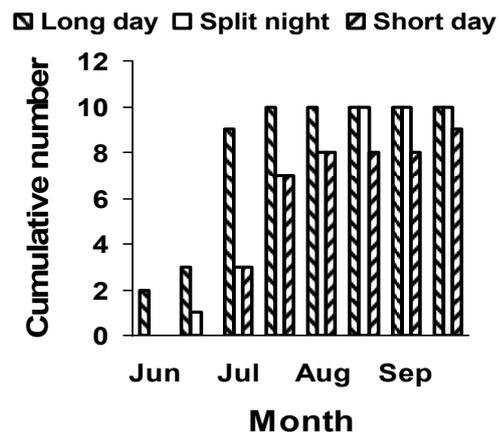
DISCUSSION

These results do not support the hypothesis that deer have a photosensitive phase during the hours of darkness in which a 1 h pulse of light will induce liveweight gains typical of spring during winter months. Weaner red deer stags in the group exposed to the split night lighting regime did not show the stimulatory effects on liveweight, feed intake, growth of antlers and testes, and plasma prolactin concentration that were recorded in the long day (16L) group.

This finding contrasts with results of a study of red deer at Invermay Agricultural Research Centre (Suttie & Webster, 1998). However, absence of a short day control group in that study means that the result is unsubstantiated. It is possible that growth of deer exposed to the variation in photoperiod at Invermay was not affected by either the 16L or split night lighting regime. Because the light treatments were not imposed until 21 June in that study, it is possible that the high liveweight gains, which occurred sooner than the normal

6 week lag period (Suttie & Simpson, 1985), may simply reflect the natural seasonal spring increase in liveweight gain (Fennessy *et al.*, 1981).

Nevertheless, evidence from the sheep studies together with the deer results from Invermay raises concern that deer do have a photo-inducible growth-stimulating phase during darkness which was missed in the present study. That the 1 h light pulse was not delivered to our deer was ruled out by direct observations of the reliability of the automated light switching equipment used here. Also, we used a lighting intensity well above the minimum that has been effective in the sheep studies (e.g. 80 - 100 lux in sheep, Brinklow & Forbes, 1984 *cf.* average of 343 lux in deer, here).

Another difference is that the lighting regimes used in other studies had exactly 16 or 8 hours of light plus periods of complete darkness, whereas our long day animals experienced natural sunrise (with attendant twilight) and the split night group experienced dawn as well and had varying periods of light (9 to 11 h per day). This was done to make the study comparable to a potential 'on farm' situation. The differences, both in hours of light per day and timing of the 1 h pulse in relation to the previous dawn, between this and other studies seem too small to account for the disparity in results. The remaining possibility is that a photo-inducible phase does exist in deer but it occurs outside the period used in this study. Studies with sheep have shown the photo-sensitive phase to be strictly limited to between 16 and 17 h after the subjective dawn, both for mimicking long day (prolactin – Thimonier *et al.*, 1978) or short day effects (testosterone – Garnier *et al.*, 1977) and this regime was followed in our study. Further work is required to explore the possibility that some other regime is appropriate for deer.

Notwithstanding the points raised above, the results obtained here rule out the existence of a photo-sensitive phase during darkness in deer and show that these animals differ from sheep in their response to photoperiodic signals.

ACKNOWLEDGEMENTS

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