This study evaluated the ability of short-term grazing of live pasture to increase ovulation rate during late summer when annual pasture is generally dead and of low quality. Ovulation rates, measured by the number of corpora lutea, were compared between 4 nutritional treatments: senesced phalaris (Phalaris aquatica), phalaris plus 500g lupin grain per day, lucerne (Medicago sativa) or chicory (Chicorum intybus) pastures. The study used 100 merino ewes per treatment, divided between 2 replicates...
Short term grazing of lucerne and chicory increases ovulation rate in synchronised Merino ewes

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Abstract
This study evaluated the ability of short-term grazing of live pasture to increase ovulation rate during late summer when annual pasture is generally dead and of low quality. Ovulation rates, measured by the number of corpora lutea, were compared between 4 nutritional treatments: senesced phalaris (Phalaris aquatica), phalaris plus 500g lupin grain per day, lucerne (Medicago sativa) or chicory (Chicorum intybus) pastures. The study used 100 merino ewes per treatment, divided between 2 replicates. The experiment was repeated in 3 years; February 2006, and January 2007 and 2008. Oestrus was synchronised and the ewes grazed the pastures for 9 days prior to ovulation at times corresponding to days 8 to 17 of the cycle in 2006, and days 6 to 14 in 2007 and 2008. The proportion of ewes producing multiple ovulations was higher (P<0.05) in the lucerne and chicory (0.36, 0.38) than the phalaris (0.27), and intermediate in the lupin (0.33) treatment. Regression analysis showed that the proportion of ewes with multiple ovulations increased with the quantity of live herbage (P<0.04). Responses were achieved even at low levels of live herbage with 90% of the maximum proportion multiples occurring at 350 kg DM/ha. It is concluded that providing short-term grazing of live chicory or lucerne to ewes can increase ovulation rates relative to ewes grazing senesced phalaris, to levels similar to those achieved by lupin grain supplementation.
1. Introduction

Increasing ewe reproductive capacity provides potential for increasing profitability in sheep meat production systems (Warn et al., 2006). This increase in reproductive rate needs to be achieved cost effectively and in a way that satisfies an increasing consumer demand for a “clean, green and ethical” product (Martin et al., 2004). Using nutrition to manipulate ovulation rate provides a useful strategy that may be inexpensive and avoids the use of chemicals and hormones.

Increased nutrition or flushing prior to mating has long been known to increase ovulation rates or the number of lambs born. This operates through either or both a ‘dynamic’ effect - a rising plane of nutrition and gaining weight at and for some weeks prior to mating (Gunn et al., 1984), or a ‘static’ effect – that of the resultant higher liveweight or condition at the time of mating (Coop, 1962; Edey, 1968). An ‘acute’ effect of nutrition has also been shown, whereby ‘short-term’ or ‘spike’ feeding with lupin grain for 4 to 6 days increases ovulation rates without affecting liveweight or body condition (Knight et al., 1975; Smith and Stewart, 1990). This short-term feeding targets a critical period in the luteal phase of the oestrous cycle around days 10 to 14 of the oestrous cycle (Stewart and Oldham, 1986), or during the period 6 days before luteolysis (Nottle et al., 1990). The benefit of this strategy is that limited feed resources can be used more efficiently than if a longer feeding period is required.

It is clear that the ovulatory response to short-term feeding with lupins is generally repeatable (Scaramuzzi et al., 2006) although responses are variable, and can provide increases in ovulation rate of up to 60% (Stewart and Oldham, 1986; Teleni et al., 1989; Nottle et al., 1990; Nottle et al., 1997; Wilkins, 1997). Lupin grain has been the most common feed supplement used in previous studies, but is expensive and not readily available in all localities. However, the use of supplements is an additional cost which may be unnecessary if similar responses could be obtained using existing pasture resources. Since research has provided increasing evidence that the effect of short-term feeding on ovulation rate is driven by dietary energy (eg Telini et al., 1989; Vinoles et al 2005), other feed alternatives that provide similar nutrition, but are less risky to metabolic health and are more cost effective than lupin supplementation, become possible. Indeed, the value of short term grazing (up to 18 days) of high quality leguminous pastures such as the perennial shrub tagasaste (*Chamaecytisus palmensis*)...
(Wilkins 1997) and *Lotus spp.* (Ramirez-Restrepo et al., 2005; Vinoles et al. 2009) have already been shown to have positive effects on prolificacy. If similar responses to those obtained with lupin grain could be achieved with commonly grown summer-active pasture species, short-term grazing to increase ovulation rates in summer/autumn joined ewes could be adopted by a substantial number of sheep producers.

Lucerne (*Medicago sativa*) and chicory (*Chicorum intybus*) are perennial pastures that provide good quality nutrition during the summer and autumn (Holst et al., 1998) when traditional annual pastures senesce and become low in nutritive value (Thomas et al., 2010). Phalaris (*Phalaris aquatic*) is widely sown as pasture in the higher rainfall temperate regions of Australia, but it is summer-dormant and less able to provide quality summer feed for finishing lambs and improved ewe nutrition at joining. Lucerne is suited to medium and high rainfall areas and in addition to extending the supply of quality pasture, can be sown as a pasture phase in crop rotations to provide a disease break and fix nitrogen. Chicory is more tolerant of acid soils than lucerne, thereby providing an alternative where lucerne cannot be grown (Upjohn et al., 2005). Lucerne and chicory are also desirable because, as perennials, they show potential to reduce ground water recharge and thus contribute to the control of dryland salinity (Dear and Ewing, 2008). Although these improved pastures have proven effective in producing high growth rates in lambs over the summer period (Holst et al., 1998) in central N.S.W., the potential of these forages to increase ovulation rate in a fashion similar to supplementation with lupin grain and the leguminous species reported by others, is not known.

The field study described in this paper was conducted over 3 years. It aimed to investigate the effects of short term grazing of lucerne and chicory on ovulation rate in Merino ewes compared to the existing perennial pasture, phalaris with and without short term lupin grain supplementation.

2. **Materials and methods**

This experiment was conducted with the approval of the Charles Sturt University Animal Ethics committee. The experiment was conducted on a property south-east of Wagga Wagga NSW (Latitude 147.5; longitude - 35.2). The climate is typical Mediterranean with hot dry summers and moderately cold winters. Rainfall is an
average 600mm per annum falling evenly throughout the year, although summer rainfall is typically less reliable.

2.1 Animals and experimental procedures

A schematic representation of the experimental design is presented in Fig. 1. The experimental design comprised 4 nutritional treatments (senesced phalaris pasture, senesced phalaris pasture plus 500g/ewe/day lupin grain (*Lupinus angustifolius*), chicory and lucerne), in a randomised block design with 2 replicates of each treatment combination. The experiment was repeated in each of 3 years (2006, 2007 and 2008). In each year, 400 medium to large-framed 5 year old Merino ewes of CentrePlus bloodline (a dual-purpose bloodline selected for both meat and wool characteristics) were stratified and randomly allocated to treatment groups (n=100) according to body condition (scale 0 (emaciated) to 5 (obese) (Jefferies 1961)) and liveweight. In 2007 and 2008, when some older ewes were replaced with younger ewes, animals were also allocated according to age group.

Insert Figure 1 here

Ewes were weighed and condition scored (without fasting) at the beginning and end of the nutritional treatment periods. Oestrous cycles were synchronised using an intravaginal CIDR® (Controlled Internal Release Device; 0.3 g progesterone, EZI-breed® NZ) inserted for 11 to 13 days. In 2006, CIDRs were inserted on day -11 and removed on day 0. It was expected that the mean time of ovulation would occur approximately 3 days after CIDRs were removed. That is, the mean time of onset of oestrus in the flock would occur around 36 hours after CIDR removal (Kohno et al., 2005) and ovulation would occur approximately 24 hours after that. All treatment groups grazed senesced pastures off plots until day -6 when they were introduced to pasture plots and remained there until day 3. Lupin grain was fed daily to the relevant group while grazing the phalaris pasture. After 2006, the protocol was modified to remove the possibility that high levels of feeding, late in the luteal phase of the oestrous cycle, may inhibit ovulatory response (Stewart and Oldham, 1986). Therefore, in 2007 and 2008, CIDRs were inserted at day -13 and removed on day 0. In these years, due to drought conditions, the ewes were supplementary fed a maintenance ration (SCA, 1990) of wheat grain until day -8 when they were placed on the pasture plots and were removed from plots at the end of the CIDR treatment. In all years, the ewes grazed plots
for a period of 9 days, corresponding to days 8 to 17 (2006) or days 6 to 14 (2007 and 2008) of the 17 day oestrous cycle. On removal from pasture treatment plots, ewes were returned as one flock to annual pasture or low quality hay until the day of ovulation, after which grain feeding re-commenced if required.

Ovulation rate, as determined by the number of corpora lutea per ewe ovulating, was measured on 6 March 2006 via laparoscopy (Oldham and Lindsay, 1980) at day 5-6 after the estimated average time of ovulation in the flock. On 29 to 31 January 2007 and 2008 ovulation rate was measured using transrectal ultrasonography (Vinoles et al., 2004) with the ewe in a standing position at day 8-11 after the estimated average time of ovulation. Transrectal ultrasound provides a less invasive technique that has a high predictive value and sensitivity for the diagnosis of functional corpora lutea (Dickie et al., 1999; Vinoles et al, 2004).

2.2 Pastures

The pastures used as the nutritional treatments compromised senesced phalaris pasture (*Phalaris aquatica* cv. Australian), senesced phalaris pasture, chicory (*Chicorum intybus* cv. Punall), and lucerne (*Medicago sativa* cv. Aurora) all with a sub-clover (*Trifolium subterranean*) component. The phalaris pasture was an existing 5 year old stand that had been sown with subclover (cv. Coolamon). The lucerne and chicory pastures were sown in spring 2005 at sowing rates of 4 and 3.5 kg seed/ha, respectively, along with 2 kg/ha subclover. The phalaris plots were 2.5 ha, and the lucerne and chicory plots 2.2 ha.

2.2.1 Pasture Biomass

Pastures were measured 2 to 4 days before ewes were put on plots, and again 3 or 9 days after ewes were removed from plots. Live and dead pasture biomass was visually estimated using the method of Haydock and Shaw (1975) as described by Cayley and Bird (1996), using an electric handpiece to cut calibration quadrats to ground level. The quantity of live pasture pre-grazing in the chicory and lucerne treatments was higher (P<0.05) than in the lupin and phalaris treatments (Table 1). Higher levels of herbage were estimated in 2008 than in other years, but in the lupin and phalaris treatments all except about 100kg was clammy goosefoot (*Chenopodium pumilio*) which is generally considered relatively unpalatable. Over the 9 days of grazing the quantity of pasture decreased, with most live leaf material consumed 3 days before ewes were removed from plots. The larger quantities of live lucerne and chicory remaining post-grazing were stem, with no or little leaf;
the live material in lupin and phalaris in 2008 was clammy goosefoot. The quantity of dead pasture was usually above levels that would limit pasture intake by sheep (SCA, 1990), both pre and post-grazing.

**Insert Table 1 here**

2.2.2 *Pasture/feed quality*

In 2007 and 2008 samples for herbage quality were taken using the ‘toe-cut’ method (Cayley and Bird, 1996) and these and lupin grain samples were tested for crude protein (CP), neutral detergent fibre (NDF), dry matter digestibility (DMD), and digestibility of organic matter (DOMD) (Department of Primary Industries, Hamilton, Victoria). Values were estimated using near infrared spectroscopy (NIR) and metabolisable energy (ME) calculated. The quality of the live component of pastures was similar (P>0.05) between all treatments pre-grazing: mean CP 17.2%; DOMD 62% and ME 9.8 MJ ME/kg DM. The quality of live pasture declined with grazing in the chicory and lucerne, but not in the phalaris or phalaris plus lupin treatments. This was partially due to a higher presence of the unpalatable goosefoot in the phalaris plots. However, the ewes also consumed most of the leaf, leaving mainly stem in the lucerne and chicory paddocks. Post-grazing quality of live pasture is shown in Table 2.

The dead component of chicory pastures was higher (P<0.05) than other pastures for crude protein, digestibility, ME and lower in NDF pre-grazing and generally post-grazing. Mean values for all pastures pre and post-grazing, respectively were CP 12.0, 9.62 %; DOMD 52, 42 %; and ME 7.56, 5.62 MJ ME/kg DM. Quality between years was generally similar (P>0.05).

The lupin grain contained a mean 29.5% CP, 80 % DOMD and 13.3 MJ ME/kg DM.

**Insert Table 2 here**

2.3 *Weather*
Temperature and rainfall data were recorded for the period of grazing and up to measurement of ovulation rate at a meteorological station 10 km from the experimental site. Mean temperatures were similar between years (Table 3).

Insert Table 3 here

2.4 Statistical analyses
Data were analysed using Genstat® 9th edition (Payne et al., 2006). The proportions of ewes failing to ovulate and, of ewes ovulating, the proportion of ewes recording multiple ovulations (2+ ovulations) were analysed by logistic regression. Condition score, measured at the start of the nutritional treatments, was used as a co-variate for the proportion of multiple ovulations. Liveweight, body condition and pasture biomass data were analysed using residual maximum likelihood (REML). Non-linear regression was used to predict the relationship between pasture biomass and the mean percentage of ewes with multiple ovulations in each group (treatment/replicate/year). Quality parameters for dead pasture for 2007 and 2008 were analysed by ANOVA; while live pasture parameters were analysed by REML because there was insufficient live to test in 2007.

3.0 Results
3.1 Liveweight and condition score
Ewe liveweight pre-grazing averaged 54.5 kg and did not differ between treatments, but increased with each successive year (P<0.001) being 51± 7 s.e., 52±6 and 61 ±7 kg respectively, in 2006, 2007 and 2008. Mean liveweight increased (P<0.05) by 2 kg during grazing, with ewes grazing phalaris only increasing by 1 kg compared with 2 to 3 kg in others. Mean condition score pre-grazing in 2006 at 3.2 was higher (P<0.001) than in later years (3.0) but was similar (P>0.05) between treatments. Post-grazing the condition score of ewes which grazed phalaris was lower (P<0.05) than for other treatments.

3.2 Ovulation rate
On average, 8% of ewes did not ovulate, and this was similar (P>0.05) between treatments and years. The majority of multiple ovulations were twins; only 1.8% of ovulating ewes had triplet ovulations. In ovulating ewes, both lucerne and chicory increased (P<0.05) the proportion of ewes with multiple ovulations compared
with phalaris pasture (0.36 vs. 0.38 vs. 0.27 respectively; Table 4). Feeding lupins produced an intermediate response (0.33). The proportion of ewes with multiple ovulations over all treatments differed between years (P<0.05): in 2006, 0.41; in 2007, 0.27; and in 2008, 0.33. However, there was an interaction (P<0.05) between treatment and year largely due to a change in ranking between chicory and lucerne between years. Data is not shown because it was the quantity of pasture, rather than the treatment, influencing this response, as presented below.

Insert Table 4 here

### 3.3 Relationship between quantity of pasture and ovulation rate

Logistic regression showed no difference (P>0.05) between treatments in the relationship between the quantity of live pasture on offer and the proportion of ewes with multiple ovulations. This indicates that it was the quantity of live pasture, rather than the species, that resulted in different ovulatory responses in this study.

Excluding the lupin treatments, where the response may not reflect the quantity of pasture, and 2006 data where ovulation rate was measured in March rather than January, the proportion of ewes with multiple ovulations was significantly increased with increasing quantities of live herbage both pre and post-grazing (Fig. 2). The regression equations, where y is proportion of ewes with multiple ovulations, were:

Pre-flushing live biomass: \( y=0.3492-0.276 \times 0.9941^{\text{biomass}} \) (P = 0.04)

Post-flushing live biomass: \( y=0.3483-0.2203 \times 0.9736^{\text{biomass}} \) (P = 0.04)

The proportion of ewes with multiple ovulations at 90% of the maximum predicted by the regression was achieved with a pre-grazing live pasture on offer of 350 kg DM/ha, and post-grazing 70 kg DM/ha. There was a poor relationship (P>0.05) between the quantity of dead pasture and ovulation rate.

Insert Fig. 2 here

### 4.0 Discussion
This study indicates that short-term grazing of live pastures can increase ovulation rate in oestrus synchronised ewes by increasing the proportion of ewes with multiple ovulations compared with those grazing senesced pasture. Grazing both chicory and lucerne increased ovulation rates to the same or higher extent when compared to ewes given supplements of 500 g/h/day of lupin grain per ewe. The ovulatory response is closely related to the quantity of live pasture available and the pattern of feeding may also be important.

The increases in ovulation rate of up to 10% in plots where sufficient live pasture was available were within the range achieved with lupin feeding in previous flushing trials of either short-term (14 to 29%) (Stewart and Oldham, 1986; Teleni et al., 1989) or longer-term (-14 to 21%) (Croker et al., 1985) flushing trials, indicating the suitability of short-term grazing as an alternative. Although there are reports of grazing lucerne reducing ovulation rate, this was due to ingestion of coumestans when lucerne is infected with fungus (Smith et al., 1979), and this situation can be avoided.

There are few reports of short-term flushing using live pasture. Wilkins (1997) investigated the potential of grazing for 18 days prior to mating using the perennial leguminous shrub tagasaste (Chamaecytisus palmensis). This plant provides fodder typically testing as 15-18% crude protein and around 70% in vitro digestibility (Oldham et al., 1994). He found that the ovulation rates of ewes grazing tagasaste in both of 2 experiments (1.34 and 1.22) were higher than that of control ewes grazing dead standing pasture (1.14 and 1.06), but not as high as that measured in ewes supplemented with lupins for 9 or 18 days prior to mating (1.80 and 1.72). Similarly, the number of lambs born per ewe has been increased by grazing Lotus corniculatus either for 12 days (Vinoles et al., 2009) or several weeks (Ramirez-Restrepo et al., 2005). Thus previous evidence supports the current study which indicated that both legume and non-legume live pastures can increase ovulation rate. It is likely that the quantity of live pasture will be the most limiting factor determining ovulatory response, due to the improvement in feed quality when compared with senescent pasture.

The proportion of ewes with multiple ovulations being higher in 2006 than in later years was probably due to several factors:- measurement via laparoscopy rather than ultrasound providing a more accurate estimate (Dickie et al., 1999), ewes being in higher condition, and because ovulation rate was measured well into, rather than at the start of the breeding season. From this study it is not possible to determine whether the ovulatory response to short-term grazing varies with time of year.
The variation in ovulatory responses in different treatments between years was largely explained by the quantities of live pasture available. This is similar to previous studies that show that increases in ovulation rate due to lupin supplementation are rate responsive (Lightfoot et al., 1976). The data here suggest that significant responses in ovulation rate can be achieved when as low as 350 kg DM/ha live pasture is available pre-grazing to synchronised ewes.

In this study the pattern of nutrition would also have varied between years. Much or all of the live pasture leaf was eaten before the end of the grazing period, at times several days before, such that both the quantity and quality of live pasture after about day 10 of the oestrous cycle would have been rapidly declining with mainly stem remaining. A varying pattern between different paddocks probably contributed to the varying response in ovulation rate, but the regressions demonstrate that even small quantities of live pasture pre-grazing are associated with significant increases in ovulation rate (figure 2). Although large quantities of live stem of low quality were available post-grazing in both lucerne and chicory in 2008, we can only speculate that ovulation rates could have been further increased if the quality of remaining pasture was higher. It is likely because the ovulation rates achieved are considered below the ewe’s genetic potential. In practice, producers need to adjust stocking rates so that sufficient live pasture remains at the end of the critical grazing period.

If a higher response is obtainable with better quality and quantity of pasture, then short-term flushing is more likely to have commercial value. In our case, while the 10% increase in ovulation rate was statistically significant, only approximately 10.5 more lambs would be born per 100 ewes joined, once embryo mortality has been accounted for. In this case, the economic benefit of the short-term feeding, after allowing for the additional costs of synchronisation (synchronisation materials, additional labour and increased ram percentage) would depend on lamb values.

From a practical viewpoint, synchronisation is a substantial cost and effort and is unlikely to be adopted unless the ovulatory response is large. However, the advantage of synchronisation is that it allows exposure of all ewes to live pasture at the “critical” stage of the oestrous cycle in a short grazing period. This is particularly beneficial in drought years such as those in this study, where the quantity of feed was limited. It also allows the reallocation of limited feed resources to other livestock classes, such as finishing lambs. Furthermore, the short
joining period associated with synchronisation facilitates the “focussed” feeding of pregnant ewes such as “colostrum feeding” (Martin et al., 2004). However, producers in extensive sheep production systems are more likely to use short-term feeding if synchronisation is not required. Although this study has shown the principle that short-term feeding of live pasture increases ovulation rates in synchronised ewes, its effectiveness in unsynchronised ewes is not known.

Conclusion

Short-term feeding of synchronised ewes on live pasture is a method of increasing ovulation rate in ewes without risking triplet pregnancies. It may be a more cost-effective alternative to both longer-term grazing or lupin supplementation, which has been shown to give highly variable responses, where suitable pastures already exist in the grazing system. However, it is also important to calculate whether the extra lambs born will lead to increased profit margins after considering the cost of synchronisation. On the other hand, these costs may be out-weighed by the benefits that growing perennial rather than annual pastures have to the local environment in their ability to reduce groundwater discharge. Further studies are needed to define optimum quantities of live pasture pre and post-grazing, to determine whether the response varies with time of year and, to evaluate whether short-term feeding is effective in unsynchronised ewes.

Acknowledgements

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References


Different Intravaginal Devices in Ewes during the Non-Breeding Season. J. Reprod. Dev. 51, 805-812


Upjohn, B, Parker, M & Kemp, D 2005, Chicory (Chicorium intybus), Agnote DPI-398, 3rd Ed., NSW Department of Primary Industries.


**Table 1** Mean quantity of live and dead pasture (kg DM/ha) pre and post-grazing for the different treatment groups averaged over 2006-2008.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Live pasture (kg DM/ha)</th>
<th>Dead pasture (kg DM/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-grazing</td>
<td>Post-grazing</td>
</tr>
<tr>
<td>Phalaris</td>
<td>86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phalaris + lupin</td>
<td>167&lt;sup&gt;a&lt;/sup&gt;</td>
<td>156&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lucerne</td>
<td>761&lt;sup&gt;b&lt;/sup&gt;</td>
<td>208&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chicory</td>
<td>884&lt;sup&gt;c&lt;/sup&gt;</td>
<td>260&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values with different superscript letters (a,b,c,d) within columns indicate means differ at P<0.05.
Table 2 Mean crude protein (CP %), dry organic matter digestibility (DOMD %) and metabolisable energy (ME, MJ/kg DM) of live pasture post-grazing for different treatments, combining data for 2007-2008.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CP (%)</th>
<th>DOMD (%)</th>
<th>ME (MJ/kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phalaris</td>
<td>21.0(^d)</td>
<td>66(^b)</td>
<td>10.5(^c)</td>
</tr>
<tr>
<td>Phalaris + lupin</td>
<td>19.6(^c)</td>
<td>63(^b)</td>
<td>9.8(^b)</td>
</tr>
<tr>
<td>Lucerne</td>
<td>13.0(^b)</td>
<td>47(^a)</td>
<td>6.5(^a)</td>
</tr>
<tr>
<td>Chicory</td>
<td>10.5(^a)</td>
<td>50(^a)</td>
<td>7.0(^a)</td>
</tr>
</tbody>
</table>

Values with different superscript letters (a,b,c,d) within columns indicate means differ at P<0.05.

Table 3 Mean daily maximum, minimum and mean temperature and total rainfall during each experimental period 2006-2008.

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (°C)</td>
<td>24.3</td>
<td>25.4</td>
<td>24.6</td>
</tr>
<tr>
<td>Mean minimum (°C)</td>
<td>16.3</td>
<td>17.2</td>
<td>18.1</td>
</tr>
<tr>
<td>Mean maximum (°C)</td>
<td>32.4</td>
<td>33.3</td>
<td>31.4</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>1</td>
<td>25</td>
<td>85</td>
</tr>
</tbody>
</table>

Table 4 The mean ovulation rate and proportion of ewes with multiple ovulations for ewes grazing 4 pastures averaged over 2006-2008, excluding non-ovulating ewes.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of ewes</th>
<th>Mean ovulations /ewe(^1)</th>
<th>Proportion of ewes with 2+ ovulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phalaris</td>
<td>266</td>
<td>1.28</td>
<td>0.27(^a)</td>
</tr>
<tr>
<td>Phalaris + lupin</td>
<td>270</td>
<td>1.35</td>
<td>0.33(^{ab})</td>
</tr>
<tr>
<td>Lucerne</td>
<td>278</td>
<td>1.41</td>
<td>0.36(^b)</td>
</tr>
<tr>
<td>Chicory</td>
<td>274</td>
<td>1.39</td>
<td>0.38(^b)</td>
</tr>
</tbody>
</table>

Values with different superscript letters (a,b) indicate means differ at P<0.05.

\(^1\)Mean ovulations per ewe and the percentage of ewes with multiple ovulations are not the same due to the occurrence of some triple ovulating ewes.
Fig. 1. Schematic representation of experimental design in 2006 and 2007/2008. Ewes were synchronised with CIDRs for either 11 (2006) or 13 days (2007/2008). Where day 0 is the day of CIDR removal, ewes grazed nutritional treatments for 9 days in all years from day -6 to day 3 (2006) and day-8 to day 0 (2007/2008). At the end of this period, all the ewes were united into one flock and grazed senesced annual pasture until ovulation rate was measured via laparoscopy at day 5-6 after expected ovulation (2006) or via trans-rectal ultrasound at day 8-11 after expected time of ovulation.

List of captions for Figures

Fig. 2. Predicted lines of regression between proportion of ovulating ewes with multiple ovulations and live pasture on offer pre (□) and post-grazing (■), combining data for 2007 and 2008.