Effects of annual rainfall and farm on lamb production after treatment with melatonin implants in Merino sheep: A 4-year study

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Abstract

AIM: To determine the effects of annual rainfall and farm on the efficacy of melatonin implants in improving lamb production in Merino sheep in Spain.

METHODS: A study was conducted on 3,871 Merino sheep on six farms over a 4-year period (2004–2007). Melatonin implants were inserted during the second half of February or early March (winter) (Melatonin group) or not (Control group). Multinomial logistic regression was used to determine the effects of melatonin, farm and year, and their interactions, on reproductive outcomes. Regression analysis was used to examine the relationship between annual rainfall and the percentage of ewes lambing, percentage of lambs born to ewes lambing, and overall lambing percentage, for each year and treatment group within farm.

RESULTS: Annual rainfall, farm and treatment with melatonin, and their interactions, had a significant effect on the reproductive performance of ewes (p<0.001). Treatment with melatonin increased the percentage of ewes lambing (Melatonin group = 77 (SEM 4)%; Control group = 44 (SEM 7)%; p<0.0001), and overall lambing percentage (Melatonin group = 109 (SEM 1)%; Control group = 59 (SEM 2)% p<0.0001). Treatment differences were especially pronounced in 2005 and 2006, when annual rainfall was exceptionally low; ewes in the Control group had the lowest lambing rates those years. Lambing rates and overall lambing percentage were positively correlated (p<0.05) with the amount of annual rainfall but the correlation coefficients were higher in the Control than Melatonin group.

CONCLUSIONS: Melatonin implants are an effective means of improving lamb production of Merino ewes, especially in harsh environments where low annual rainfall limits the availability of food. When melatonin treatment was used, however, the responses of flocks on individual farms were difficult to predict because within a year, responses did not occur on all farms.

KEY WORDS: Sheep, melatonin, rainfall, between-year variation, inter-farm variation

Introduction

Subcutaneous melatonin implants have been designed to provide artificial control of oestrus in sheep, and are used widely to advance the breeding season and to improve reproductive performance during anoestrus in highly seasonal (Haresign et al. 1990) and Mediterranean (Chemineau et al. 1996) breeds of sheep. The increase in the final number of lambs produced per ewe is due to incremental increases in fertility and prolificacy (Forcada et al. 1995; Chemineau et al. 1996; Abecia et al. 2007), which are derived, in part, from increased survival of embryos caused by exogenous melatonin (Vázquez et al. 2009).

To varying degrees the effects of exogenous melatonin on reproductive performance can be achieved on commercial farms if an appropriate assessment of the specific conditions on each farm is used when selecting a suitable treatment time (Kouimtzis et al. 1994). In an experiment designed to evaluate the effects of farm on the efficacy of melatonin treatments in three breeds of sheep (Abecia et al. 2007), the hormone increased the overall number of lambs produced, although efficacies appeared to differ depending on the breed and time of treatment. In Merino ewes, reproductive performance increased after treatment in February (winter) only. This suggests that melatonin might be a useful tool to improve lamb production but within each breed, efficacy seemed to vary between farms and seasons. Typically, melatonin implants are inserted around the time of the summer solstice, to advance the breeding season (Haresign et al. 1990). Unlike the breeds of sheep from northern Europe, those from the Mediterranean have a short seasonal anoestrus, especially when social (ram effect) or nutritional factors are managed appropriately (Lindsay 1996). Compared with genotypes farther north, sheep breeds from the Mediterranean have an earlier onset of breeding, even when both are subjected to the same photoperiodic treatment (Martin et al. 1999). Thus, at the commercial level, sheep in Mediterranean flocks are administered melatonin implants at about the midpoint of spring and early summer at latitude 38°S in Australia and in New Zealand but breeds from the United Kingdom (UK) only responded during a relatively short part of the season after the time of the summer solstice (Williams et al. 1992).

Photoperiod is not the only factor responsible for seasonal breeding in ewes, especially in Mediterranean breeds. Other factors such as nutrition and possibly relative humidity, precipitation and temperature might have an effect on periods of reduced oestrous activity (Galina et al. 1996). Losses in liveweight and body condition caused by poor-quality feed and inadequate feeding during the pre-mating and mating periods are detrimental to the reproductive rate (Forcada et al. 1992; Abecia et al. 2006). Hypothetically, undernutrition caused by irregular and insufficient rainfall might play an important role in the reproductive failure of sheep by producing abnormalities of the ovum or the embryo, luteal inadequacy, and failure of the supply of progesterone to the uterus, or the mechanisms involved in the maternal recognition of pregnancy (for a review, see Abecia et al. 2006).

The aim of this study was to determine the effects of annual rainfall and farm on the efficacy of melatonin implants to improve the reproductive performance of Merino flocks in Spain.
Materials and methods

All procedures used in this study were approved by the Ethics Committee for Animal Experimentation of the University of Zaragoza, Zaragoza, Spain.

Animals

The study was conducted on six sheep farms within a 50-km radius of the cooperative 'Dehesas Cordobesas' in Córdoba, Spain, over 4 years (2004–2007). Members of the cooperative in the Los Pedroches region of southern Spain (~38°N) own >150,000 Merino sheep. Over the 4-year period of the study, 3,871 ewes from the six farms were selected for the study if they had at least one lambing the previous year.

The study ewes on each farm were maintained under traditional pastoral management of the 'Dehesa' landscape, which is an open, park-like, savannah oak (Quercus rotundifolia) forest, the most extensive agrosilvopastoral system in the Mediterranean Basin (Eichhorn et al. 2006), mainly in the southwestern Iberian Peninsula. Sheep grazed the natural pasture in fenced paddocks, were provided with water, and given no supplementary feed.

Experimental procedures

Each year on the six farms, the study ewes were randomly selected and then isolated from rams at least 2 months before mating. They received a S/C implant, at the base of the left ear, containing 18 mg melatonin (Melovine; CEVA Salud Animal, Barcelona, Spain) (Melatonin group; n=2,980), or no implant (Control group; n=891). The electronic ruminal bolus numbers of the ewes were recorded to identify their experimental group. Melatonin implants were inserted during the second half of February or early March (winter). On the day that ewes were treated, all the rams received three melatonin implants, according to the manufacturer’s instructions. To induce a ram effect, rams (Merino breed; one ram per 20 ewes) were introduced 45 days after melatonin treatments, and remained in the flock for a further 45 days. Treated and untreated ewes were kept apart in two isolated groups throughout the mating period. After the rams were withdrawn, the groups on each farm were combined into single flocks, until lambing. As it was not possible to use the same group of rams in the experimental groups on the six farms over the 4 years of the study, efforts were made to balance their characteristics across groups, i.e. age, previous sexual experience, breeding soundness, etc.

The number of lambs born per ewe was determined every morning from the onset of each lambing period. In each year, rainfall (mm) was recorded from September (autumn) to May (spring) ('agricultural year'), using data from the closest meteorological station to the six farms, located at the IFAPA Research Centre (Hinojosa del Duque, Córdoba, Spain). The reproductive parameters assessed were percentage of ewes lambing (number of ewes lambing per 100 ewes presented to rams), percentage of lambs born to ewes lambing (number of live and dead lambs born per 100 ewes lambing), and overall lambing percentage (number of live and dead lambs born per 100 ewes presented to the ram).

Statistical analysis

To test for significant differences in the responses to melatonin treatment, the reproductive parameters were analysed using multinomial logistic regression with ewe as the unit of measurement, according to the following model: Y=Xb+e, where Y is the n x 1 vector of records, b denotes the effects in the model (treatment or not with melatonin, six farms, and four measurements of rainfall) with the associated matrix X, and e denotes the vector for residual effects.

To quantify the effect of rainfall on reproductive performance of the experimental groups, regression analysis was used to examine the relationship between percentage of ewes lambing, percentage of lambs born to ewes lambing and overall lambing percentage, and the amount of annual rainfall. Regression equations were calculated with group within farm for each year as the unit of measurement (SPSS 14.0; SPSS Inc, Chicago IL, USA).

Results

For various reasons, data could not be recorded on Farm 6 in 2004 and Farm 5 in 2007. Annual rainfall, farm, treatment with melatonin, and their interactions, had a significant effect on the percentage of ewes lambing and overall lambing percentage (p<0.001). There was also a significant effect on percentage of lambs born per ewe lambing (p<0.001), although there were no interactions between factors. The effect of melatonin treatment on percentage of ewes lambing, percentage of lambs born per ewe lambing, and overall lambing percentage for each farm, for the 4 years of the study, are shown in Figures 1, 2 and 3, respectively.

Overall (six farms and the 4 years combined), treatment with melatonin had a significant effect on the percentage of ewes lambing (Melatonin group = 77 (SEM 4)% vs Control group = 44 (SEM 7)%; p<0.0001), percentage of lambs born to ewes lambing (Melatonin group = 141 (SEM 1)% vs Control group = 134 (SEM 2)%; p<0.05), and overall lambing percentage (Melatonin group = 109 (SEM 1)% vs Control group = 59 (SEM 2)%; p<0.0001).

This study confirmed that melatonin was effective at increasing the lambing percentage of Merino ewes mated out of season, and this response was associated with a significant increase in percentage of ewes lambing across all years of the study (Table 1). Total rainfall for each of the 4 years of the study is shown in Table 1. Treatment only improved the percentage of lambs born to ewes lambing in 2004. The percentage of ewes lambing (R²=0.47; p<0.05) and overall lambing percentage (R²=0.49; p<0.05) were positively correlated with annual rainfall. The correlations were greater in the Control group compared with the Melatonin group (R²=0.69 and R²=0.73; p<0.01, and R²=0.36 and R²=0.44; p<0.01 and p<0.05, respectively). There was only a weak correlation between annual rainfall and percentage of lambs born to ewes lambing (R²=0.02). The amount of variation in reproductive parameters explained by rainfall (R² values) was higher in the Control group than in the Melatonin group (48% vs 13% for percentage of ewes lambing, and 54% vs 19% for overall lambing percentage). Thus, the Control group exhibited more variable lamb production in response to differences in rainfall between years, as shown by the different slopes of the regression lines (Figure 4).

Discussion

In this study, treatment of ewes with melatonin resulted in a significant increase in lamb production. However, the study did not differentiate between lambs born alive or dead, and other factors, such as body condition of the ewe, production of colostrum,
Figure 1. Mean percentage (± SEM) of Merino ewes lambing that were treated (a) or not treated (c) with melatonin in (a) 2004, (b) 2005, (c) 2006, and (d) 2007, on six farms in southwestern Spain. Implants were given in February-March (winter), and rams introduced 45 days later. Significance of difference due to melatonin: * p<0.05; *** p<0.001.

Figure 2. Mean (± SEM) percentage of lambs born to Merino ewes lambing that were treated (a) or not treated (c) with melatonin in (a) 2004, (b) 2005, (c) 2006, and (d) 2007, on six farms in southwestern Spain. Implants were given in February-March (winter), and rams introduced 45 days later. Significance of difference due to melatonin: * p<0.05; ** p<0.01.

Table 1. Mean (± SEM) percentage of ewes lambing (number of ewes lambing per 100 ewes presented to the ram), percentage of lambs born to ewes lambing (number of lambs born per 100 ewes lambing), and overall lambing percentage (number of lambs born per 100 ewes presented to the ram) of melatonin-treated (M) and untreated (C) Merino sheep on six farms in southwestern Spain over 4 years (2004–2007).

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfalla</th>
<th>n</th>
<th>% of Ewes lambing</th>
<th>% of Lambs born to ewes lambing</th>
<th>Overall lambing %</th>
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<tr>
<td></td>
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<td>M</td>
<td>C</td>
<td>M</td>
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<tr>
<td>2004</td>
<td>704</td>
<td>476</td>
<td>118</td>
<td>87 ± 4%a</td>
<td>78 ± 9%a</td>
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<tr>
<td>2005</td>
<td>153</td>
<td>778</td>
<td>306</td>
<td>72 ± 4%a</td>
<td>36 ± 6%b</td>
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<tr>
<td>2006</td>
<td>228</td>
<td>941</td>
<td>284</td>
<td>69 ± 4%a</td>
<td>31 ± 6%b</td>
</tr>
<tr>
<td>2007</td>
<td>529</td>
<td>785</td>
<td>183</td>
<td>86 ± 3%a</td>
<td>56 ± 7%b</td>
</tr>
</tbody>
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a Total rainfall recorded from September to May of the next year (mm)

x,y Significant difference p<0.05
and feed supply, affect lamb survival. Nevertheless, the overall 0.5 extra lambs/treated ewe reflected an 85% increase in the overall lamb production on these farms. Abecia et al. (2007) observed the same effect in Merino ewes after treatment at the same time of the year.

In this study, annual rainfall and farm also had a significant effect on the response of Merino ewes treated with melatonin, similar to those observed in France by Chemineau et al. (1991), and in the UK by Haresign (1992). The interaction between farm and response to treatment could be associated with a range of factors such as the skill of farmers, condition of the ewes, stress, and animal management. Factors such as reproductive calendar and animal handling can have an effect on fertility outcomes (Anel et al. 2005). Timing of both treatment and introduction of the rams can also influence the response to treatment (Knight et al. 1992).

A possible explanation for the effect of annual rainfall, and to some extent farm, was associated with the nutritional status of the ewes in the period leading up to and during mating. Nutrition can have a significant effect on many aspects of reproduction, e.g. secretion of hormones, fertilisation, and development of embryos (Boland et al. 2001). Oocytes derived from underfed ewes yielded fewer blastocysts and had lower rates of cleavage and formation of blastocysts than did control ewes (Borowczyk et al. 2006). This study showed the potential value of treating ewes with melatonin when nutrition may be a limiting factor. Assuming that the low annual rainfall observed in this study was associated with low nutrition, treatment improved the number of ewes lambing per ewes put to the ram. This response could have been due to more ewes resuming oestrous cycles and becoming pregnant, or more ewes becoming pregnant after mating, or a combination of both; we did not observe or record ewes being mated. However, melatonin appeared to be beneficial to survival of the embryo (Abecia et al. 2002, 2008; Forcada et al. 2006), and could increase survival of the embryo and in-vitro rates of fertilisation (Valasi et al. 2006). Possibly, the effects of rainfall on livestock production are mostly through the availability of forage. For instance, the most significant effect of drought on pastoral farms is the reduction in livestock production caused by shortages of fodder and reductions in feed quality (McWilliam et al. 2004). In our study, the shortage

Figure 3. Mean (± SEM) overall lambing percentage of Merino ewes that were treated (■) or not treated (○) with melatonin in (a) 2004, (b) 2005, (c) 2006, and (d) 2007, on six farms in southwestern Spain. Implants were given in February-March (winter), and rams introduced 45 days later. Significance of difference due to melatonin: * p<0.05; *** p<0.001.

Figure 4. Linear correlations between (a) the percentage of Merino ewes lambing, and (b) overall lambing percentage, and rainfall over a 4-year period (2004–2007) on six farms in southwestern Spain, where ewes were treated (■—■—■—) or not treated (○—○—○—) with melatonin. Implants were given in February-March (winter), and rams introduced 45 days later. (a) Melatonin group: Fertility = 68.925 + 0.023*rainfall; R²=0.130; p=0.10; Control group: Fertility = 11.799 + 0.094*rainfall; R²=0.480; p<0.001. (b) Melatonin group: Fecundity = 0.911 + 0.000*rainfall; R²=0.190; p<0.05; Control group: Fecundity = 0.072 + 0.001*rainfall; R²=0.538; p<0.001.
of rain in 2005 and 2006, which led to a considerable drought, might have contributed to some degree of undernutrition, which was reflected by the poor results of the ewes in the Control group in those years. In contrast, it could be interpreted that the Control groups in the ‘wet’ years enjoyed good levels of body condition, which in turn produced an extension of the breeding season (Forcada et al., 1992), resulting in satisfactory fertility results that may have overshadowed the positive effects of melatonin.

In the Spanish Ibex (Capra ibex), production and survival of offspring were significantly positively correlated with annual precipitation (Escos and Alados 1991). The abundance of many Mediterranean grassland species in the Dehesa is positively correlated with rainfall, which could explain up to 83% of the variation between years (Figueroa and Davy 1991). In our study, treatments with melatonin contributed to stable lamb production regardless of the environmental conditions, being a useful tool for improving lamb production in dry environments, when food is limited and, possibly, sheep are undernourished.

In conclusion, in the Mediterranean climatic region, a reproductive management strategy that is based strictly on photoperiodic cues might not be the most suitable, given the pronounced variation in rainfall between years (Martin et al., 2002). Treatment with melatonin implants can improve lamb production in Merino ewes, especially in harsh environments where food is limited because of low rainfall; however, when melatonin treatment was used the responses of flocks on individual farms were difficult to predict because within a year, responses did not occur on all farms.

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