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Genetic Selection to Improve Fertility in Spring Matings: Selection Response, Impact on Duration of the Seasonal Anestrus, Potential Genetic Markers, and Fertility of Lactating Ewes in Spring Matings

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Background
Seasonal breeding is a major factor limiting efficiency of lamb production. With a typical gestation length of 145 d, ewes can theoretically lamb every 7 to 8 months, but seasonal breeding relegates most ewes to an annual lambing pattern. Fertility in spring and summer is generally considered lowly heritable and unresponsive to selection, but breed differences in timing and duration of anestrus exit, documenting genetic control of seasonal breeding. In the late 1970’s, ASI identified the reduction in seasonality of breeding as a research priority.

Statement of Purpose
A flock of 50% Dorset, 25% Rambouillet, and 25% Finnsheep ewes was established at Virginia Tech in 1983, and selection to reduce seasonality of breeding began in 1988. Initial objectives were to 1) determine if ewe fertility in spring could be improved by selection; 2) understand genetic mechanisms controlling seasonal breeding; and 3) develop germplasm with an extended breeding season. Additional objectives, identified as the study progressed, were to assess potential to 4) use genetic markers to accelerate selection response and 5) use selected animals in accelerated lambing systems.

Summary of Findings
Selection was based on ewe fertility in single-sire matings in May and June. Performance of selected ewes was compared to that of unselected control ewes produced in a fall-breeding flock and transferred to the spring-breeding system for evaluation. Selection was initially based on mean ewe fertility in spring matings. Calculation of Estimated Breeding Values (EBVs) for spring fertility was implemented in 1994, and selection ended in 1998. Fertility of adult ewes in the selection line increased from approximately 60% in 1988 to approximately 85% in 1998. Genetic trends in fertility in selected and control lines are shown in Figure 1. The heritability of spring fertility was low at 8%, but high levels of variation within the flock were adequate to support sustained genetic improvement.

Comparison of high and low EBV ewes in 1992 (Figure 2) revealed much longer breeding seasons in high-EBV ewes. When combined with similar studies in 1993 and 1995, high EBV ewes had an average duration of anestrus of only 28 days; each 1% increase in EBV corresponded to a 2-day decline in length of anestrus. By 1997, the average length of anestrus in a group of elite selection-line ewes was less than 2 weeks.

Under controlled lighting, selected ewes had a mean duration of anestrus of 33 days, and were unaffected by exposure to long (16-hr) days from
late January through mid-July. These results confirm that in adult ewes (3 years old and older), selection effectively abolished the seasonal anestrus in some ewes and reduced anestrus to only 2 to 5 weeks in the flock as a whole. Because of the low heritability of spring fertility, genetic markers associated with reduced seasonality would be very useful. The melatonin receptor 1a (MTNR1A) gene is polymorphic in this flock, and an association exists between MTNR1A genotype and spring fertility (Figure 3). Individuals homozygous for alternative forms of the gene differ by 15% in spring fertility. However, studies at other locations suggest that this is a breed-specific marker, limiting its effectiveness in more seasonal breeds. A final set of studies (Table 1) characterized ability of selected ewes to rebreed while lactating in spring. In 2003, lactating January-lambing ewes were exposed to rams in March at 70 days postpartum; 85% of ewes mated and 67% lambed at approximately 8 months postpartum. In a similar study in 2004, 97% mated and 94% were diagnosed pregnant. When compared to St. Croix hairsheep ewes in March and April, 42% of selected ewes but no St. Croix ewes mated in the first 21 d. By 42 days, 71 and 35%, respectively, had mated, but only 43 and 39% lambed, apparently due to fetal lamb losses in lactating ewes that conceive at less than 75 days postpartum in spring. This result was confirmed in 2007, when 53% of March-lambing, lactating selected ewes mated in May and 38% were diagnosed pregnant but only 21% delivered full-term, viable lambs.

![Figure 1.](image1)

Changes in estimated breeding values (EBV) for fall fertility, defined as the percentage of ewes that lamb in fall, over time in selected and control lines

![Figure 2.](image2)

Duration of the seasonal anestrus in ewes from the Virginia Tech Out-of-Season Selection line with high (H) and low (L) estimated breeding values for fertility in spring matings. Each line represents an individual ewe. Darkened bars indicate periods of estrous behavior (as indicated by vasectomized rams equipped with marking harnesses) and open lines indicate periods of anestrus between January and August 1992.

![Figure 3.](image3)

Differences in fertility in spring matings between adult ewes with different genotypes at the melatonin receptor 1a gene.
Conclusions
Genetic improvement in length of the breeding season in sheep is clearly possible, with effective abolishment of the breeding season in elite selected ewes. Improvement in spring fertility was associated with a longer breeding season and early rebreeding of spring-lambing, lactating ewes, but shortening lambing intervals to less than 7 months was associated with increased fetal death loss. Development of less-seasonal sheep breeds would allow greater flexibility and intensification of sheep production.

Applications
An ideal population structure to capitalize on genetic variation in timing and duration of the breeding season would involve creation of nucleus flocks intensively selected for out-of-season lambing. Ewes from such flocks could then be merchandized for use in larger commercial flocks using accelerated or other multi-season lambing systems.

Table 1. Reproductive performance of ewes from the Virginia Tech Out-of-Season (OOS) Selection line exposed to rams while lactating in the spring.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Breed</td>
<td>OOS</td>
<td>OOS</td>
<td>OOS</td>
<td>St. Croix</td>
<td>OOS</td>
</tr>
<tr>
<td>Number of ewes</td>
<td>39</td>
<td>22</td>
<td>24</td>
<td>23</td>
<td>35</td>
</tr>
<tr>
<td>Mean lambing date</td>
<td>January 6</td>
<td>January 11</td>
<td>January 22</td>
<td>February 1</td>
<td>March 20</td>
</tr>
<tr>
<td>Date of ram introduction</td>
<td>March 17</td>
<td>March 15</td>
<td>March 24</td>
<td>March 24</td>
<td>May 3</td>
</tr>
<tr>
<td>Mean days postpartum</td>
<td>70</td>
<td>64</td>
<td>62</td>
<td>52</td>
<td>43</td>
</tr>
<tr>
<td>% Mated within 21 days</td>
<td>82</td>
<td>94</td>
<td>58</td>
<td>9</td>
<td>35</td>
</tr>
<tr>
<td>Total % mated</td>
<td>85</td>
<td>94</td>
<td>96</td>
<td>44</td>
<td>53</td>
</tr>
<tr>
<td>% diagnosed pregnant</td>
<td>77</td>
<td>94</td>
<td>67</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>% lambing</td>
<td>67</td>
<td>94</td>
<td>48</td>
<td>35</td>
<td>29 (21) a</td>
</tr>
</tbody>
</table>

aWhile 29% of OOS ewes lambed, only 21% had full-term lambs with normal birth weights.