Control of Fertility and Fecundity of Sheep by Means of Hormonal Manipulation

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Abstract
The results of four experiments are presented in summary form. The data are considered in relationship to the improvement of the fecundity and fertility of the Australian ewe breeding flock. In the first, three commonly used methods of oestrous synchronization were examined and showed differences that are attributed to the different patterns of hormonal changes associated with the methods demonstrated. The second experiment looked at the use of active immunization against testosterone and concluded that this method can improve fecundity but not fertility. The third experiment, a group of five trials, studied the use of progestagen sponges and PMSG in anoestrous ewes as a means of inducing normal fertility. The extensive data produced in this experiment allowed the relationships between ovulation rate and fertility and between fertility and prolificacy (fecundity) to be examined. Fertility appeared greatest when the mean flock ovulation rate was about 2.5. At this ovulation rate prolificacy was also improved and a high proportion of twins were produced. We concluded that high fertility and low prolificacy (i.e. of 1-00) are an unlikely combination. In the final experiment the effect of post-mating hormonal supplementation on fertility was examined and a number of earlier reports were confirmed by showing that fertility can be improved with supplementary progestosterone between days 10 and 25 post-mating. The effect appears to be modified by hormonal and nutritional factors.

Introduction
The sheep is a seasonal breeder and, at least under Australian conditions, an animal of low prolificacy and poor fertility. These facts represent a major constraint to farm productivity and managerial flexibility under typical farming conditions in Australia. This situation would have been most obvious to many of the agricultural scientists working in the field of applied farm animal reproduction. Professor T. J. Robinson was at the forefront of this first wave of scientists working to enhance the reproductive performance of Australian flocks. It is therefore most appropriate that this symposium to mark the occasion of his recent retirement as Professor of Animal Husbandry at the University of Sydney is devoted to the subject of Controlled Breeding of Sheep.

Robinson was among the first to realize that many of the essentially practical farm problems of reproduction had underlying causes that were hormonal in nature. He was quick to realize the practical potential of the then only recently isolated and synthesized steroid hormones and of the relatively crude preparations of gonadotrophins as a means of improving the productivity of our national flock (Robinson 1950, 1951). He also believed that in order to eliminate or control these productivity constraints it was first necessary to develop a better understanding of the physiology of oestrus (Robinson 1952, 1954) and ovulation (Robinson 1955). Consequently Robinson spent the greater part of his working life pursuing the study of oestrus and ovulation and in developing practical techniques that allow producers the opportunity for total control of the breeding cycle of the ewe (Robinson 1965, 1980).

Yesterday's Problems
At the outset the task must have seemed beyond reach. Those of us today who stand on
a new threshold of technological development may take some consolation from the progress achieved in the space of one working life. The opportunities for success are still present, they remain well disguised and the requirements for success are much the same as they were in 1947 when Terry Robinson left Western Australia and set out for Cambridge and his Ph.D. degree. To praise Robinson is not to diminish the work of others who have contributed to the study of reproductive biology of the ewe, for after all this symposium is a tribute to the work of Professor Robinson. There can be little doubt that if a definitive history of reproductive research in farm animals is ever written the name of Terrence James Robinson will be prominent.

In 1947 the problems facing Robinson and other scientists with an interest in controlled breeding were numerous. It was not possible to induce normal oestrus in the ewe. Ovulation could be induced using exogenous gonadotrophins but fertility was poor and ovulation could not be synchronized either between ewes or with oestrus. Hormones could only be measured using cumbersome and often imprecise bioassays and then quite often only in the organ producing the hormone. Today in 1987 we are able to do all of these and much more to control and manipulate the reproductive cycles of our farm animals. The subject has been extensively covered in a recent book by Gordon (1983).

**Today’s Problems**

Not withstanding the progress of the past 40 years, techniques for the controlled breeding of sheep remain far from perfect. Yesterday’s problems have been replaced with a new set of problems. Naturally enough these have to a large degree evolved from yesterday’s problems and often become a matter of fine tuning. Fertility following a synchronized oestrus is depressed, due in part to a relatively poor synchronization of oestrus and ovulation. Suboptimal transport of spermatozoa associated with quantitatively abnormal blood levels of steroid hormones remains a serious source of poor fertility following oestrous synchronization. A reliable alternative to the progestagen sponge—pregnant mare serum gonadotrophin (PMSG) combination for the induction of a fertile ovulation in anoestrous ewes remains to be found. The question of a suitable means of establishing normal fertility in lactating ewes induced to ovulate and especially during seasonal anoestrus remains unsolved. The level of mortality among new-born lambs especially twin lambs remains unacceptably high. Finally, satisfactory methods to limit the level of early embryo mortality, a significant impediment to both fertility and prolificacy, are not presently available. The potential of the new techniques for improving fecundity, such as steroid-immunization, is consequently limited by early embryo mortality. Many such problems remain and in this paper we shall address several of them.

**The Precision of Synchronization**

Fertilization, whether to a natural or induced ovulation, depends very much on the degree of synchronization between oestrus and ovulation. Even when fixed-time artificial insemination is used a high degree of synchronization of ovulation within a flock is essential to ensure high fertility. Oestrus and ovulation are not causally related but both events are the product of the changing hormonal milieu during the follicular phase of the oestrous cycle. Techniques for the synchronization of oestrus all depend on modifying the hormonal milieu of the ewe by therapeutic means. The synchronous termination of the luteal phase and initiation of a new follicular phase is normally achieved by progestagen therapy or by the use of luteolytic prostaglandins. The hormonal events which follow such treatments, while qualitatively similar to those leading to natural oestrus and ovulation, differ in important quantitative detail resulting in a lower level of fertility (Cognie et al. 1975; Cognie and Pelletier 1976). PMSG is used primarily to induce ovulation in anoestrous ewes but can also be used in cyclic ewes to increase prolificacy and to improve oestrous synchronization.

Three methods commonly used to synchronize oestrus and ovulation in cyclic ewes were compared in an experiment with 200 mature Merino ewes. The methods tested were: treatment for 12 days with progestagen-containing pessaries (Repromap, Upjohn Pty Ltd), treatment for 12 days with two silastic implants containing progesterone (Silestrus, Abbott Laboratories)
and an injection during the mid-luteal phase of a luteolytic dose (125 µg intramuscular) of a synthetic analogue of prostaglandin F$_{2\alpha}$ (Estrumate, ICI Pty Ltd).

The flock had been previously treated with Repromap sponges and so were synchronized at the time the experiment was commenced. Sponge or implant treatments were started during the mid-luteal (days 9 or 10) stage of the oestrous cycle. Two days after sponge or implant treatment commenced all ewes were given an injection of a luteolytic dose of Estrumate (125 µg intramuscular) ensuring that no endogenous progesterone was present in the ewes synchronized with sponges or implants and that prostaglandin-synchronized ewes were all mid-luteal at the time of their second prostaglandin injection 10 days later. Half of the ewes were immunized with Fecundin (Glaxo Pty Ltd) using the manufacturer’s recommended procedures 9 and 5 weeks before the end of the synchronizing treatments. The removal of pessaries and implants and the second injection of prostaglandin were carried out on the same day. At this time 20 vasectomized rams fitted with mating harnesses and crayons (Sire-Sine, Hortico), were introduced to the flock. The time of onset of oestrus was determined by examination of the flock at intervals of 6 h at which time oestrous ewes were recorded and removed from the flock to facilitate accurate detection of oestrus in all ewes. Ewes with faint or otherwise uncertain raddle marks were individually observed for oestrus with a fresh ram in a small observation area and her oestrous state confirmed. Ovulation rate was determined at endoscopy carried out approximately 10 days after the onset of oestrus.

The ovulation rate was increased by treatment with Fecundin but the method used to synchronize oestrus and ovulation had no effect on ovulation rate (Table 1). The pattern and

Table 1. Ovulation rate of Merino ewes immunized with Fecundin and whose oestrous cycles have been synchronized by three methods

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Method of synchronization</th>
<th>No. of ewes</th>
<th>No. of ovulations</th>
<th>Ovulation rate$^A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fecundin</td>
<td>Sponge</td>
<td>33</td>
<td>0 10 19 4</td>
<td>1.82$^a$</td>
</tr>
<tr>
<td>Fecundin</td>
<td>Prostaglandin</td>
<td>32</td>
<td>3 7 19 3</td>
<td>1.86$^a$</td>
</tr>
<tr>
<td>Fecundin</td>
<td>Implant</td>
<td>34</td>
<td>1 7 24 2</td>
<td>1.85$^b$</td>
</tr>
<tr>
<td>Control</td>
<td>Sponge</td>
<td>32</td>
<td>1 27 4 0</td>
<td>1.16$^b$</td>
</tr>
<tr>
<td>Control</td>
<td>Prostaglandin</td>
<td>32</td>
<td>0 24 8 0</td>
<td>1.25$^b$</td>
</tr>
<tr>
<td>Control</td>
<td>Implant</td>
<td>34</td>
<td>3 24 7 0</td>
<td>1.23$^b$</td>
</tr>
</tbody>
</table>

$^A$Ovulation rates with different superscripts differ at the 5% level of significance.

time of onset of oestrus was influenced by both the method of synchronization and the use of Fecundin (Table 2). Fecundin advanced the onset of oestrus in ewes treated with Repromap

Table 2. Time from prostaglandin injection, sponge or implant removal to the onset of oestrus in Merino ewes immunized with Fecundin

<table>
<thead>
<tr>
<th>Synchronization treatment</th>
<th>Mean time (± s.e.m.) to onset of oestrus (h)</th>
<th>Ewes not in oestrus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immunized Control</td>
<td>Immunized Control</td>
</tr>
<tr>
<td>Repromap sponges</td>
<td>43.8 ± 2.03$^a$</td>
<td>53.6 ± 1.80$^{a**}$</td>
</tr>
<tr>
<td>Prostaglandin</td>
<td>42.2 ± 2.21$^a$</td>
<td>42.9 ± 1.41$^b$</td>
</tr>
<tr>
<td>Silestrus implants</td>
<td>31.4 ± 1.67$^b$</td>
<td>32.9 ± 1.13$^c$</td>
</tr>
</tbody>
</table>

Within a column values with different superscripts differ at the 5% level of significance. **$P < 0.01$ (compared with immunized; unpaired t-test)

sponges ($P < 0.05$) an observation which is an apparent contradiction of published data (Robinson and Scaramuzzi 1986). These ewes although treated during the breeding season had no endogenous progesterone because they had been given prostaglandin soon after sponge insertion. The time to the onset of oestrus was shortest when progesterone implants were
used, longest when sponges were used and least precise when prostaglandin was used, especially in Fecundin-treated ewes. A greater number of ewes (6 out of 32) treated with Fecundin and synchronized using prostaglandin did not show oestrus compared with all other treatments (2 out of 160).

These data lead us to conclude that the precision of oestrous synchronization is influenced by the method of oestrous synchronization and is related to the pattern of hormonal changes during the peri-ovulatory period. The delayed onset of oestrus associated with sponge use may well be due to a slower rate of metabolism of the synthetic progestagen used in the sponges when compared with the progesterone used in the implants. The use of prostaglandin especially in immunized ewes appears the least satisfactory method and may well indicate a reduced sensivity of the corpus luteum to the luteolytic effects of prostaglandin in Fecundin-treated ewes. The importance of these effects in relation to flock fertility remains to be evaluated.

**Increasing Prolificacy**

Prolificacy of ewes can be manipulated in a number of ways. Therapeutic methods include the use of gonadotrophins (Robinson and Scaramuzzi 1986), immunization against androstenedione (Geldard et al. 1984) and other steroids (Cox et al. 1982) and more recently the use of melatonin (Staples et al. 1986). In a collaborative experiment with R. M. Hoskinson and D. Paull we have examined the use of testosterone as an alternative steroid hapten to androstenedione. Data from Edinburgh (Land et al. 1982) has suggested that passive immunity to testosterone improved fertility as well as fecundity. Active immunity to testosterone might therefore be a satisfactory substitute for androstenedione immunity. Border Leicester × Merino ewes were immunized with testosterone-7α-carboxyethyl thiourea–human serum albumin. Primary immunization in February 1984 consisted of 1-5 mg of immunogen made up to 2 ml in 5% (w/v) DEAE dextran given 7 weeks before joining. Booster immunizations were given 4 and 50 weeks later, i.e. 4 and 6 weeks before joining in 1984 and 1985 respectively. Joining was in the first week of April in both years. The ewes were mated to two of Poll Dorset rams per 100 ewes for 5 weeks. Ovulation rates were recorded at endoscopy during the conception cycle and litter sizes were recorded at birth.

A blood sample was taken from all immunized ewes 7 days after booster immunization and the anti-testosterone titre determined on the plasma (Abraham 1974).

Part of this data is shown in Table 3 and a more complete account of this work is in preparation (Scaramuzzi et al., unpublished data). In year 1 immunization against testosterone increased ovulation rate and lambing percentages, these increases were associated with a mean flock titre of 1:18 300 ± 338 and no increase in the proportion of barren ewes among the immunized ewes (Table 3). In year 2 immunization again increase ovulation rate but the lambing percentage did not increase and was actually slightly reduced. This poor performance was associated with a mean flock antibody titre of 1:48 000 ± 581 and 19% of barren ewes (Table 3). This high rate of reproductive wastage probably occurred before day 60 of pregnancy.
because the estimates of lambing performance obtained using real-time ultrasound scanning were almost identical to the actual lambing performance.

These results show that immunity to testosterone can increase lambing percentage, and that excessive antibody responses will actually reduce lambing performance. There is no evidence from this work to suggest that testosterone-immunity improves fertility as previously suggested (Land et al. 1982). The poor results obtained in 1985 were reversed in 1986 when an interval of 12 weeks between booster immunization and joining was used in place of the standard interval of 4–6 weeks (results not presented), adding further weight to the argument that poor reproductive performance of immunized ewes is associated with excessive antibody responses. Immunization against ovarian steroid hormones such as androstenedione (Fecundin) or testosterone are useful therapeutic methods of increasing lambing percentages. The increase in ovulation rate is always greater than the ensuing increase in lambing percentage and highlights the importance of embryonic death as a source of reproductive wastage in sheep with high ovulation rates.

**Increasing Fertility**

Low fertility is a continuing problem in Australian flocks (Scaramuzzi and Lindsay 1986). Very often it is associated with climatic and seasonal conditions over which the producer has little control. On the other hand there are numerous production factors which influence fertility and which are amenable to management. Fertility is usually poor in ewes induced to ovulate in the spring or while lactating. The use of PMSG to enhance prolificacy is a relatively minor one, the principal use being the induction of ovulation in anoestrous states.

A large collaborative experiment was carried out to examine the effect of different doses of PMSG on the fertility and prolificacy of anoestrous Border Leicester × Merino ewes induced to ovulate during seasonal anoestrus (Robinson and Scaramuzzi 1986). The ewes were treated with progestagen (Flugestone acetate 30 mg) containing pessaries (Chrono-gest Sponges, Intervet Pty Ltd) for 12 days in early September. At the time of pessary removal the ewes were treated with varying doses of PMSG (Robinson and Scaramuzzi 1986) and joined to Poll Dorset rams using an intensive system of mating management (Robinson et al. 1987). Half of the ewes had been previously treated with Fecundin from 15 to 49 days prior to mating. Conception rates and ovulation rates were estimated using endoscopic examination of the ovaries 20 days after mating. Lambing performance was recorded by direct observation twice daily over the expected lambing period. These results obtained on over 1000 ewes are summarized in Table 4. These data show that fertility increased over the dose range 250–750 i.u. of PMSG but

**Table 4. Effect of PMSG on the fertility, prolificacy and lambing percentages of Border Leicester × Merino ewes induced to ovulate during anoestrus**

<table>
<thead>
<tr>
<th>Dose of PMSG (i.u.)</th>
<th>No. of ewes</th>
<th>Ovulation rate</th>
<th>Fertility (EL/EJ)</th>
<th>Prolificacy (LB/EL)</th>
<th>Lambing % (LB/EJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>195</td>
<td>1.51&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.49&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>500</td>
<td>558</td>
<td>1.73&lt;sup&gt;b&lt;/sup&gt;,b</td>
<td>0.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>750</td>
<td>553</td>
<td>2.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.60&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.93&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1000</td>
<td>84</td>
<td>4.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.61&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total</td>
<td>1390</td>
<td>2.03</td>
<td>0.54</td>
<td>1.56</td>
<td>0.84</td>
</tr>
</tbody>
</table>

<sup>a</sup>Ewes lambing/ewes joined.
<sup>b</sup>Lambs born/ewes lambing.
<sup>c</sup>Lambs born/ewes joined.

when the dose of PMSG was increased to 1000 i.u. fertility dropped despite a further increase in ovulation rate at the higher dose. The effect of Fecundin on ovulation rate was additive with that of dose of PMSG over the dose range tested. The effect of Fecundin on reproductive performance was dependent on the time interval between treatment with Fecundin and mating (Robinson and Scaramuzzi 1986).
These results clearly demonstrate the ability of PMSG to improve the fertility of anoestrous Border Leicester × Merino ewes. Alternative methods for enhancing the fertility of such ewes (e.g. 'the ram effect') are less reliable especially when used early in the spring. The use of melatonin treatment to improve the fertility and prolificacy of spring-mated ewes is a relatively recent innovation (Staples et al. 1986) and there is insufficient information available to allow a full comparison with established and well-tested methods such as the 'sponge-PMSG' combination. Melatonin when administered continuously over a period of weeks will induce oestrus and ovulation in anoestrous ewes and with the additional benefit of an increase in ovulation rate. The highest levels of fertility achieved in these experiments was 65% and while this may seem low it is comparable with the fertility obtained at a single mating in the breeding season (74% untreated control ewes in Table 6). The level of fertility which can be regarded as 'normal' for spring-mated ewes is subject to conjecture but we can be certain it would not be 100%. An acceptable estimate would be 60-70% (Gordon 1983, Ch. 14). We now know that the level of fertility can be influenced by many factors, an important one of which is ovulation rate. The effect of PMSG in enhancing fertility is probably a direct consequence of its action in increasing ovulation rate. The optimum level of PMSG will vary with the natural level of prolificacy and perhaps other breed characteristics. In these experiments the optimum ovulation rate appears to be around 3, and the optimum level of PMSG is that producing a mean flock ovulation rate of 3. Larger doses will probably lead to reduced fertility and to problems of lamb survival.

Relationship between Fertility and Prolificacy

A relationship between prolificacy and ovulation rate has been described (Hanrahan and Quirke 1985) which shows that as ovulation rate increases so does litter size up to an optimum ovulation rate and beyond which litter size will decrease as uterine capacity becomes an increasingly more important limiting factor. Recent results also show a positive relationship between ovulation rate and fertility (Robinson and Scaramuzzi 1986). A summary of these data is presented in Table 5. As the number of ova shed increases from 1 to 3 both fertility and prolificacy also increases, but when the ovulation rate is above 3 both variables decline, leading to a reduction in the lambing percentage in ewes with an ovulation rate above 3. These results suggest that optimum fertility can be best achieved by a flock ovulation rate of between 2 and 3. A flock ovulation rate of 1 will inevitably result in poor fertility because it magnifies the effect of embryonic death on fertility. If the flock ovulation rate is 2, however, the death of a single embryo will not affect fertility because the ewe will still produce a single lamb. Prolificacy and the lambing performance will of course be reduced but not fertility.

These results demonstrate the importance of a high ovulation rate as a means of ensuring high fertility. The often-stated ideal of every ewe in a flock producing a single lamb can on this account be seen as highly improbable. The price of high fertility is more twins.

<table>
<thead>
<tr>
<th>Ova shed</th>
<th>No. of sheep</th>
<th>Fertility (EL/EJ)A</th>
<th>Prolificacy (LB/EL)B</th>
<th>Lambing % (LB/EJ)C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>363</td>
<td>0·40b</td>
<td>1·00b</td>
<td>0·40b</td>
</tr>
<tr>
<td>2</td>
<td>422</td>
<td>0·59b</td>
<td>1·66b</td>
<td>0·98b</td>
</tr>
<tr>
<td>3</td>
<td>179</td>
<td>0·65b</td>
<td>1·90c</td>
<td>1·24c</td>
</tr>
<tr>
<td>4</td>
<td>98</td>
<td>0·61b</td>
<td>1·77b,c</td>
<td>1·09b,c</td>
</tr>
<tr>
<td>Total</td>
<td>1062</td>
<td>0·54</td>
<td>1·56</td>
<td>0·84</td>
</tr>
</tbody>
</table>

A Ewes lambing/ewes joined.
B Lambs born/ewes lambing.
C Lambs born/ewes joined.
Embryo Mortality

The level of embryo mortality is an important determinant of fertility and to a lesser extent of prolificacy. Broadly speaking embryo mortality can be classified into two classes, that associated with chromosomal and other genetic abnormalities and that associated with environmental causes (Murray et al. 1985). The former must for the present be seen as an inescapable source of reproductive wastage while the latter may well be amenable to therapeutic intervention. Recently a number of papers examining the effect of supplementary progestagen administered post-mating on embryo survival have appeared (Peterson et al. 1984; Parr et al. 1986). The effect of such treatments have not been uniformly beneficial perhaps because of an interaction between nutrition, the level of circulating progesterone and embryo mortality (Parr et al. 1986). The use of progesterone treatment post-mating requires further evaluation before its effectiveness can be properly assessed.

We have investigated the role of progesterone post-mating in reducing the high level of embryo wastage caused by Fecundin when used under a particular set of conditions designed to maximize embryo wastage. Previous work has shown that Merino ewes immunized with Fecundin 2 and 6 weeks earlier have high levels of embryo wastage (Boland et al. 1986). We have used this model and have attempted to influence the level of embryonic death by administering progesterone from 1 to 15 or 10 to 25 days post-mating. Progesterone was administered by means of two progesterone-releasing silastic devices (Silestrus, Abbott Laboratories) implanted surgically beneath the skin in the inguinal region. The ovulation rate during the conception cycle was determined by endoscopy and the pregnancy rate was determined using real-time ultrasound scanning 60 days post-mating.

Table 6. Effect of progesterone supplementation post-mating on fertility, prolificacy and lambing percentage of Fecundin-treated ewes

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ovulation rate</th>
<th>Fertility (EL/EJ)</th>
<th>Prolificacy (LB/EL)</th>
<th>Lambing % (LB/EJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>1.19^a</td>
<td>0.72^a</td>
<td>1.11^a</td>
<td>80^a,b</td>
</tr>
<tr>
<td>Progesterone 1–15 days^D</td>
<td>1.31^a</td>
<td>0.55^b</td>
<td>1.25^a,b</td>
<td>69^a</td>
</tr>
<tr>
<td>Progesterone 10–25 days^E</td>
<td>1.38^a</td>
<td>0.76^a</td>
<td>1.36^b</td>
<td>103^b,c</td>
</tr>
<tr>
<td>Immunized</td>
<td>2.08^b</td>
<td>0.62^a,b</td>
<td>1.83^c</td>
<td>114^cd</td>
</tr>
<tr>
<td>Immunized and progesterone 1–10 days</td>
<td>1.85^b</td>
<td>0.62^a,b</td>
<td>1.56^b</td>
<td>96^a,b,c</td>
</tr>
<tr>
<td>Immunized and progesterone 10–25 days</td>
<td>2.08^b</td>
<td>0.76^a</td>
<td>1.74^b,c</td>
<td>132^d</td>
</tr>
</tbody>
</table>

^aEwes lambing/ewes joined.
^bLambs born/ewes lambing.
^cSupplementary progesterone administered from 1 to 15 days post-mating.
^dSupplementary progesterone administered from 10 to 25 days post-mating.

The results of this experiment (Table 6) show that the administration of progesterone post-mating can influence the level of embryonic death. In non-immunized ewes progesterone administration from day 1 reduced fertility without any effect on ovulation, ovulation rate or prolificacy, while in immunized ewes early progesterone had no effect on fertility. Progesterone from day 10, on the other hand, had no effect on fertility of non-immune ewes but did increase slightly the fertility of immune ewes ($P < 0.01$). These data suggest that the Fecundin-treated ewe may have excessively high levels of progesterone over the first few days of pregnancy (days 1–5) and a deficiency of progesterone somewhere between days 10 and 25 of pregnancy. The pattern of progesterone levels in Fecundin-treated ewes (Fig. 1) show a rapid rise such that the average level of progesterone exceeded 1 ng/ml by day 3 after oestrus whereas untreated ewes required 6 days in which to exceed 1 ng/ml average progesterone concentration. The
levels of progesterone between days 10 and 25 of pregnancy are much higher in Fecundin-treated ewes (Fig. 1) and yet despite this progesterone supplementation was able to improve fertility from 0.62 to 0.76.

![Graph](image_url)

**Fig. 1.** Plasma progesterone concentration in untreated (♀, n = 15) and Fecundin-treated (■, n = 11) ewes from 0 to 8 and 13 to 21 days post-mating. Following detection of oestrus (every 8 h) the ewes were cannulated, placed into single pens and bled every 8 h.

These results show that the level of early embryonic death in sheep can be influenced by hormonal manipulation. Further study of the problem can be expected to lead eventually to techniques for the control of this important source of reproductive waste.

**Conclusions**

The data summarized in this paper demonstrate an impressive array of techniques available to the producer who wishes to manipulate the reproductive performance of a flock. Most of these procedures are the result of research carried out in Australia by agricultural and other scientists. Terry Robinson's contributions to this body of knowledge are most impressive indeed and this symposium is a fitting tribute.

The precision of oestrous synchronization can be influenced by the manipulation of the hormonal milieu around oestrus. Additional research is needed to define more precisely the limits of asynchrony that are compatible with normal fertility and to estimate the extent to which the present patterns of synchronization are a cause of reduced fertility at a synchronized mating.

Increasing the ovulation rate by using an immunization treatment or PMSG will increase prolificacy and will also improve fertility. They are certainly a useful adjunct to oestrous-synchronization programs. The use of PMSG is essential if the synchronized flock is anoestrous. Contrary to popular opinion increasing ovulation rate can be seen as one of the keys to increasing fertility. Increasing ovulation rate has the undesired effect of also increasing embryonic wastage. Research in future should be directed increasingly to the study of embryonic mortality if the full benefits of the present array of techniques for improving ovulation rate are to be fully realized.

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References


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