A STUDY OF THE REPRODUCTIVE PERFORMANCE OF TWO YEAR-OLD ROMNEY AND BORDER LEICESTER X ROMNEY EWES AFTER DIFFERENTIAL FEEDING AND GONADOTROPHIN TREATMENT

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ABSTRACT

The reproductive performance of 207 first-cross Border-Leicester x Romney (Border-Romney) and Romney 2 year-old ewes was compared after they grazed in the autumn for 2 months at 2 levels of feeding and treatment with 0, 600 or 1200 i.u. Pregnant Mare's Serum Gonadotrophin (PMSG).

To induce and synchronise oestrus at the start of the breeding season, intravaginal progestagen sponges were inserted for 14 days. PMSG was injected on day 12 or 13 after first heat and ewes were then run with entire Southdown rams. Each ewe was laparotomised within a week of PMSG injection to record the ovarian activity. Peripheral blood was collected from a sample of ewes at intervals throughout pregnancy and progesterone concentration determined. The number and weight of lambs at birth and at weaning were recorded.

High-plane ewes gained 1.39 kg and low-plane ewes lost 1.51 kg over the 2-month period of differential feeding.

Following sponge withdrawal and at the next cycle 80% and 90% of all ewes were in oestrus and of these 77% and 80% were mated over 2 and 3 consecutive days, respectively. PMSG did not affect the degree of synchronisation of oestrus but treatment with the drug, improved feeding and injection on day 12 rather than 13, each reduced the mean cycle length.

Border-Romney ewes had higher natural ovulation rate, lambing performance and response to PMSG than Romney ewes.

PMSG reduced (16%) the conception rate at first service, proportionately more ewes returned to service at prolonged intervals (>20 days), and this "carry-over" effect reduced the incidence of ewes that later became pregnant. There was marked variation in ovarian response to PMSG. However, litter size increased with up to 5 ovulations per ewe despite an increasing percentage of potential lambs lost.

Uterine capacity in terms of both number and weight of lambs born was greatest in Border-Romney ewes but exceeded natural ovulation rate in both breeds. Potential reproductive performance is, therefore, limited by the number of eggs released and in practice management factors before and at mating and selection of ewes with a propensity for higher ovulation rates should be emphasised.

Lambs born to Border-Romney ewes were heavier at birth and grew more rapidly to weaning. It is likely that part of this superiority of growth rate was related to a greater milk production by these crossbred ewes and this possibility should be investigated further.

Diagnosis of ewes with either single- or multiple-bearing pregnancies on the basis of blood progesterone levels (measured either early or late in pregnancy) was found to be no more accurate than other methods (rectal-abdominal palpation, ultrasonics and radiography) currently available. Variation in lamb birthweight within birth rank appeared to limit the accuracy of diagnosis of single- or multiple-bearing ewes late in pregnancy. Liveweight of the ewe and weight of lamb born were antagonistic in their effects on blood progesterone concentration.

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PREFACE

This investigation was conducted at the Sheep Production Centre, part of the Department of Sheep Husbandry, Massey University. The experimental work was one of one year's duration commencing in January 1973 and represents original research by the author under supervision of Dr M.F. McDonald, Reader, Sheep Husbandry Department, Massey University.

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CHAPTER I

INTRODUCTION

The number of eggs released by the ovary sets a limit to the number of lambs that can be weaned. This potential may be reduced by prenatal mortality and by lamb deaths. Treatment with gonadotrophins such as Pregnant Mare's Serum Gonadotrophin (PMSG) is one method of increasing the number of ova shed in ewes. By allowing these ewes to lamb, or by use of egg transfer methods, the number of lambs produced per ewe can be increased. This procedure could have application in: the rapid spread of desirable genotypes throughout a population; as a means of increasing lambing percentage in commercial flocks; as well as in a range of experimental uses such as investigating reproductive differences between breeds.

Several factors limit the effectiveness of PMSG and it is important to study these if best results are to be obtained.

Factors Influencing the Effectiveness of Response to PMSG

1. Progestagen pretreatment

Early work showed that exogenous progesterone suppressed ovulation and oestrus in sheep (Dutt and Casida, 1948); that PMSG induced oestrus in anoestrous ewes (Cole and Millar, 1933) and increased fecundity in cycling ewes (Robinson, 1951). Both compounds have since been used separately and in combination, to synchronise, to superovulate and to induce out-of-season breeding in ewes.

Some of the associated effects of these drugs at different stages of the ewe's reproductive phase are discussed under the following headings:

(a) Oestrous response

PMSG treatment following progestagen sponge withdrawal increases the incidence of oestrus in anoestrous ewes (Robinson and Smith, 1967), and late anoestrous ewes (Gordon, 1971). Onset of oestrus is earlier (Robinson, 1955; Robinson and Smith, 1967) and more predictable (Robinson, 1955) if progesterone treatment is accompanied by PMSG. These effects are more noticeable in younger ewes (Robinson, 1961).

PMSG treatment of cycling ewes on the 12th or 13th day of either the natural or progestagen-synchronised cycle has resulted in a proportion of 'silent heats' implying an adverse effect of exogenous gonadotrophin rather than from progestagen (Bradford et al., 1971). Similarly the oestrous response of progestagen-treated cyclic ewes may not be improved by PMSG administration (Foord, 1966; Clarke, 1973). The timing of PMSG injection may be important since administration at progestagen withdrawal, compared to 24 hours before this, has resulted in an increased incidence of oestrus in ewes (Holst, 1969).

Injection of PMSG during the follicular phase of the oestrous cycle may reduce cycle lengths (Warwick and Casida, 1943; Robinson, 1951; Cumming and McDonald, 1967) although other reports have noted inconsistent or no difference between treated and untreated ewes (Wallace, 1954; Larsen, 1971). PMSG administration on day 12 rather than day 13 of the cycle may shorten cycle length

(Cumming and McDonald, 1967) although this effect is not always clearcut (Wallace, 1954; Larsen, 1971).

(b) Ovulation rate

Progestagen pretreatment of both anoestrous and cyclic ewes modified the ovulatory response to PMSG (Lamond, 1964a, b; Hulet and Foote, 1967; Gordon, 1972).

Increased doses of progestagen significantly influence ovulation responses to PMSG in sheep (Allison and Robinson, 1970) and in cattle (Lamond, 1973). In the latter case the effect varied with breed.

The type of progestagen pretreatment can affect the ovulation response to a given dose of PMSG (Lamond, 1964a; Roberts and Edgar, 1966). The ovulation rate following a second progestagen-PMSG treatment sequence is less than the first while that following a second PMSG injection not preceded by exogenous progestagen may be greater (Hulet and Foote, 1967, 1969). Similarly injection with PMSG 14 days after cessation of progestagen pretreatment may cause smaller litter sizes than when ewes receive gonadotrophin 12 or 13 days following natural oestrus (detected by vasectomised rams) (Newton and Betts, 1968). However, a second PMSG treatment just prior to the second oestrus can result in smaller litter sizes than after a single injection at progestagen pessary withdrawal (Gordon, 1963). Refractoriness to PMSG has been reviewed by Clarke (1973).

Ovulation rate may depend on the timing of PMSG administration during the oestrous cycle (Neville, 1966) although Robinson (1951), Wallace (1954), Cumming (1965), Bindon *et al.*(1971) and Larsen (1971) found no significant difference in ovulation rate between groups of ewes injected from days 11 to 14 of the cycle (oestrus = day 0).

The interval between progestagen pretreatment and PMSG may affect ovulation rates (Roberts and Edgar, 1966; Hulet and Foote, 1967; Roche, 1968). Although greater ovulation rates can result from PMSG injection 2 to 4 days before progestagen sponge removal, this often results in depressed mating and conception rates at the controlled oestrus (Gordon, 1972). Thus injection at pessary withdrawal is considered more practical (Holst, 1969). Similarly ovulation rates may be lower after injection at sponge withdrawal than after PMSG administration on day 13 of the cycle (without progestagen pretreatment) (Newton et al., 1972). The difference is less if the former injection time is delayed until onset of synchronised oestrus when blood progesterone levels are lower. PMSG may have a predominantly follicle-stimulating or a predominantly ovulatory action depending on dose and time of injection in relation to the end of progestagen administration (Braden et al., 1960).

(c) Conception rate

Treatment with 250-500 i.u. PMSG at cessation of progestagen treatment can greatly improve conception rates compared to similar ewes not receiving PMSG. However, doses above 500 i.u. PMSG tend to depress conception rates (Gordon, 1972). PMSG treatment on days 12 or 13 of the cycle after either progestagen synchronisation (Allison, 1973, 1975) or detection of natural heat by teaser rams (Robinson, 1951) may reduce conception rates. Ewes injected with gonadotrophin 14 days after sponge removal which fail to conceive to first mating may also return to second oestrus (Newton et al., 1968).

This may be due to a combined PMSG-progestagen action (Newton et al., 1972) although the evidence is not conclusive.

Conversely, several workers have reported no depression of conception rate following PMSG therapy, with or without progestagen synchronisation (Wallace, 1954; Gordon, 1963; Tait, 1971; Laster and Glimp, 1974).

2. Nutrition and liveweight

Poorly-fed ewes may show greater responses to PMSG than heavier, better-fed ewes (Wallace, 1954; Allen and Lamming, 1961). PMSG may compensate for nutrient deficiencies in restricted animals (Lamond, 1963). Ovulation response following administration of PMSG may be more closely related to bodyweight in under-fed ewes (Lamond, 1963).

In contrast, more recent reports note greater ovulation rates in heavier, well-fed ewes receiving the drug (Allison, 1973, 1975; Hedges and Reardon, 1973). Other reports, however, show a less clear relationship between feeding level and dose of PMSG on either ovulation rate (Bellows et al., 1963) or lambing data (Tait, 1971).

Recent work implicates Vitamin A affecting the conception and lambing rates to PMSG (Migalina, 1973) but there are few reports on the effects of other vitamins or dietary constituents.

A positive relationship between ewe liveweight and ovulation rate after PMSG has been noted (Guerra et al., 1971; Killeen, 1972) although other reports do not support this (Bindon et al., 1971; Allison, 1973, 1975). Breeds varying widely in mean bodyweight show little association between ovulating response to PMSG and these mean bodyweights (Bradford et al., 1971).

In ewes treated with progestagen and PMSG in the nonbreeding season, restriction of feeding with resultant decreases in liveweight has been shown to reduce ovulation rate (Keane, 1973).

The components of liveweight (body size and body condition) have each been related to ovulation rate (Guerra _et al_., 1972). While there were significant relationships between these liveweight components and incidence of multiple ovulations, bodyweight proved a more effective predictor of ovulation rate than either body size or body condition. Significant positive relationships have, however, also been reported between body condition score and both ovulation rate and lambing performance (Gunn _et al_., 1969, 1972; Bastiman, 1972; Gunn and Doney, 1973). An interaction between body condition score and level of feeding at mating may exist for ovulation rate data (Gunn _et al_., 1969).

Russel _et al_. (1969) reported that liveweight was a less accurate predictor of total body fat than body condition score. Plasma progesterone concentration may be negatively related to total body fat (Cumming _et al_., 1971; Lamond _et al_., 1972) and to large follicle development (Ginther, 1971). This may partly explain the reduced ovulation responses to PMSG in underfed ewes reported (Allison, 1973, 1975; Hedges and Reardon, 1973). There appear to be no reports relating body fat condition score (Jeffries, 1961; Russel _et al_., 1969) to reproductive response to PMSG during the breeding season. During the nonbreeding season, however, Keane (1973) found little effect of body condition on ovulation rate rollowing progestagen-PMSG treatment.

An alternative to the theory of 'ovarian sensitivity' to explain differential ovulation response to PMSG involves differences in endogenous levels of gonadotrophin (Allen and Lamming, 1961). Endogenous levels of LH affect the ovulatory response to PMSG in laboratory animals (Lamond and Emmens, 1959; Lamond and Bindon, 1966a, b) but it remains unclear whether the nutritional influence on PMSG action in ewes is centred at the pituitary gland, at the ovary or a combination of the two (Trounson and Moore, 1972).

The mode of action of PMSG has been reviewed by Clarke (1973).

3. Season of administration

There is great variability in response of the same ewes to the same dose of PMSG over several consecutive years (Palssen, 1962). Within the breeding season little relationship exists between the time of PMSG treatment and ovulation response (Robinson, 1951). A temporal relationship might have been expected because of reported seasonal differences in ovulation rate (Radford, 1959; McDonald and Ch'ang, 1966; Dermody et al., 1970). In anoestrous ewes the month of treatment can influence response to the drug (Hunter, 1968; Hulet and Stormshak, 1972).

Reports conflict as to whether ovulation responses differ between groups of animals treated within the anoestrous period compared to those treated during the breeding season. Holst (1969) found that treatment of anoestrus ewes gave greatest responses to PMSG, the effect being greatest at higher dose rates. This effect may have been due to higher endogenous gonadotrophin levels reported for seasonal anoestrous ewes (Kammalade et al., 1952). Conversely greater ovarian responses may follow injection during the breeding season than after either progestagen-PMSG treatment in the anoestrous period, or PMSG administration late in anoestrus (Averill, 1958). The difference may be dose dependent since non-superovulatory doses of PMSG can effect similar ovarian responses in both cyclic and anoestrus ewes (Lamond, 1962).

4. Age of ewe

Ovulatory responses to PMSG by lambs may not be as great as for mature ewes (Robinson, 1951) although Finn lambs (weighing 60% mature body weight) may have similar ovulation rates after PMSG to mature ewes (Bradford et al., 1971). In contrast, Averill (1958) obtained consistently steeper dose-response regression lines for mature compared to 2 year-old ewes. Thus the affect of age of ewe on reproductive response to PMSG remains unclear.

5. Nature of PMSG

Variation in biological potency of gonadotrophic preparations is likely to be a source of variation among experiments (Laster, 1972). At comparable dose levels, whole serum PMSG may be more effective at inducing super fertility than freeze-dried or purified serum. Freeze-dried preparations are generally more effective than purified serum (Gordon, 1958). The ratio of LH to FSH activity varies greatly between batches of PMSG and this may be a major cause of variation in response between experiments (Polge and Rowson, 1973). PMSG samples may have ovulating capacities of about a third that of human chorionic gonadotrophin (HCG) (Lamond, 1962) while others have an FSH/LH ratio of 2:1 (Schmidt-Emendoff et al., 1962). The addition of HCG to raise the LH activity of PMSG may augment a more efficient super-ovulatory response in ewes (Braden et al., 1960;

Killeen and Moore, 1970; Hunt _et al._, 1971). Breed may affect the proportion of follicles ovulated following PMSG treatment since Bradford _et al._ (1971) reported that the more prolific Finn ewes naturally ovulated a higher proportion of follicles compared to breeds of lower natural fecundity. It may be significant that Finn sheep have a higher LH secretion level than many breeds (Land, 1974).

6. _Breed or strain of ewe_

Early work suggested that naturally more prolific breeds of ewe may show greater ovulation responses to PMSG than less fertile breeds (Robinson, 1951; Wallace, 1954). This concept was supported by Bradford _et al._ (1971) although other results suggest that the drug causes greatest increases in lambing performance with breeds of naturally smaller average litter size (Gordon, 1958; Newton _et al._, 1970). An effect of breed was also reported by Laster and Glimp (1974).

Merino ewes selected for multiple births over several years showed greater ovulation responses to PMSG than did ewes with lower natural ovulation rates due to negative selection (Bindon _et al._, 1971; Trounson and Moore, 1972). Similarly with New Zealand Romneys, Wallace (1954) suggested that the strain of ewe may affect ovarian response to the gonadotrophin. Russian work, however, reported greater lambing responses to PMSG from ewes producing no lambs or singles the previous season compared to twin-bearing ewes (Yuzlikaev, 1973).

Progesterone Level and Reproductive Phase

Factors that increase ovulation rate are also likely to increase the range of litter size (Bradford, 1972). Pre- and post-natal death of lambs is likely to be increased unless ewes carrying different litter sizes can be identified early in pregnancy and fed according to their requirements. For example, ewes with larger litters are more susceptible to metabolic disorders late in pregnancy and are likely to produce small, weak lambs if not adequately nourished at this time (Reid, 1950). Conversely, over-feeding ewes carrying single lambs in late pregnancy may increase the incidence of dystocia (Coop, 1972).

One possible method of early identification of litter size in ewes involves the relationship between litter and peripheral plasma progesterone levels.

The introduction of competitive protein-binding (CPB) methods (Murphy, 1964, 1967) and radioimmunoassay (RIA) techniques (Niswender and Midgley, 1970) for steroid determination has resulted in simple and sensitive assays that measure levels as low as 0.1 - 0.2 ng/ml of progesteron in 0.5 - 2 ml of peripheral plasma (Thorburn et al., 1969; Sarda et al., 1973). Very low levels of progesterone occur in ewes in oestrus; in anoestrus or in ovariectomised ewes; or in wethers (Thorburn et al., 1969; Sarda et al., 1973). Before the development of these sensitive techniques the limit of sensitivity for progesterone concentration was about 4 ng/100 ml (Moore et al., 1969). This was not sensitive enough to measure peripheral plasma concentration and required 8 mls (Short et al., 1963) or 20 ml (Moore et al., 1969) of uterine vein plasma.

Unless separated out by methods such as chromatography, the CPB technique measures a number of closely related steroids as well as progesterone. Such separation procedures appear unnecessary in the routine assay for progesterone in the peripheral plasma of non-pregnant sheep (Thorburn et al., 1969). Differences in assay technique may explain some of the observed differences in measured progesterone concentrations between experiments (Thorburn et al., 1969) although many other factors are also involved.

Factors affecting progesterone in peripheral blood

1. Stage of the reproductive phase

Concentration of progesterone in the peripheral plasma and the pattern of progesterone production at various reproductive phases have been documented by many authors some of whom are listed under the following headings:

(a) anoestrus or ovariectomised ewes

Thorburn et al. (1969); Fylling (1970);
Sarda et al. (1973).

(b) ewes during the oestrous cycle

Stabenfeldt et al. (1969); Thorburn et al. (1969)
Obst et al. (1970); Allison and McNatty (1972);
Dunn et al. (1972); Lamond and Gaddy (1972);
Pant et al. (1972); McNatty et al. (1973);
Sarda et al. (1973); Thorburn et al. (1973).

(c) pregnant or mated ewes

Basset *et al*. (1969); Bindon (1971a, b);
Bindon *et al*. (1971); Cumming *et al*. (1971);
Obst *et al*. (1972); Robertson *et al*. (1971);
Russel and Foot (1971); Slotin *et al*. (1971);
Bedford *et al*. (1972); Gadsby *et al*. (1972);
Liggins *et al*. (1972); McNatty *et al*. (1972);
Moore *et al*. (1972); Saumande and Thimonier (1972);
Stabenfeldt *et al*. (1972); Thorburn *et al*.(1972)(1973);
Sarda *et al*. (1973); Shemesh *et al*. (1973);
McNatty *et al*. (1974); Thompson and Wagner (1974).

The principal source of progesterone in the ewe during the oestrous cycle and in early pregnancy is the ovary with a small contribution from the adrenal gland (Sarda *et al*., 1973). The increase in blood progesterone levels observed in the second half of pregnancy is attributed largely to placental production (Denamur and Martinet, 1973) which is capable of maintaining pregnancy after about 50 days from mating (Denamur and Martinet, 1955; Short, 1957). The ovarian contribution may be either maintained at a level typical of the first trimester of pregnancy, or may decrease as placental production increases (Moore *et al*., 1972; Sarda *et al*., 1973; Thompson and Wagner, 1974). The placenta continues to secrete progesterone until just before delivery (Sarda *et al*., 1973). Older ewes may have two peaks of progesterone activity during the latter stages of pregnancy, while 2 year-old ewes often have just one peak (McNatty *et al*., 1972).

2. Temporal variation

Blood levels of progesterone fluctuate widely between days indicating that factors other than the secretory ability of the corpus luteum determine the amount of progesterone getting into the peripheral circulation (Lamond, 1973).

Mid-cycle plasma progesterone concentrations may be higher in autumn than summer (Lamond *et al.*, 1972) although temperature has little influence (Dunn *et al.*, 1972).

Conflicting results have been reported regarding diurnal fluctuations of plasma progesterone concentrations. Thus Thorburn *et al.* (1969) and Allison and McNatty (1972) failed to show diurnal changes during the oestrous cycle. The latter workers concluded that short-term fluctuations observed in progesterone concentration would mask any diurnal fluctuations. Similarly McNatty *et al.* (1974) could not detect a significant diurnal pattern of progesterone production either early or later in pregnancy. Conversely significantly higher luteal plasma progesterone levels were reported for daylight compared to darkness (McNatty *et al.*, 1973) and in the afternoon compared to the morning (Dunn *et al.*, 1972) in cycling ewes.

3. Number of corpora lutea or foetuses

The successful use of peripheral plasma progesterone concentration for pregnancy determination has been reported by several workers (e.g. Robertson *et al.*, 1971; Gadsby *et al.*, 1972; Saumande and Thimonier, 1972; Shemesh *et al.*, 1973). The latter workers concluded that factors of cost, labour and the need to sample a known time after mating, limit the use of progesterone concentration for pregnancy diagnosis to that for research purposes.

Early work showed little difference in the progesterone concentration in ovarian vein blood from ovaries with either one or two corpora lutea (Edgar and Ronaldson, 1958). Similarly, more recent work reported little value from peripheral plasma progesterone levels in distinguishing between ewes with one or two corpora lutea (Bindon et al., 1971; Robertson and Sarda, 1971; Lamond and Gaddy, 1972) or foetuses (Basset et al., 1969; McNatty et al., 1972; Stabenfeldt et al., 1972; Sarda et al., 1973). Conversely Cumming et al. (1971) reported that ewes with no embryonic loss had greater peripheral blood progesterone concentrations on days 15 and 16 of 'pregnancy' if they had 2 rather than 1 corpus luteum. Other workers have also shown good relationships between corpora lutea (or foetal) number and peripheral plasma concentration in prolific ewes (Russel and Foot, 1971; Gadsby et al., 1972; Thompson and Wagner, 1974) and following PMSG administration (Thorburn et al., 1969; Bindon et al., 1971). Earlier work of Short (1960; 1961) also reported a positive association between corpora lutea number (following PMSG treatment) and progesterone concentration in blood from the ovarian vein. A significant relationship has been found between corpora lutea numbers and plasma progesterone concentration in cows not returning to service 22 days after mating. Accuracy of prediction in this case was, however, limited due to a wide scatter of values (Lamond and Gaddy, 1972).

Greater levels of embryonic death following superovulation is not due to an inadequate progesterone concentration (Short, 1960). Similarly higher endogenous levels of progesterone are associated with lower embryonic mortality (Cumming et al., 1971; Trounson and Moore, 1973, 1974; Cumming et al., 1974).

The ewe appears not to have a 'feedback' mechanism to control the secretion rate of progesterone by the corpora lutea in response to raised blood progesterone levels (Short et al., 1963). Thus in superovulated ewes (Bindon et al., 1971) and cows (Lamond and Gaddy, 1972; Lamond, 1973), progesterone concentrations are often increased above normal physiological levels. Whether such high levels of progesterone have any influence on the maintenance of pregnancy is not clear (Lamond, 1973).

The variance of progesterone concentration characteristically increases with increasing concentration and log transformation of values is necessary to maintain homogeneity of variation for many methods of analysis (Bindon et al., 1971; Gadsby et al., 1972).

Greater weights of lamb born have been associated with the weight of functional cotyledons (Alexander, 1964) and with higher progesterone production rates (Russel and Foot, 1971; Thompson and Wagner, 1974). Differences in foetal weight carried may help to explain the great variation in plasma progesterone levels often observed after about day 100 or pregnancy (Bedford et al., 1972). Weight of cotyledons or increasing uterine volume associated with foetal growth may be responsible for the above relationship (Bedford et al., 1972; Thompson and Wagner, 1974). Other workers report no good relationship between the weight of the foetus(es) or placental development and progesterone levels in blood (Sarda et al., 1973; Alexander and Williams, 1966).

4. Level of feeding and ewe condition

A poor level of feeding of ewes from the second until the sixteenth day after mating increased the concentration of progesterone in peripheral plasma (Cumming et al., 1971) and this effect was greater in twin-ovulating compared to single-ovulating sheep (Cumming, 1972). Similarly, Lamond et al. (1972) reported that thin ewes had higher blood progesterone levels possibly due to a reduced extravascular body pool size resulting from a low body fat content.

Oestrogenic pastures may reduce progesterone levels in pregnant ewes (Obst et al., 1972).

5. Breed

A breed difference in the rate of decline in progesterone levels towards the end of the oestrous cycle has been reported for cows by Lamond et al. (1971). There was no difference between Merinos and Romneys in either the pattern of progesterone production or in the absolute levels recorded during the oestrous cycle (Allison and McNatty, 1972).

Weight of Lambs at Birth

The ability to identify litter size and to adjust feeding levels of pregnant ewes accordingly allows some control of variation of lamb birth weight. Many other factors besides nutrition operate to control lamb birthweight, however. Some of these have been reviewed by Hafez (1963); Larsen (1971); Everitt (1967a) and Terrill (1972), although more recent developments are discussed with earlier work below.

Factors affecting birthweight in sheep

1. Genotype

Breed differences for lamb birthweights have been reported (e.g. Chapman and Lush, 1932; Donald and McLean, 1935; Hunter, 1956; Dickinson et al., 1962; Moore, 1968; Karihaloo and Combs, 1971a, b; Larsen, 1971). Parental breeds differing widely in size have been used to study maternal environment and foetal contributions to birthweight (Hunter, 1956; Dickinson et al., 1962; Karihaloo and Combs, 1971a, b). Maternal effects appear more important in some studies (Larsen, 1971; Karihaloo and Combs, 1971a, b), although the foetus has more influence in others (Hunter, 1956; Dickinson et al., 1962). The size of the maternal environment effect remains unclear. Thus Bowman (1967) and Hunter (1956) concluded that this effect was only important when genotype for size of foetus was markedly different from that of the dam but this contention has not always been supported (Larsen, 1971).

2. Size of ewe

The relationship of lamb birthweight with ewe body size is not clear. A positive relationship was reported by several workers (e.g. Donald and McLean, 1935; Wallace, 1948; Donald and Russel, 1970; McClelland and Forbes, 1973; Bradford et al., 1974) while others could find no significant correlation between ewe weight and lamb birthweight (Hunter, 1956; Karihaloo and Combs, 1971a).

3. Age of ewe

Increasing age of ewe has been positively associated with greater birthweights (Hammond, 1932, 1944; Hunter, 1956; Russel and Foot, 1973). An interaction between age of ewe and level of nutrition has also been reported (Bennett et al., 1964).

Age is correlated with ewe liveweight in many environments (Coop, 1973; Hight and Jury, 1973) and is also closely related to parity. However, although increasing parity (independent of liveweight) has been associated with increased birthweight (Dickinson et al., 1962), this study used separate breeds for each parity group and did not control age of ewe effects.

4. Nutrition

The effects of nutrition during pregnancy on birthweight in sheep have been reviewed by Thompson and Aitken (1959) and Everitt (1967a).

Undernutrition has its greatest effect on pre-natal growth in late pregnancy (Everitt, 1967a) although birthweights may be reduced by poor feeding earlier in gestation (Bennett et al., 1964). Energy intake of the pregnant ewe does not always influence lamb birthweight (Palsson and Verges, 1952) but depends on the degree of undernourishment in late pregnancy (Papadopoulos and Robinson, 1957). Thus unless the 'low level' of feeding is severe enough, birthweight may not be affected by the nutritional treatment (e.g. Underwood and Shier, 1942; Coop 1950; Papadopoulos and Robinson, 1957; Hodge, 1966; Evans and Wilcox, 1969; Monteath, 1971; McClelland and Forbes, 1973; Robinson, 1973; Louca et al., 1974). Conversely, more extreme levels of nutrition have affected lamb birthweight (e.g. Thompson and Fraser, 1939; Underwood et al., 1943; Wallace, 1948; Thompson and Thompson, 1949; Coop, 1950; Bennett et al., 1964; Everitt, 1967b; Sheehan and Lawlor, 1972.

The use of biochemical parameters such as the plasma levels of non-esterified fatty acids (NEFA) may be a more precise index of the adequacy of nutritional level in late pregnancy (Reid, 1956; 1963; Russel et al., 1967a, b: Davies et al., 1971). For a given level of feeding in late pregnancy, ewes carrying twin foetuses suffer greater levels of undernourishment than do single-bearing ewes (Davies et al., 1971). Differences in birthweight due to different feeding treatments are more commonly reported for multiple compared to single-bearing ewes (Palsson and Verges, 1952; Louca et al., 1974).

Overfat ewes may have light lambs at birth (Jeffries and Fearn, 1956) although this is not always the case (Papadopoulos and Robinson, 1957).

Both season and stocking rate may affect lamb birthweight (Kenny et al., 1974).

Crude protein intake during the second half of pregnancy has a variable effect on birthweight. Thus the birthweight of lambs may not be significantly influenced by level of crude protein in the diet (Klosterman et al., 1953; Forbes and Robinson, 1967) although extreme levels of protein can affect this (Robinson and Forbes, 1968). Other workers, however, have reported the birth of heavier lambs following raised protein intake (Slen and Whiting, 1952; Parkins et al., 1974). The latter report suggests that positive effects on lamb birthweight may be expected from increased crude protein feeding when plasma urea concentrations fall below a critical level of about 10 mg/100 mls.

The availability of drinking water can affect birthweights of lambs (Lynch et al., 1972).

Underfeeding in early pregnancy can restrict placental development which may reduce the weight of lambs at birth (Everitt, 1967a). Birthweight is correlated with the weight of cotyledons in late pregnancy (Alexander, 1964) but factors determining the weight of the placenta in ewes remain largely unknown (Huggett, 1959). Progesterone and oestrogen blood levels may be involved since they have been implicated in the control of placental weight of laboratory animals (Alexander, 1964) although more recent work in the sheep tends to negate this (Alexander and Williams, 1966). Poor feeding may differentially influence the weight and morphology of individual cotyledons according to their position within the uterine horn (Everitt, 1967a) and this supports the theory of local haemodynamic control of pre-natal growth in sheep as suggested for laboratory animals (McLaren and Michie, 1960). This contrasts with the general systemic principle proposed by Hammond (1944).

5. Litter size

Whatever the mechanism, litter size in sheep is inversely related to lamb birthweight (Hammond, 1932; Terill, 1944; Boshier et al., 1969; Karihaloo and Combs, 1971a; Larsen, 1971; Bradford et al., 1974).

6. Sex

Males are often heavier at birth than females (Dickinson, 1960; Terrill, 1972; Bradford et al., 1974) although this effect is not always significant (Hunter, 1956; Karihaloo and Combs, 1971a). Male lambs from twin-bearing ewes tend to have heavier birthweights than females (Dickinson, 1960) the difference being greatest when males are co-twin to females rather than a comparison of like-sexed litter birthweights (Donald and Purser, 1956; Larsen, 1971; Burfening, 1972; Terrill, 1972).

7. Exercise, disease and heat stress

Although exercise has not been shown to influence lamb birthweights (Culpin, 1962), infectious disease in pregnant ewes may result in the birth of small lambs (Hughes, 1972). Similarly, heat stress from the middle of pregnancy can significantly reduce birthweights independently of a reduction in feed intake (Yeates, 1953; Alexander and Williams, 1971).

8. Gestation length

An inverse relationship has been observed between litter size and gestation length (Hammond, 1932; Forbes, 1967) although other results show little evidence of such a relationship (Terrill, 1944; Boshier et al., 1969; Larsen, 1971; Karihaloo and Combs, 1971a).

Gestation length has been correlated with birthweight in sheep (McLaren and Michie, 1963; Terrill, 1972). Pregnancy in large breeds is extended by the presence in utero of foetuses of smaller breeds (Hunter, 1956; Dickinson et al., 1962; Moore, 1968; Karihaloo and Combs, 1971a) but results using breeds with a lesser size difference have been less conclusive (Larsen, 1971). The foetus has been estimated to account for two thirds of the genetic variation in gestation length (Bradford et al., 1972) with the initiation of parturition probably being dependent on the foetal adrenal-pituitary axis (Liggins, 1968; Liggins et al., 1972). The size (Alexander, 1964) and weight (Boshier et al., 1969) of the foetus have been reported to have a poor relationship with the initiation of parturition which probably suggests an overriding effect of the foetal adrenal-pituitary pathway (Boshier et al., 1969).

Poor nutrition during the last two months of pregnancy reduces the length of gestation (Wallace, 1948; Thompson and Thompson, 1949; Alexander, 1956) being more pronounced in twin-bearing ewes (Terrill, 1972) and for ewes restricted late in pregnancy (Alexander, 1956). Conflicting results have been cited by Thompson and Aitken (1959).

Sex may (Dickinson et al., 1962; Bradford et al., 1974) or may not (Forbes, 1967; Larsen, 1971) affect gestation length in ewes. Similarly the length of pregnancy may increase with age of ewe (Terrill and Hazel, 1947) although this relationship is unclear (Forbes, 1967).

The spasmodic occurrence of an unusual number of lambs of extreme size in the absence of known factors shows that much remains to be learnt about the processes controlling birthweight (Braden and Baker, 1973).

Weight of Lambs at Weaning

The final measure of the reproductive performance of the breeding ewe is often a function of the weaning weight of her lamb. The factors known to influence weaning weight have been reviewed by Hafez (1963); Kirton (1970) and Larsen (1971).

Factors affecting weaning weight

1. Genotype

The breed of dam (Coop, 1957; McConnell and Jagusch, 1972; Geenty and Jagusch, 1974) and of sire (Carter, 1968; Donald *et al.*, 1970) both affect the weight of the weaned lamb. Progeny from Border Leicester x Corriedale (F_1) and straight-bred Corriedale ewes (Coop, 1957) had differences in weaning weight which were comparable to those reported between Border Leicester x Romney and straight-bred Romney sheep (Coop and Clark, 1965). First-cross progeny are markedly superior in weaning weight to the parent breeds but this advantage diminishes to the F_3 generation when no selection for the trait is practiced (Clarke, 1962). Intensive selection for reproductive characteristics may, however, maintain the liveweight of crossbred sheep at a level similar to that of the F_1 (Coop, 1967).

Crossbreeding Merinos with British breed sires resulted in progeny which grew more rapidly than the straight-bred Merino lambs due largely to a greater capacity to consume feed (Langlands, 1973). A similar effect was noted with Border Leicester lambs compared to Merinos (Langlands, 1972).

Within a breed the variation in weaning weight between sires may be almost as great as that between breeds (Carter, 1968; Donald *et al.*, 1968).

Inbreeding can have a depressing effect on weaning weight (Hazel and Terrill, 1945). The estimated heritability of weaning weight is low (Ch'ang and Rae, 1961, 1970; Young *et al.*, 1965). The ewe influences the weaning weight of her progeny both through the genes she transmits and by the maternal environment she provides (Ch'and and Rae, 1961).

2. Weight of ewe

Heavy ewes may allow faster growth rates of lambs under certain conditions (Donald *et al.*, 1970). An advantage of low ewe live-weight during lactation on the efficiency of production, however, has been suggested by Large (1970) and supported by Geenty and Jagusch (1974) and Spedding *et al.* (1974).

3. Age of dam and of lamb at weaning

The age of the dam (Terrill and Hazel, 1945; Ch'ang and Rae, 1961, 1970) and of the lamb at weaning (Barnicoat *et al.*, 1957; Ch'ang and Rae, 1961, 1970; Kirton, 1970) have moderate effects on weaning weight.

4. Birthweight

Weaning weight of lambs has been positively associated with birthweight (Thompson and Aitken, 1959; Scales, 1968). This effect may be mediated through the observed relationship between birthweight and milk yield since the latter is related to weaning weight (Thompson and Aitken, 1959).

5. Birth and rearing rank

The type of birth and rearing have an important effect on the variation of weaning weight (Hazel and Terrill, 1945; Papadopoulos and Robinson, 1957; Ch'ang and Rae, 1961, 1970; Donald *et al.*, 1970; Burfening, 1972). The greater weaning weight of singles may be partly explained by their greater birthweight as well as by their greater intake of milk (Barnicoat *et al.*, 1949). Twins reared as singles are usually heavier at weaning that twin-reared lambs and this is probably due to a greater milk availability (Ch'and and Rae, 1961).

6. Milk production

The importance of ewe milk on weaning weight and factors affecting yield of milk in ewes have been reviewed by Glover (1972). Milk yields reported for ewes are greatly influenced by methods of measurement used (Coombe et al., 1960; Treacher, 1970b).

The level of feeding in late pregnancy (Treacher, 1970a; Louca et al., 1974) but more especially in early lactation (Coop et al., 1972a, b) has an important influence on milk yield and on weaning weight.

Apart from the ewe's inherent ability to produce it, milk production is also affected by the potential of lambs to obtain it (Moore, 1966). Not all reports agree, however, since birth rank (Davies, 1963; Glover, 1972) or lamb genotype (Davies, 1963; Langlands, 1973) may or may not affect milk yield in ewes (Forbes, 1969; Langlands, 1972).

7. Sex

Lamb weaning weights may depend on sex (Ch'ang and Rae, 1961, 1970; Kirton, 1970) although method and time of castration appear to have little influence on the parameter (Wilcox, 1968). Induced cryptorchids may grow faster than wethers (Corbett et al., 1973). Interactions have been reported for weaning weight between sex of lamb and level of feeding (Palsson and Verges, 1952; Papadopoulos and Robinson, 1957; Everitt, 1967a) and between sex of lamb and birth or rearing rank (Papadopoulos and Robinson, 1957; Burfening, 1972). Hence males gain and lose weight more rapidly under good and poor feeding conditions respectively than females. The latter grow faster if reared co-twin to females rather than to males.

Purpose and Scope of the Investigation

The purpose of the investigation was to study some of the physiological factors which may cause the observed differences in reproductive performance between F_1 Border Leicester x Romney and Romney 2 year-old ewes. Ewes were injected with PMSG after being grazed at either a high or a low level of feeding and studies were made on: activity of the ovaries; lambing and weaning performance of ewes; and the pre-natal and post-natal growth of lambs.

The trial also offered the opportunity to investigate changes in peripheral blood progesterone throughout pregnancy and to consider the possibilities of using such information to predict numbers of offspring carried by the ewe.

C H A P T E R   II

M A T E R I A L S   A N D   M E T H O D S

CHAPTER II

MATERIALS AND METHODS

Animals

The animals used were an unselected group of 207, 18 month-old (hereafter described as 2 year-old) maiden Romney and F_1 Border Leicester x Romney (Border-Romney) ewes. All ewes were the product of mating Romney and Border Leicester rams to Romney ewes derived from a randomly bred flock maintained at Massey University since 1944, and comprised the complete age group for that year. Ewes in the experiment had been run together since birth, they were identified by serially numbered brass ear tags and corresponding numbers were branded midside at the commencement of the trial.

Experimental Plan

The experimental plan and calendar of events is set out in Fig. 2-1 and Fig. 2-2 and discussed in the following sections.

1. Nutrition

Ewes were weighed during the pre-experimental period and then allocated at random within breed to groups. They were then fed (from February 2 until after laparotomy) at either a high or low level of nutrition. The ewes were grazed on 10 hectares (several paddocks) of predominantly ryegrass-white clover pasture. Management was aimed at increasing the liveweight of ewes on the high plane as much as possible while maintaining or allowing slight weight loss in ewes allocated to the low plane of nutrition.

FIGURE 2–1:-

GENERAL EXPERIMENTAL PLAN AND CALENDAR OF EVENTS

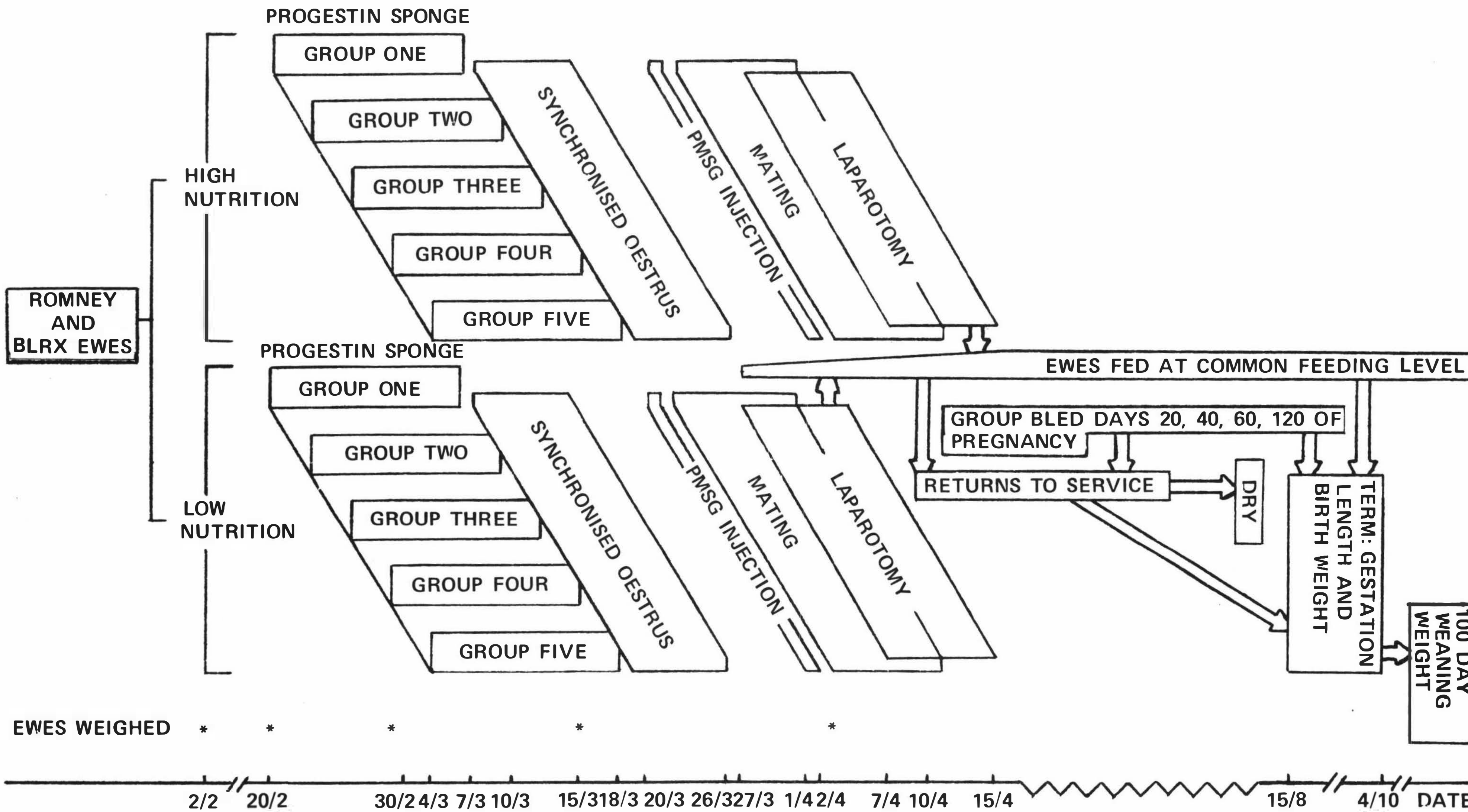
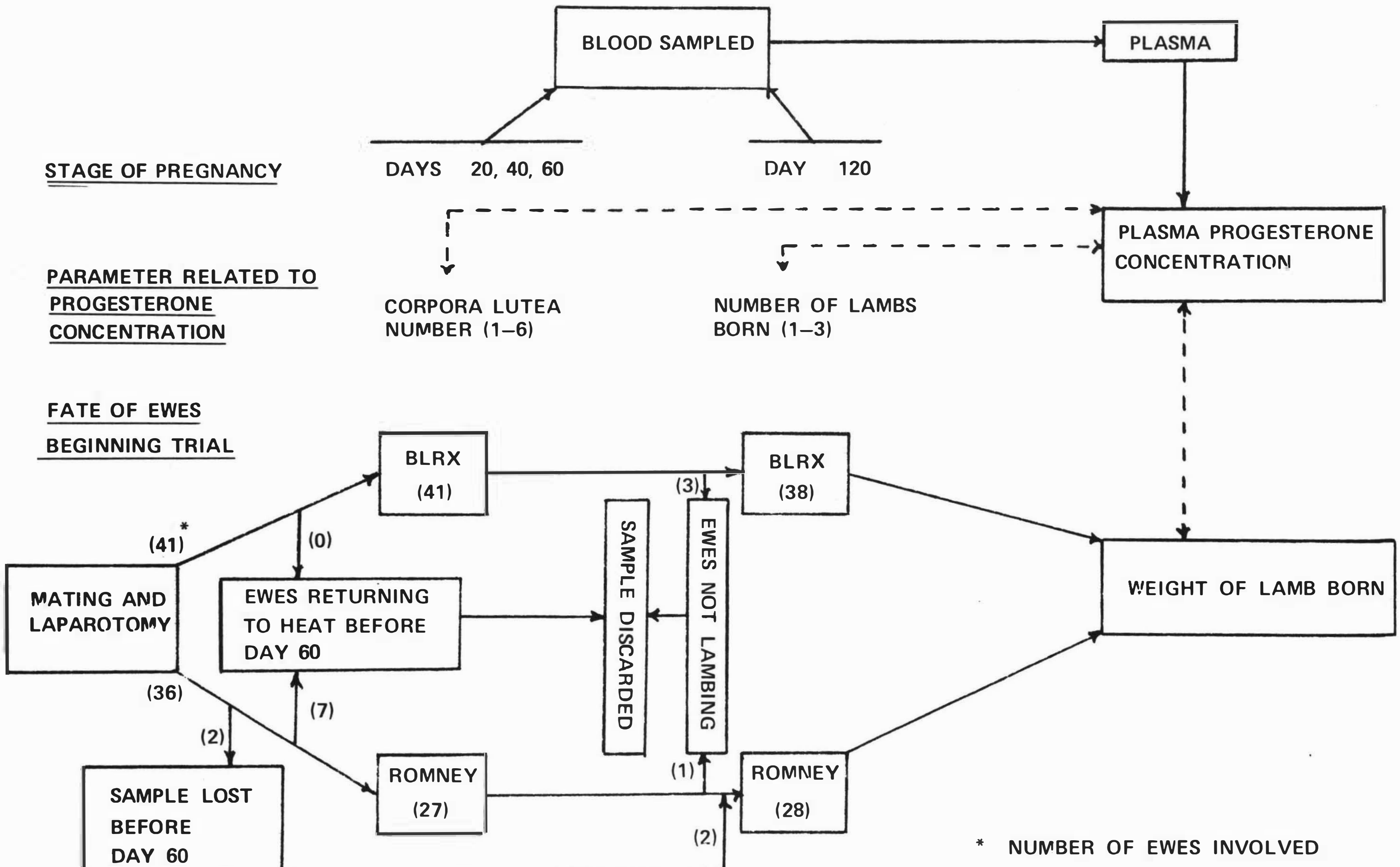


FIGURE 2–2:–
EXPERIMENTAL PLAN – PLASMA PROGESTERONE CONCENTRATION AND REPRODUCTIVE PHASE



Since gutfill forms an important component of the liveweight of sheep, especially in well-fed animals, an attempt was made to measure this using the method described by Allison (1968). Thus 6 sheep of each breed from each of the feeding levels were weighed on February 14 and transferred to the opposite nutritional group. Six days later the ewes were reweighed and returned to their original group and reweighed on February 26. The loss and regain in weight for ewes from each nutritional regime was determined and the difference in gutfill between the feeding groups calculated. This was used to adjust liveweights to a common level of gutfill.

Following laparotomy, ewes from each level of feeding were combined and managed as a single group through to weaning. Weighing commenced at the beginning of the nutritional treatment and continued at about fortnightly intervals until a final weighing at mating.

2. Hormonal treatments

To induce and synchronise oestrous cycles of ewes early in the breeding season, 14-day treatments with polyurethane intravaginal sponges containing 40 mg methyl-acetoxy progesterone (M.A.P.) were administered. Ewes were allocated at random (within breed and nutritional group) to one of 5 similar sized groups treated with progestagen sponges at 3-daily intervals (from February 20 to March 3). This procedure was designed to provide manageable numbers of ewes for laparotomy.

Vasectomised rams fitted with Sire Sine harnesses were used to detect ewes in oestrus following pessary removal. Ewes received a single 2 ml subcutaneous injection of either distilled water (0 i.u. PMSG), 600 i.u. PMSG or 1200 i.u. PMSG on day 12 or 13 of the oestrous cycle (oestrus = day 0). Ewes not recorded in oestrus were injected 14 days following sponge withdrawal (based on the estimated time of ovulation).

3. Detection of oestrus and ovulation

Ewes were inspected daily at 0800 and 1700 h for occurrence of oestrus. Following injection, ewes were run with harnessed entire Southdown rams on the appropriate nutritional treatment. Each group was run with 2 rams which had been proven in previous seasons and were regularly changed between groups to minimise biases due to ram failure.

Laparotomies were conducted 4 or 5 days after the ewes were first observed in oestrus. Ovaries were examined for number of recent corpora lutea (as evidence of ovulation) as well as the size and state of unovulated follicles.

Before laparotomy, ewes were yarded and starved overnight to reduce the risk of death following anaesthesia and surgery. Ewes were returned to pasture following the operation but separated from rams for at least 3 days.

Ewes which returned to oestrus following laparotomy were naturally mated to one of the Southdown sires. Harnessed entire rams (later replaced with vasectomised rams) were run with the ewes until about the end of the breeding season (August 6) to detect later returns to oestrus.

4. Plasma progesterone concentration

Following mating and laparotomy ewes were selected on the basis of corpora lutea number, and blood sampled at 20-day intervals throughout pregnancy as shown in Fig. 2-2. These ewes were managed as one group separated only for blood sampling.

Ewes returning to oestrus before day 60 of pregnancy were removed from the early part of analysis and ewes not lambing were disregarded for the latter part of analysis (Fig 2-2). For practical reasons, ewes to be bled were grouped into 5-day periods; for example, ewes said to be sampled on day 20 of gestation also included ewes that were actually 18 to 22 days pregnant.

Jugular vein blood samples (20 ml) were collected in heparinised tubes and immediately placed on ice. All collections were made between 0830 and 0930 h and centrifuged within 45 minutes of collection and 10 ml of plasma per collection was stored at -15°C until assay.

Plasma samples collected on days 20, 40, 60 and 120 were assayed using a method described by Smith et al. (1975). Although no chromatographic step was included in the assay Thorburn et al. (1969) have indicated that interfering substances in sheep plasma are not significant and that at least 90% of the indicated value is progesterone.

5. Observations on progeny

Ewes in late pregnancy were managed according to expected lambing performance. At birth, lambs were identified by a serially numbered ear tag as well as a brand (in the case of multiples). Birthweight, birth rank, and sex of the lamb(s) were recorded and the gestation length (in days) was calculated.

Ewes were given every chance to rear all their lambs although with triplets it often became necessary to rear at least one lamb on a foster dam. Lambs removed from their dams were discarded from subsequent analyses.

Male lambs were castrated. All lambs were weaned at about 100 days of age and liveweights were recorded.

Analysis of Data

Data from 8 ewes were excluded from analysis for a variety of reasons: failed to ovulate (three ewes), retained sponge (one ewe), facial eczema (two ewes), death prior to or following laparotomy (two ewes).

Discrete data were analysed using Chi-square tests or the G statistic (Sokal and Rohlf, 1969).

Data involving:

i. cycle length
ii. ovarian response
iii. ovum wastage
iv. progesterone concentration in peripheral plasma
v. weight of lamb born
vi. gestation length
vii. birth and weaning weight information

were analysed by analysis of variance applied to a completely randomised factorial experimental design (Kempthorne, 1952).

1. Transformations

(a) Discrete data

Data involving counts, i.e. for corpora lutea and follicle numbers (ovarian response), studied using analysis of variance methods, were found to be Poisson rather than normally distributed. Thus by use of Bartlett's test on data concerning numbers of corpora lutea, variance was shown to increase with greater PMSG doses and mean numbers of corpora lutea. A square-root transformation was applied to the data (Sokal and Rohlf, 1969) which reduced heterogeneity of variance (Appendix I).

As a result of this evidence the square-root transformation was applied to all discrete data.

(b) Plasma progesterone data

A Bartlett's test for homogeneity of variance on plasma progesterone data indicated that the variance of this variable increased with its absolute magnitude. The data were therefore subjected to a $\log_e$ transformation which resulted in homogeneity of variation prior to analysis of variance.

(c) Other data

A Bartlett's test on cycle length data indicated non significant heterogeneity of variation and no transformation of the data was required.

2. Analysis of variance

The classification model which describes the response for multiway factorial experiment of completely randomised design is:

$$y_{ij} = u + t_j + e_{ij}$$

where:

y_{ij} is the response variable (e.g. $\sqrt{\text{corpora lutea number}}$) for the i^{th} individual receiving the j^{th} treatment

u is the general mean effect

t_j is the effect of the j^{th} treatment

e_{ij} is the error peculiar to each y_{ij}

The model was fitted by ordinary least squares methods after reparametrisation to obtain full rank. The method of reparametrising non full rank (experimental design) models to regression models of full rank is discussed by Kempthorne (1952) and has been summarised by Pascoe (1973).

For most of the analyses of variance it was possible to reparametrise the model so that the least squares regression coefficients estimated (directly) the treatment comparisons of interest and also gave (directly) the estimated variances of these estimates.

However, when birth rank was considered as a treatment (e.g. in the analysis of weight of lamb born and gestation length), the model was not reparametrised to estimate treatment effects directly. Since ewes in the control PMSG group did not lamb triplets, missing treatment classes existed and complicated the problem of deriving the desired reparametrisation (see Appendix II). In this case the model was reparametrised to full rank to give the analysis of variance and selected treatment comparisons were estimated from the treatment means.

Thus:

$\Sigma_j\ c_j t_j$ is a treatment comparison

where $\Sigma_j c_j = 0$

The least squares estimate of $\Sigma_j c_j t_j$ is given by:

$$\Sigma_j c_j t_j = \Sigma_j c_j \bar{y}_j$$

where $\bar{y}_j$ is the mean of the j^{th} treatment

also

$$\text{Var}\ (\Sigma_j c_j \bar{y}_j) = \Sigma_j c_j^2\ \text{Var}\ (\bar{y}_j)$$
$$= \sigma^2 \Sigma_j c_j^2\ (\frac{1}{n_j})$$

where n_j is the number of individuals receiving the j^{th} treatment.

This variance is estimated by:

$$\sigma_e^2\ \Sigma_j c_j^2\ (\frac{1}{n_j})$$

where σ_e^2 is the error mean square obtained from the analysis of variance.

The c_j values are selected so as to estimate treatment comparisons on a per sheep (individual) basis.

A significance level for the null hypothesis:

$$H_0:\ \Sigma_j c_j t_j = 0$$

and the alternative hypothesis:

$$H_A:\ \Sigma_j c_j t_j \neq 0$$

can then be obtained from the t statistic

$$t = \Sigma_j c_j \bar{y}_j / \sqrt{\sigma_2^2\ \ \Sigma_j c_j^2 (\frac{1}{n_j})}$$

which follows the t frequency function with degrees of freedom associated with E.M.S.* under the null hypothesis.

Comparisons of treatment means were made following analyses of variance which gave statistically significant results. These means were inspected using the Student-Newman-Keuls test (Sokal and Rohlf, 1969).

*error mean square

3. Relationship of liveweight and ovulation rate

Relation of liveweight at PMSG injection (and change in weight over the 2 months before injection) to ovulation rate.

Separate regressions were calculated (after reparametrisation of the model) of the square root of corpora lutea number on ewe liveweight at injection for each of the 12 (Breed-Nutrition-PMSG dose) treatment groups. The sums of squares of this model were compared to those when a common regression across all treatment groups was used:

Thus the general model was:

$$y_{ij} = u + B_j X_{ij} + t_j + e_{ij}$$

where y_{ij} is the square root of corpora lutea number for the i^{th} ewe receiving the j^{th} treatment ($j = 1$-12).

u is an estimate of the general mean

B_j is the regression coefficient for the j^{th} treatment group

X_{ij} is the weight at injection of the i^{th} ewe receiving the j^{th} injection

t_j is the effect of the j^{th} treatment

e_{ij} is the residual error which is assumed to have zero mean and constant variance

The hypotheses tested by analysis of variance were:

$$H_0 : B_1 = B_2 = B_3 = \dots\dots\dots\dots B_{12} = B$$

$$H_A : B_1 \neq B_2 \neq B_3 \neq \dots\dots\dots\dots B_{12} \neq B$$

where B_1 ..... B_{12} are regression coefficients for the 12 treatment groups and B is the regression coefficient for the common regression of $\sqrt{\text{corpora lutea number}}$ on mating weight across all treatments.

A similar method was used to study the effects of a change in ewe liveweight before injection on ovulation rate and of ewe liveweight together with the weight of lamb born on blood progesterone concentration.

4. Weaning weight data

Weaning weights were analysed after adjusting for age at weaning using the regression of age of lamb at weaning on weaning weight in a similar manner to that described for relating ewe liveweight to ovulation rate.

Weight gain per day for each lamb was estimated thus:

$$\frac{\text{Weight at Weaning} - \text{Weight at Birth}}{\text{Age at Weaning (days)}} \text{ (kg/day)}$$

CHAPTER III

LIVEWEIGHT, OVARIAN CHANGES, OESTRUS PHENOMENA AND CYCLE LENGTH OF EWES

CHAPTER III

LIVEWEIGHT, OVARIAN CHANGES, OESTROUS PHENOMENA AND CYCLE LENGTH OF EWES

Liveweight of Ewes

Mean liveweights of each of the breed[A] and nutritional groups are listed in Table 3-1 and in Fig. 3-1.

Although allocation of ewes to treatment groups was at random, there was an initial difference of about 1 kg in mean liveweight between Romneys on the high level of feeding and poorly fed Romneys.

The estimated weight of the difference in gutfill between the high and low plane feeding groups was about 1 kg. This weight was deducted from liveweights of better fed ewes to express bodyweights from February 20 onwards at a common level of gutfill.

The nutritional treatment resulted in the high plane group of ewes gaining 1.39 kg and the low plane ewes losing 1.52 kg. At mating, ewes receiving the high level of nutrition (Border-Romneys, 54.23 $\pm$ 0.72 kg; Romneys, 46.03 $\pm$ 0.71 kg) were significantly heavier ($P < 0.005$) than the less well fed ewes (Border-Romneys, 50.97 $\pm$ 0.71 kg; Romneys, 44.57 $\pm$ 0.82 kg). A lower than average rainfall (Appendix IV) restricted pasture production which prevented achievement of greater differences in liveweight between feeding groups. Crossbred ewes over both levels of feeding were heavier at mating ($P < 0.001$) than the Romneys (see Table 3-2).

[A] Although, strictly, F_1 Border-Romney sheep do not constitute a breed, for simplicity they will be referred to as such in this work.

TABLE 3-1: MEAN EWE LIVEWEIGHTS (kg) CLASSIFIED ACCORDING TO BREED, NUTRITIONAL LEVEL AND DATE OF WEIGHING

Breed of Ewe	Border-Romney			Romney			Both Breeds	
Nutritional Level	Low	High	Combined	Low	High	Combined	Low	High
Number of Ewes	57	56	113	43	44	87	100	100
Time of weighing								
Pre-experimental								
Mean	52.19	52.19	52.19	46.36	45.28	45.82	49.28	48.74
± S.E.	0.74	0.75	0.53	0.85	0.84	0.60	0.56	0.59
February 20								
Mean	52.35	53.48	52.92	46.08	46.06	46.07	49.21	49.77
± S.E.	0.74	0.75	0.52	0.85	0.84	0.60	0.56	0.56
March 3								
Mean	51.32	53.84	52.58	44.55	45.20	44.88	47.94	49.52
± S.E.	0.76	0.76	0.54	0.87	0.86	0.61	0.57	0.57
March 15								
Mean	50.77	53.86	52.32	45.13	46.07	45.38	47.95	49.97
± S.E.	0.69	0.70	0.49	0.80	0.79	0.56	0.52	0.53
April 4								
Mean	50.97	54.23	52.60	44.57	46.03	45.30	47.77	50.13
± S.E.	0.71	0.72	0.51	0.82	0.81	0.58	0.54	0.54

FIGURE 3–1:–
EWE LIVEWEIGHT CHANGES

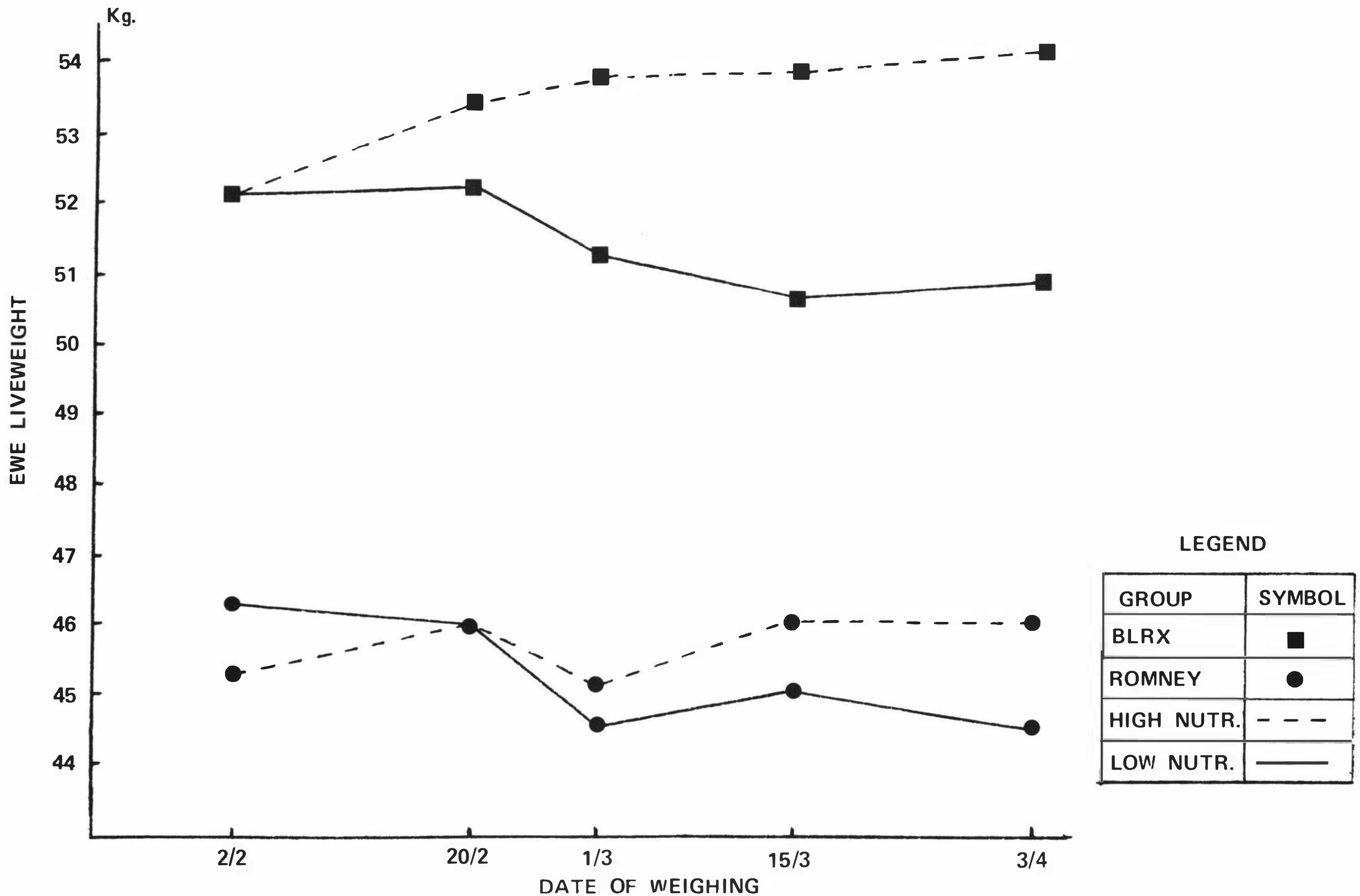


TABLE 3-2: EFFECT OF BREED AND NUTRITIONAL LEVEL ON LIVEWEIGHT AT MATING

Classification	No. of Ewes	Ewe Liveweight (kg) (Mean ± S.E.)
Breed of Ewe		
Border-Romney	113	52.60 ± 0.51
Romney	87	45.30 ± 0.58
Level of Nutrition		
Low	100	47.77 ± 0.54
High	100	50.13 ± 0.54

Analysis of Variance

Source of Variation	d.f.	Mean squares
Between Breeds	1	2604.84 ***
Between Nutritional Levels	1	280.23 **
Interaction	1	36.49
Error	195	28.33
Total	199	

*** $P < 0.001$

** $P < 0.01$

* $P < 0.05$

- $0.05 < P < 0.1$

N.B. These symbols will be used to signify levels of statistical significance for the remainder of Analyses.

Induction and Synchronisation of Oestrus

The use of progestagen sponges to induce and synchronise oestrus in young ewes provided data on the effectiveness of synchronisation soon after pessary removal (expected first oestrus) and one cycle later (expected second oestrus). The effects of breed, nutritional level and dose of PMSG were studied.

1. Incidence of oestrus

(a) Expected 'first' oestrus

Table 3-3 summarises the incidence of oestrus in terms of breed of ewe and level of feeding. Fewer (14.5%) Border-Romney ewes had 'silent' heats ($P < 0.05$) than Romneys. There was no significant effect of nutritional level on the proportion of ewes showing 'overt' heat at this time. There were no significant interactions.

Examination of the ovaries for corpora albicans (old corpora lutea) showed that all ewes had ovulated at expected first oestrus.

(b) Expected 'second' oestrus

There were no significant effects of breed, level of feeding or dose of PMSG on the occurrence of overt oestrus at the time of expected second heat following sponge withdrawal (Table 3-4).

Over all treatments there was a lower proportion of ewes in oestrus immediately after sponge removal 159/200 than at the expected second heat 191/200 ($P < 0.001$).

2. Synchronisation of oestrus

(a) Expected first oestrus

Frequency distributions of ewes in oestrus over the 7-day period after sponge removal are shown in Table 3-5 and Fig. 3-2.

TABLE 3-3: EFFECT OF BREED AND NUTRITIONAL LEVEL ON THE INCIDENCE OF OESTRUS WITHIN 7 DAYS OF PROGESTAGEN SPONGE TREATMENT

Classification:		No. of Ewes Showing:		Total No. of Ewes	% Ewes Showing Overt Oestrus
Breed of Ewe	Level of Nutrition	Overt Oestrus	Silent Oestrus		
Border-Romney	Low	51	6	57	89.5
	High	46	10	56	82.1
	Both levels	97	16	113	85.8
Romney	Low	33	11	44	75.0
	High	29	14	43	67.4
	Both levels	62	25	87	71.3
Both Breeds	Low	84	17	101	83.2
	High	75	24	99	75.8
	Both levels	159	41	200	79.5

Test of Independence: G Statistic	d.f.	G	Significance
Breed x Incidence of Oestrus Independence	1	6.37	*
Nutrition x Incidence of Oestrus Independence	1	1.29	N.S.
Breed x Nutrition x Incidence Interaction	1	0.58	N.S.
Breed x Nutrition x Incidence Independence	4	8.24	-

TABLE 3-4: BREED, NUTRITIONAL AND PMSG EFFECTS ON THE OCCURRENCE OF OESTRUS AT THE EXPECTED SECOND HEAT PERIOD AFTER PROGESTAGEN TREATMENT

Classification	No. of Ewes Showing		Total No. of Ewes	% Ewes Showing Overt Oestrus
	Overt Oestrus	Silent Oestrus		
Breed of Ewe				
Border-Romney	110	3	113	97.3
Romney	81	6	87	93.1
Level of Nutrition				
Low	96	5	101	95.1
High	95	4	99	96.0
Dose of PMSG (i.u.)				
0	60	3	63	95.2
600	66	3	69	95.6
1200	65	3	68	95.6
Total	191	9	200	95.5

Test of Independence: G Statistic

	d.f.	G	Significance
Breed x Incidence of Oestrus Independence	1	0.02	N.S.
Nutrition x Incidence of Oestrus Independence	1	2.05	N.S.
PMSG x Incidence of Oestrus Independence	1	0.09	N.S.

TABLE 3-5: EFFECT OF BREED AND LEVEL OF NUTRITION ON THE INTERVAL BETWEEN SPONGE REMOVAL AND THE ONSET OF OESTRUS

Classification: Breed of Ewe	Level of Nutrition	Days from Sponge Removal 1	2	3	4	5	6	7	Total No. of Ewes
		Number (percentage) of Ewes in Heat[A]							
	Low	8(15.7)	34(66.7)	5(9.8)	4(7.8)	0	0	0	51
Border-Romney	High	5(8.7)	30(65.2)	6(13.0)	3(6.5)	1(2.2)	1(2.2)	0	46
	Both Levels	13(13.4)	64(66.0)	11(11.3)	7(7.2)	1(1.0)	1(1.0)	0	97
	Low	8(24.2)	11(33.3)	10(30.3)	1(3.0)	0	1(3.0)	2(6.1)	33
Romney	High	1(3.5)	21(72.4)	5(17.2)	1(3.5)	0	1(3.5)	0	29
	Both Levels	9(14.5)	32(51.6)	15(24.2)	2(3.2)	0	2(3.2)	2(3.2)	62
	Low	16(19.1)	45(53.6)	15(17.9)	5(6.0)	0	1(1.2)	2(2.4)	84
Both Breeds	High	6(8.0)	51(68.0)	11(14.7)	4(5.3)	1(1.3)	2(2.7)	0	75
	Both Levels	22(13.8)	96(60.4)	26(16.4)	9(5.7)	1(0.6)	3(1.9)	2(1.3)	159

Test of Independence: G Statistic	d.f.	G	Significance
Breed x Distribution Independence	6	11.90	-
Nutrition x Distribution Independence	6	9.81	N.S.
Breed x Nutrition Independence	1	0.01	N.S.
Breed x Nutrition x Distribution Interaction	6	7.48	N.S.
Breed x Nutrition x Distribution Independence	19	29.19	-

[A] Figures in brackets refer to percentage ewes in heat

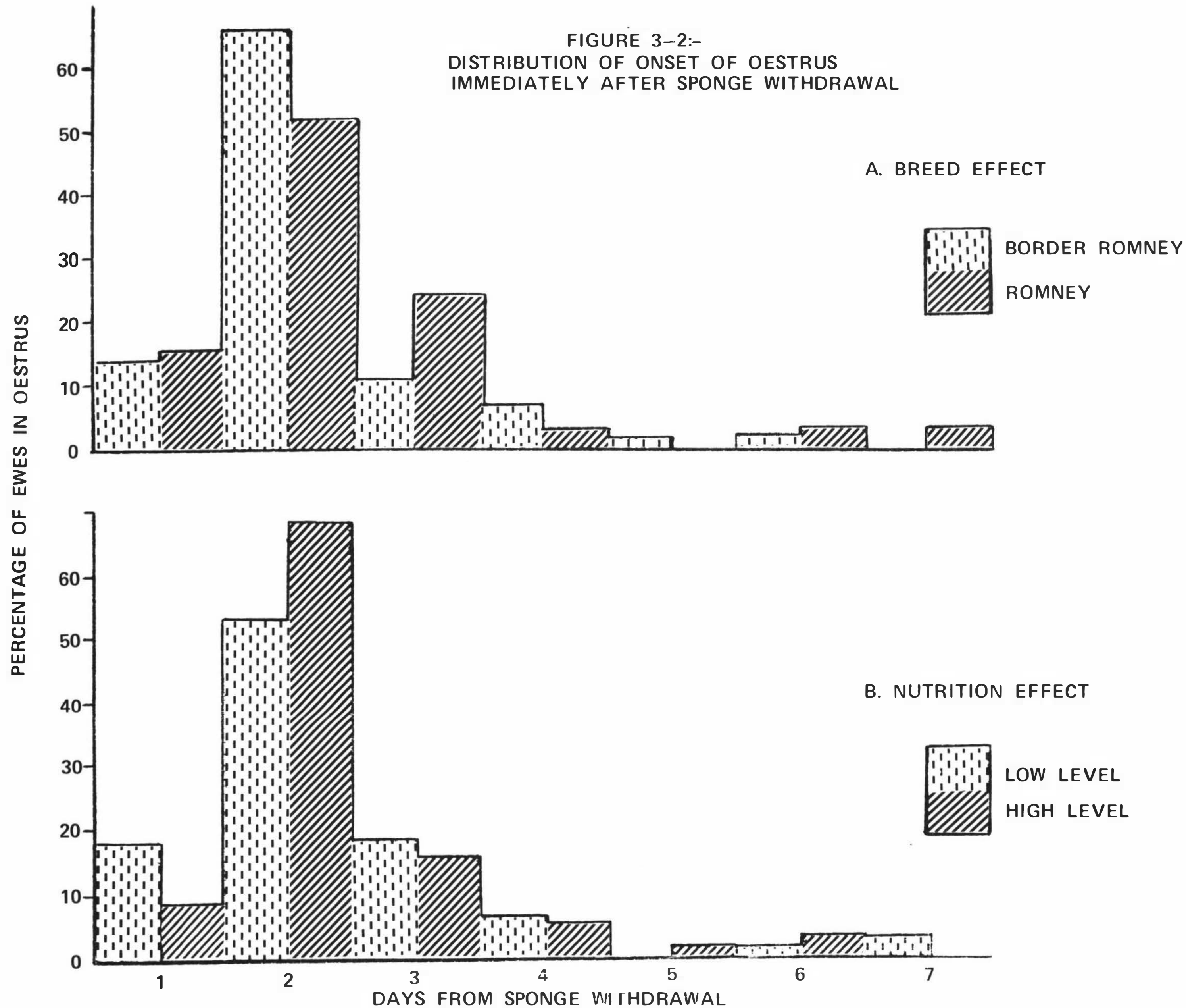


FIGURE 3–2:–
DISTRIBUTION OF ONSET OF OESTRUS
IMMEDIATELY AFTER SPONGE WITHDRAWAL
A. BREED EFFECT
BORDER ROMNEY
ROMNEY
B. NUTRITION EFFECT
LOW LEVEL
HIGH LEVEL
PERCENTAGE OF EWES IN OESTRUS
DAYS FROM SPONGE WITHDRAWAL
0
10
20
30
40
50
60
1
2
3
4
5
6
7

Synchronisation of oestrus was similar in both the crossbred and Romney ewes (79.4% v. 75.8% marked over 2 consecutive days) although Romneys tended to show heat slightly later ($P < 0.1$).

The level of feeding had no significant effect on the frequency distribution.

(b) Expected second oestrus

Border-Romney ewes appeared to be mated earlier (58.2% days 2 and 3 of mating) than the Romneys (56.8% days 3 and 4) (Fig.3-3A). The difference in temporal distribution of onset of heat was not significant between the breed groups (Table 3-6).

Feeding level did not significantly influence the pattern of onset of oestrus at this time (Table 3-6). The effects are represented diagramatically in Fig. 3-3B.

PMSG treatment did not affect the degree of synchronisation at second heat although the peak onset of oestrus in treated ewes tended to be earlier ($P < 0.05$) than in the controls (61.1% on days 2 and 3 of mating v. 58.3% on days 3 and 4). There was no significant difference in distribution of onset of heat between ewes receiving 600 i.u. and those injected with 1200 i.u. PMSG (Table 3-6). PMSG dose effects on the temporal distribution of onset of oestrus are summarised in Fig. 3-4.

Cycle Length

The effects of breed of ewe, dose of PMSG and level of feeding on oestrous cycle length are summarised in Table 3-7. Cycle length was similar in both breeds although an improved feeding level reduced the variable significantly ($P < 0.05$). PMSG treatment also shortened

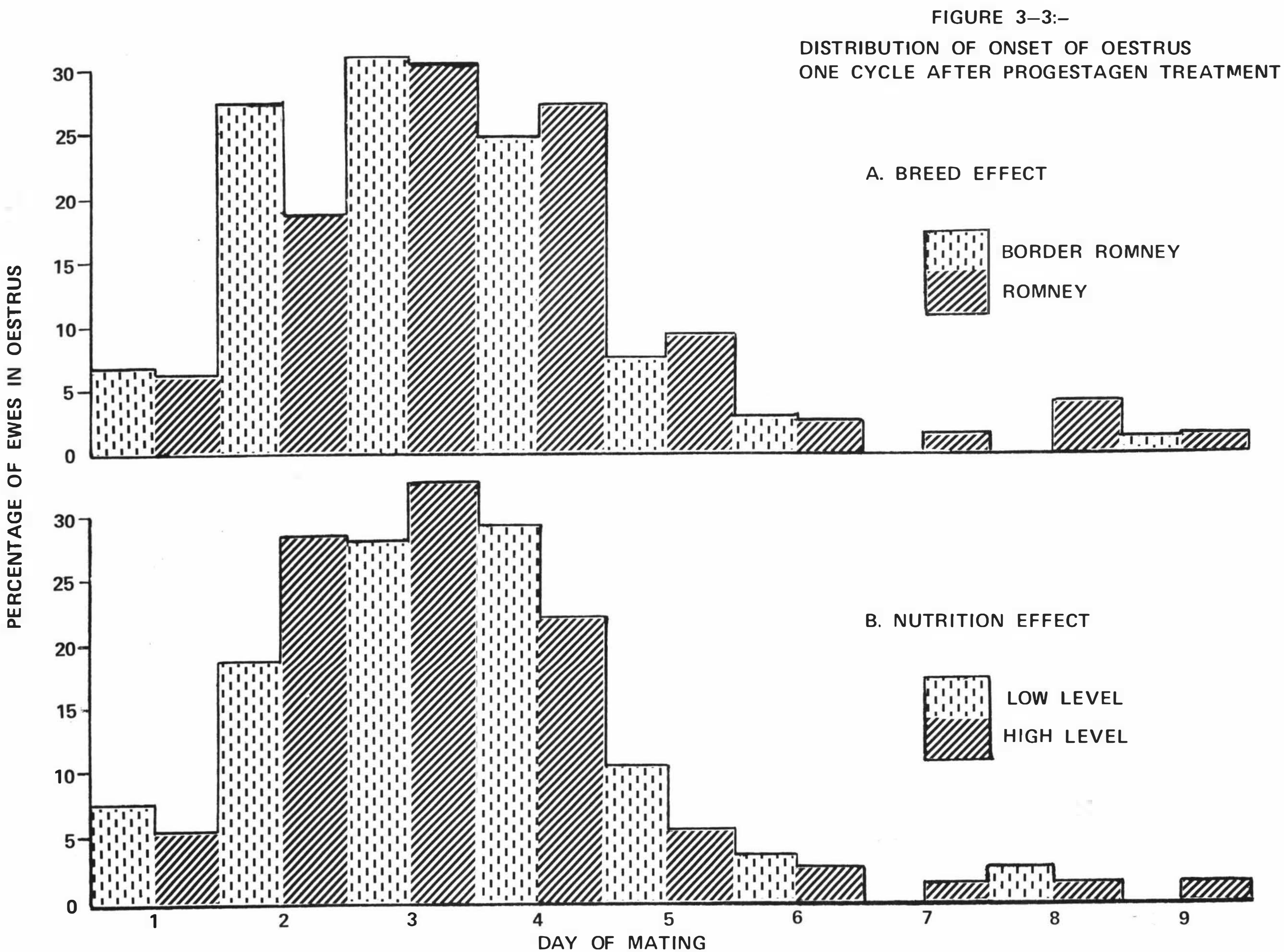


FIGURE 3–3:–
DISTRIBUTION OF ONSET OF OESTRUS
ONE CYCLE AFTER PROGESTAGEN TREATMENT
A. BREED EFFECT
BORDER ROMNEY
ROMNEY
B. NUTRITION EFFECT
LOW LEVEL
HIGH LEVEL
PERCENTAGE OF EWES IN OESTRUS
DAY OF MATING
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9

TABLE 3-6: BREED, NUTRITIONAL AND PMSG EFFECTS ON THE SYNCHRONISATION OF OESTRUS ONE CYCLE AFTER PROGESTAGEN TREATMENT

Classification	Days of Mating							Total No. of Ewes
	1	2	3	4	5	6	7-9	
	Number (percentage) of Ewes in Heat							
Breed of Ewe								
Border-Romney	7(6.4)	30(27.3)	34(30.9)	27(24.6)	8(7.3)	3(2.7)	1(0.9)	110
Romney	5(6.2)	15(18.5)	24(29.6)	22(27.2)	8(9.9)	2(2.5)	5(6.2)	81
Level of Nutrition								
Low	7(7.3)	18(18.8)	27(28.1)	28(29.2)	10(10.4)	3(3.1)	3(3.1)	96
High	5(5.3)	27(28.4)	31(32.6)	21(22.1)	6(6.3)	2(2.1)	3(3.2)	95
Dose of PMSG (i.u.)								
0	6(10.0)	8(13.3)	15(25.0)	20(33.3)	7(11.7)	1(1.7)	3(5.0)	60
600	4(6.1)	22(33.3)	22(33.3)	13(19.7)	3(4.6)	1(1.5)	1(1.5)	66
1200	2(3.1)	15(23.1)	21(32.3)	16(24.6)	6(9.2)	3(4.6)	2(3.1)	65
All Doses	12(6.3)	45(23.6)	58(30.4)	49(25.7)	16(8.4)	5(2.6)	6(3.1)	191

Test of Independence: G Statistic	d.f.	G	Significance
Breed x Distribution Independence	6	6.88	N.S.
Nutrition x Distribution Independence	6	4.44	N.S.
PMSG x Distribution Independence	12	18.59	-
0 i.u. v. (600 i.u. and 1200 i.u.)	6	13.85	*
600 i.u. v. 1200 i.u.	6	4.74	N.S.
Breed x Nutrition x Distribution Interaction	6	9.64	N.S.
Breed x PMSG x Distribution Interaction	12	11.21	N.S.
PMSG x Nutrition x Distribution Interaction	12	13.75	N.S.

FIGURE 3–4:–
EFFECT OF PMSG DOSE ON SYNCHRONISATION OF OESTRUS ONE CYCLE AFTER PROGESTAGEN TREATMENT

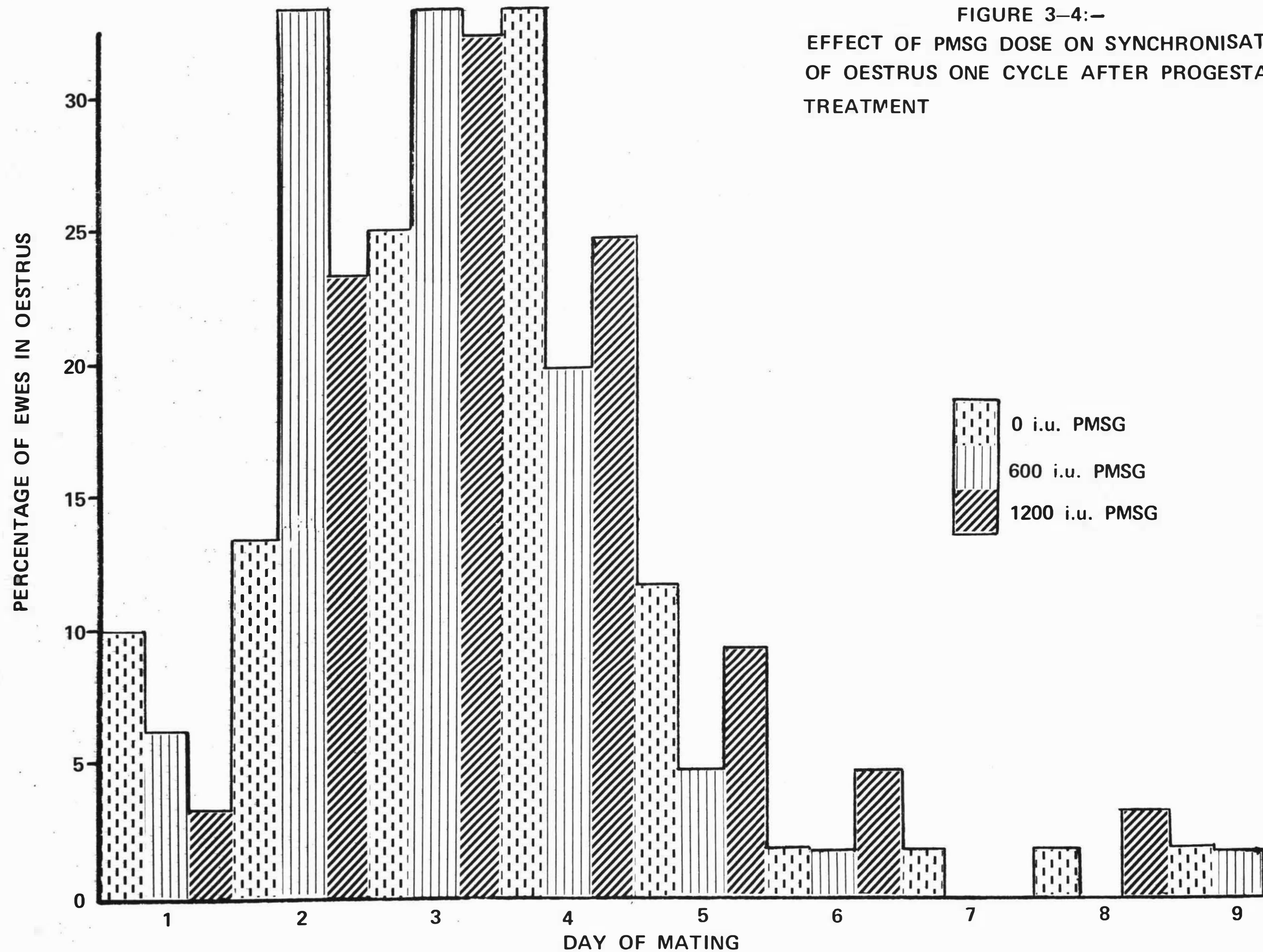


TABLE 3-7: EFFECT OF BREED, PMSG AND NUTRITIONAL LEVEL ON CYCLE LENGTH

Classification	No. of Ewes	Cycle Length (days) (Mean ± S.E.)
Breed of Ewe		
Border-Romney	98	15.88 ± 0.09
Romney	64	15.85 ± 0.11
Level of Nutrition		
Low	85	16.03 ± 0.10
High	77	15.70 ± 0.10
Dose of PMSG (i.u.)		
0	52	16.16 ± 0.12 a[A]
600	57	15.67 ± 0.12 b
1200	53	15.77 ± 0.12 cb

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.03	0.04 N.S.
Between PMSG doses (P)	2	3.30	4.06 *
Between Nutrition Levels (N)	1	4.50	5.54 *
B x P Interaction	2	0.47	0.57 N.S.
B x N Interaction	1	2.19	2.69 N.S.
P x N Interaction	2	1.22	1.50 N.S.
B x P x N Interaction	2	1.67	2.06 N.S.
Error	150	0.81	

[A] Values followed by the same letter are not significantly different ($P < 0.05$).

the cycle ($P < 0.05$). A Student-Newman-Keuls test was used to test for significance between PMSG treatment means (Appendix V) and the results are summarised in Table 3-7. Thus injection with either 600 i.u. or 1200 i.u. PMSG reduced cycle length ($P < 0.05$) although the difference in cycle length between groups receiving 600 i.u. and 1200 i.u. was not significant.

There were no significant interactions between any of the main effects.

Table 3-8 summarises the effects of breed of ewe, dose of PMSG, nutritional level, and day of PMSG injection on those ewes injected with PMSG only. Ewes injected with the drug on day 12 had shorter cycles than those treated on day 13. Improved feeding also reduced cycle length in this sample of ewes ($P < 0.05$). Breed of ewe and dose of PMSG had non significant effects on the variable in this group of ewes.

There were significant interactions between dose of PMSG and breed of ewe ($P < 0.05$) and level of nutrition ($P < 0.05$). Thus although 600 i.u. PMSG caused longer cycles than 1200 i.u. in Border-Romney ewes, the reverse occurred with Romneys. Similarly, 600 i.u. of PMSG increased cycle length compared to 1200 i.u. in poorly-fed ewes, although this effect was reversed with improved nutrition.

There were no other significant interactions between treatments for this group of ewes.

Ovarian Response

1. Ovulation rate

Square root transformed and detransformed means together with the ranges of the numbers of corpora lutea counted are presented in Table 3-9.

TABLE 3-8: EFFECT OF BREED, PMSG DOSE, NUTRITIONAL LEVEL AND DAY OF PMSG INJECTION ON CYCLE LENGTH
(Data from ewes treated with PMSG)

Classification: Breed of Ewe	Dose of PMSG (i.u.)	Nutritional Level	No. of Ewes	Cycle Length (days) (Mean ± S.E.)
Border-Romney	600		33	16.01 ± 0.14
	1200		32	15.72 ± 0.15
	Both Doses		65	15.86 ± 0.10
Romney	600		24	15.63 ± 0.17
	1200		21	16.04 ± 0.18
	Both Doses		45	15.83 ± 0.12
Both Breeds	600	Low	30	16.18 ± 0.15
		High	27	15.45 ± 0.16
		Both Levels	57	15.82 ± 0.11
	1200	Low	28	15.85 ± 0.15
		High	25	15.91 ± 0.16
		Both Levels	53	15.88 ± 0.11
All Breeds and Doses		Low	58	16.02 ± 0.11
		High	52	15.68 ± 0.11
Day of Injection				
12			87	15.62 ± 0.09
13			23	16.07 ± 0.17

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.02	0.03 N.S.
Between PMSG Levels (P)	1	0.11	0.16 N.S.
Between Nutritional Levels (N)	1	3.21	4.79 *
Between Days of Injection (D)	1	3.69	5.51 *
B x P Interaction	1	3.38	5.05 *
N x P Interaction	1	4.27	6.37 *
B x N Interaction	1	0.10	0.15 N.S.
B x D Interaction	1	0.82	1.22 N.S.
P x D Interaction	1	0.44	0.66 N.S.
N x D Interaction	1	0.08	0.12 N.S.
Error	99	0.67	

Note: 1) When tested in the full model, the higher order interactions were all found to be non significant and were absorbed into the error term for testing of other effects in the analysis.

2) Since there were no significant interactions between day of injection and any of the other treatments, a simplified layout of means was used.

TABLE 3-9: NUMBER OF CORPORA LUTEA IN EWES RELATIVE TO BREED, DOSE OF PMSG AND LEVEL OF NUTRITION

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes	Corpora Lutea Number Data: Transformed (Mean ± S.E.)	Detransformed Mean (Range)
Border-Romney	0	36	1.18 ± 0.05 a[A]	1.40 (1-2)[B]
	600	39	1.39 ± 0.05 eb	1.94 (1-4)
	1200	38	1.84 ± 0.05 d	3.39 (1-8)
Romney	0	27	1.08 ± 0.06 a	1.16 (1-2)
	600	30	1.26 ± 0.06 ab	1.58 (1-4)
	1200	30	1.54 ± 0.06 ec	2.39 (1-6)
All Doses of PMSG				
Breed of Ewe				
Border-Romney		113	1.47 ± 0.03	2.17 (1-8)
Romney		87	1.29 ± 0.03	1.67 (1-6)
Level of Nutrition				
Low		100	1.38 ± 0.03	1.91 (1-8)
High		100	1.38 ± 0.03	1.91 (1-6)

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	1.60	15.51 ***
Between PMSG Doses-linear (Pl)	1	10.12	98.40 ***
Between PMSG Doses-quadratic (Pq)	1	0.32	3.11 -
Between Nutritional Levels (N)	1	0.0001	0.001 N.S.
B x Pl Interaction	1	0.29	2.83 -
B x Pq Interaction	1	0.05	0.49 N.S.
B x N Interaction	1	0.0005	0.004 N.S.
N x Pl Interaction	1	0.0005	0.005 N.S.
N x Pq Interaction	1	0.002	0.023 N.S.
B x N x Pl Interaction	1	0.12	1.45 N.S.
B x N x Pq Interaction	1	0.10	1.01 N.S.
Error	188	0.10	

[A] Values followed by the same letter are not significantly different ($P < 0.05$)

[B] Figures in brackets refer to the range of corpora lutea counted

Feeding level had no effect on ovulation rate. PMSG treatment increased numbers of corpora lutea (linear effect, $P < 0.001$; quadratic effect $P < 0.1$). The breed x linear PMSG interaction approached statistical significance ($P < 0.1$). Comparison of breed-PMSG dose sub-group means by Student-Newman-Keuls test is summarised in Table 3-9. Thus Border-Romney ewes injected with 1200 i.u. had more ovulations than similar Romney ewes ($P < 0.05$) but the difference between the breeds when either 0 i.u. or 600 i.u. PMSG was administered failed to reach significance.

Fig. 3-5 presents the detransformed corpora lutea means for each breed-dose of PMSG sub-group. Dose response relationships from other New Zealand reports for a similar range of PMSG dose levels are also presented.

2. Total follicular response

The sum of the number of follicles more than 3 mm in diameter (measured with sterile slide calipers) plus corpora lutea number is defined as the total follicular response.

Breed of ewe had a significant effect on this variable ($P < 0.05$) as did the linear component of PMSG ($P < 0.001$). There were no other treatment effects or interactions that approached significance, however (Table 3-10).

3. Day of PMSG injection

Both ovulation rate and total follicular response were independent of whether PMSG was injected on day 12 or 13 of the oestrous cycle (Table 3-11).

FIGURE 3–5:–
DOSE RESPONSE RELATIONSHIPS FOR EWES TREATED WITH PMSG
– N.Z. DATA

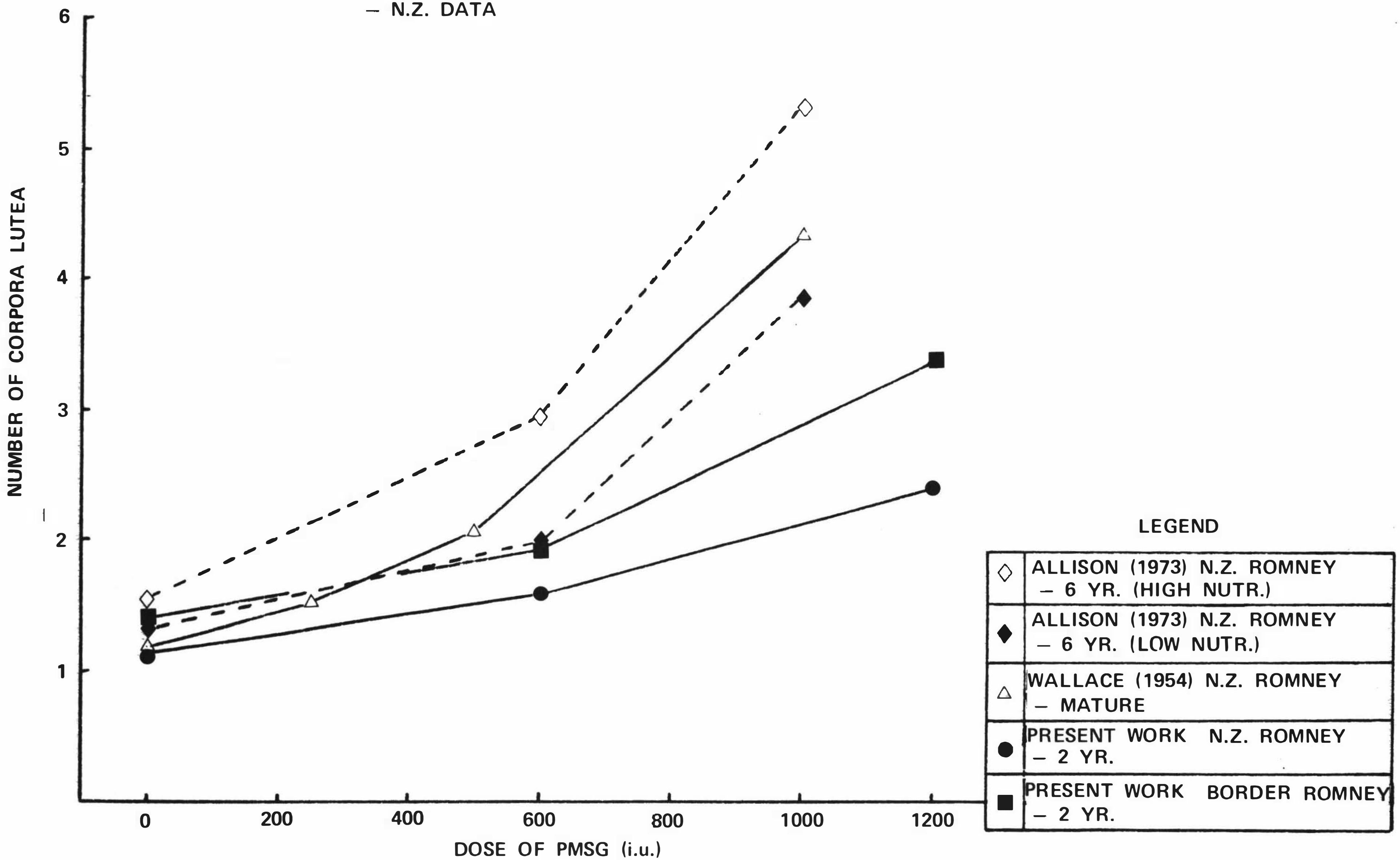


TABLE 3-10: TOTAL FOLLICULAR RESPONSE RELATIVE TO BREED, DOSE OF PMSG AND LEVEL OF NUTRITION

Classification	No. of Ewes	Total Follicular Response Data: Transformed (Mean ± S.E.)	Detransformed Mean (Range)
Breed of Ewe			
Border-Romney	117	1.92 ± 0.04	3.70 (1- 9)[A]
Romney	87	1.77 ± 0.04	3.14 (1-11)
Dose of PMSG (i.u.)			
0	63	1.62 ± 0.05	2.62 (1- 6)
600	69	1.83 ± 0.05	3.36 (1- 7)
1200	68	2.09 ± 0.05	4.38 (1-11)
Level of Nutrition			
Low	100	1.81 ± 0.04	3.29 (1-11)
High	100	1.88 ± 0.04	3.54 (1- 8)

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F	
Between Breeds (B)	1	1.10	6.72	*
Between PMSG doses-linear (Pl)	1	7.24	44.03	***
Between PMSG doses-quadratic (Pq)	1	0.02	0.14	N.S.
Between Nutritional Levels (N)	1	0.21	1.29	N.S.
B x Pl Interaction	1	0.21	1.26	N.S.
B x Pq Interaction	1	0.004	0.03	N.S.
B x N Interaction	1	0.30	1.83	N.S.
N x Pl Interaction	1	0.0002	1.26	N.S.
N x Pq Interaction	1	0.0001	0.001	N.S.
B x N x Pl Interaction	1	0.48	2.89	N.S.
B x N x Pq Interaction	1	0.01	0.05	N.S.
Error	188	0.16		

[A] Figures in brackets refer to range of corpora lutea plus large follicles counted

TABLE 3-11: EFFECT OF BREED, LEVEL OF NUTRITION, DOSE OF PMSG AND DAY OF INJECTION ON OVARIAN RESPONSE
(Data from ewes treated with PMSG)

Classification	No. of Ewes	No. of Corpora Lutea (Transformed) (Mean ± S.E.)	Total Follicular Response (Transformed) (Mean ± S.E.)
Breed of Ewe			
Border-Romney	65	1.63 ± 0.04	2.12 ± 0.05
Romney	43	1.42 ± 0.05	1.93 ± 0.07
Dose of PMSG (i.u.)			
600	56	1.34 ± 0.05	1.91 ± 0.06
1200	52	1.71 ± 0.05	2.14 ± 0.06
Day of Injection			
12	85	1.60 ± 0.04	2.02 ± 0.05
13	23	1.46 ± 0.07	2.03 ± 0.09
Level of Nutrition			
Low	56	1.54 ± 0.05	1.96 ± 0.06
High	52	1.52 ± 0.05	2.09 ± 0.06

Analysis of Variance

Source of Variation	d.f.	No. of Corpora Lutea Mean Squares	Total Follicular Response Mean Squares
Between Breeds (B)	1	0.62 *	0.52 N.S.
Between PMSG Doses (P)	1	1.93 ***	0.78 *
Between Days (D)	1	0.27 N.S.	0.002 N.S.
Between Nutritional Levels (N)	1	0.002 N.S.	0.26 N.S.
B x P Interaction	1	0.001 N.S.	0.04 N.S.
B x D Interaction	1	0.14 N.S.	0.001 N.S.
B x N Interaction	1	0.06 N.S.	0.79 *
P x D Interaction	1	0.06 N.S.	0.18 N.S.
P x N Interaction	1	0.27 N.S.	0.30 N.S.
D x N Interaction	1	0.02 N.S.	0.14 N.S.
Error	97	0.12 N.S.	0.19 N.S.

4. Proportion of follicles ovulating

The ratio of corpora lutea number to total follicular response was analysed relative to breed of ewe and dose of PMSG (Table 3-12).

Crossbred ewes ovulated a greater proportion of follicles compared to the Romneys (62.6% v. 58.2%) although this failed to reach statistical significance.

Injection of PMSG also increased the percentage of follicles ovulating ($P < 0.01$) being mainly due to the increased proportion for ewes receiving 1200 i.u. compared to the 0 i.u. group ($P < 0.01$). The 600 i.u. dose of PMSG caused non significantly more follicles to be ovulated compared to control ewes but resulted in a lower ratio of follicles ovulating ($P < 0.05$) than for 1200 i.u.

5. Distribution of corpora lutea between ovaries

The distribution of corpora lutea between the left and right ovaries as influenced by both breed of ewe and dose of PMSG is shown in Table 3-13.

Although a greater proportion of ovulations occurred on the right ovary in Romney compared to Border-Romney ewes (59.9% v. 54.9%) this was not statistically significant. Similarly PMSG had no effect and there was no evidence of an interaction.

Over all of the treatments, 56.7% of ovulations occurred on the right ovary ($P < 0.05$).

Figure 3-6 shows the exposed reproductive tract (4 days or 96 hours after first observation of heat) of a 2 year-old Romney ewe which had received 1200 i.u. PMSG. This tract illustrates the marked difference in ovarian size and symmetry of ovulation that may

TABLE 3-12: EFFECT OF BREED AND DOSE OF PMSG ON THE PROPORTION OF FOLLICLES OVULATING

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes	No. Corpora Lutea / Total Follicular Response (Mean ± S.E.)
Border-Romney	0	36	0.583 ± 0.04
	600	39	0.578 ± 0.04
	1200	38	0.718 ± 0.04
	All Doses	113	0.626 ± 0.02
Romney	0	27	0.509 ± 0.05
	600	30	0.581 ± 0.05
	1200	30	0.657 ± 0.05
	All Doses	87	0.582 0.03
Both Breeds	0	63	0.546 ± 0.03)
	600	69	0.580 ± 0.03)*)**
	1200	68	0.690 ± 0.03))

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.09	1.59 N.S.
Between PMSG Doses (P)	2	0.36	6.05 **
B x P Interaction	2	0.03	0.48 N.S.
Error	194	0.06	

TABLE 3-13: EFFECT OF BREED AND DOSE OF PMSG ON THE DISTRIBUTION OF CORPORA LUTEA BETWEEN OVARIES

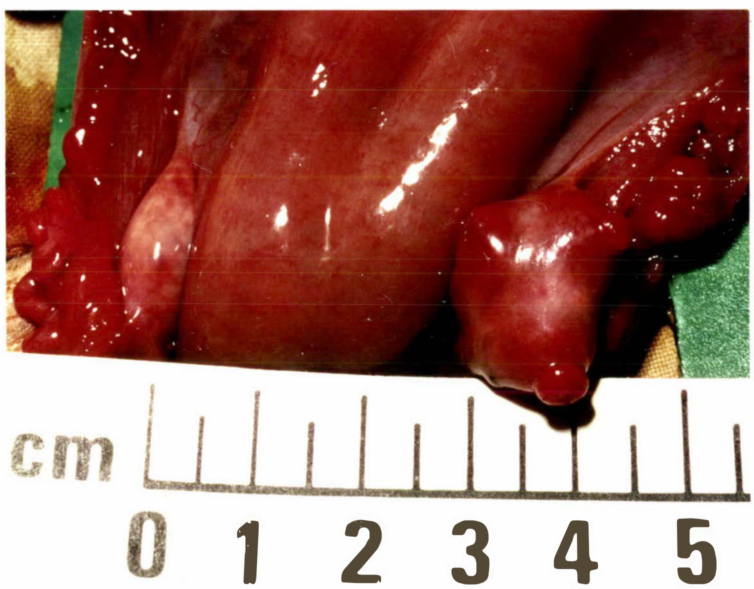
Classification:		No. of Corpora Lutea:			% Corpora Lutea on Right Ovary
Breed	Dose of PMSG (i.u.)	Left Ovary	Right Ovary	Total	
Border-Romney	0	19	33	52	63.5
	600	37	41	78	52.6
	1200	64	72	136	52.9
	All Doses	120	146	266	54.9
Romney	0	15	15	30	50.0
	600	19	31	50	62.0
	1200	29	48	77	62.3
	All Doses	63	94	157	59.9
Both Breeds	0	34	48	82	58.4
	600	56	72	128	56.3
	1200	93	120	213	56.3
	All Doses	183	240	423	56.7[A]

Test of Independence: G Statistic

	d.f.	G	Significance
Breed x Distribution Independence	1	1.002	N.S.
PMSG x Distribution Independence	2	0.14	N.S.
PMSG x Breed x Distribution Interaction	2	3.30	N.S.

[A] $Chi^2 = 3.84$ ($P < 0.05$)

Fig. 3-6:- EXPOSED GENITAL TRACT OF A 2 YEAR-OLD ROMNEY EWE 96 HOURS AFTER OESTRUS FOLLOWING TREATMENT WITH 1200 i.u. PMSG


cm
0 1 2 3 4 5

occur within a stimulated ewe. The left ovary is similar in size, shape and overall appearance to one that might occur in a non stimulated ewe.

6. Incidence of cystic ovaries

Cystic ovaries as described by Clarke (1973) occurred in 3 Romney and in 2 Border-Romney ewes treated with 1200 i.u. PMSG and in one Border-Romney ewe which received 600 i.u. PMSG.

7. Relationship between liveweight and ovulation response to PMSG

(a) Liveweight at PMSG injection

Although two treatment groups had significant partial regression coefficients (Border-Romney, low nutrition, 1200 i.u. PMSG and Romney, low nutrition, 1200 i.u.), one was positive while the second showed a negative relationship between number of corpora lutea and ewe liveweight (Table 3-14). The analysis showed that the 12 separate partial regression coefficients for each treatment group were non significantly different from a common regression across all treatments - which itself was found to be non significant (Table 3-14).

(b) Change in liveweight over the 2 months before PMSG injection

As with 'absolute' liveweight only 2 of the 12 partial regression coefficients in the present analysis were significant. Both groups were Romney ewes receiving 1200 i.u. PMSG although one was well fed while the other was on a low level of feeding. These significant effects were negative although generally there was a poor and inconsistent relationship between corpora lutea number and change in liveweight. The analysis of variance in Table 3-14 shows similar results to those of section(a). Thus the 12 partial regression coefficients were non significantly different from a common regression which itself was not significant (Table 3-14).

TABLE 3-14: EFFECT OF EWE LIVEWEIGHT AT PMSG INJECTION AND CHANGE OF LIVEWEIGHT OVER THE TWO MONTHS BEFORE INJECTION ON NUMBER OF OVULATIONS (Data square root transformed)

Treatment Group				Regression Coefficients: Ewe Liveweight		Regression Coefficients: Change in weight	
1.	Border-Romney	Low Nutrition	0 i.u.	0.01	N.S.	0.02	N.S.
2.	" "	" "	600 i.u.	-0.02	N.S.	0.001	N.S.
3.	" "	" "	1200 i.u.	0.04	**	-0.04	N.S.
4.	" "	High "	0 i.u.	0.01	N.S.	-0.001	N.S.
5.	" "	" "	600 i.u.	-0.01	N.S.	0.002	N.S.
6.	" "	" "	1200 i.u.	-0.01	N.S.	0.002	N.S.
7.	Romney	Low "	0 i.u.	0.003	N.S.	0.02	N.S.
8.	"	" "	600 i.u.	0.02	N.S.	0.002	N.S.
9.	"	" "	1200 i.u.	-0.04	*	-0.09	*
10.	"	High "	0 i.u.	-0.01	N.S.	-0.02	N.S.
11.	"	" "	600 i.u.	0.03	N.S.	0.02	N.S.
12.	"	" "	1200 i.u.	0.01	N.S.	-0.12	**
	Common across all Treatments			0.004	N.S.	-0.01	N.S.

Analysis of Variance

Source of Variation: Hypothesis[A]	d.f.	Ewe Liveweight: Sums of Squares	Ewe Liveweight: Mean Squares	Change in Liveweight: Sums of Squares	Change in Liveweight: Mean Squares
Ha	23	15.32		14.65	
Ho	12	13.44		13.47	
Difference	11	1.88	0.17 N.S.	1.18	0.11 N.S.
Error	176	17.37	0.10	18.04	0.10

[A] Ha $B_1 \neq B_2 \neq B_3 \ldots \neq B_{12} \neq B$

Ho $B_1 = B_2 = B_3 \ldots = B_{12} = B$

CHAPTER IV

STUDIES ON UTERINE CAPACITY

CHAPTER IV

STUDIES ON UTERINE CAPACITY

Pregnancy in Ewes

1. First mating

Table 4-1 summarises the effects of breed of ewe, dose of PMSG and level of nutrition on pregnancy rate. Only PMSG treatment had a significant effect ($P < 0.05$). Thus both 600 i.u. and 1200 i.u. PMSG reduced the proportion of ewes lambing to first mating compared to control ewes ($P < 0.05$) although there was no significant difference between these two dose levels.

2. All matings

The percentages of ewes lambing to all services and the influence of various treatments are summarised in Table 4-2. In this sample of ewes also, PMSG had the only significant effect ($P < 0.05$). Conception rates were reduced (by about 16%; $P < 0.05$) following gonadotrophin injection although the difference between groups receiving 600 i.u. and 1200 i.u. PMSG was not significant.

3. 'Returns' to first mating

(a) Conception rate

Ewes treated with PMSG that did not get pregnant to first mating were less likely ($P = 0.05$) to lamb to later matings compared to similar, untreated ewes (Table 4-3). All other factors studied in Table 4-3 were not significant although Romneys appeared to have better conception rates to later services than the crossbred ewes.

(b) Interval to next service

Table 4-4 shows the influences of breed of ewe and dose of PMSG

TABLE 4-1: THE INFLUENCE OF BREED OF EWE, DOSE OF PMSG AND LEVEL OF NUTRITION ON CONCEPTION RATE TO FIRST SERVICE

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes: Non-Pregnant	Pregnant	Total No. of Ewes	% of Ewes Pregnant
Border-Romney	0	11	25	36	69.4
	600	21	18	39	46.2
	1200	17	21	38	55.2
	All Doses	49	64	113	56.6
Romney	0	10	16	26	61.5
	600	17	13	30	43.3
	1200	14	16	30	53.3
	All Doses	41	45	86	52.3
Both Breeds	0	21	41	62	66.1
	600	38	31	69	44.9
	1200	31	37	68	54.4
Low Nutrition		45	55	100	45.0
High Nutrition		45	54	99	45.5

Test of Independence: G Statistic	d.f.	G
Breed x Conception Rate Independence	1	0.40 N.S.
PMSG x Conception Rate Independence	2	6.03 *
PMSG 0 i.u. v. (600 i.u. and 1200 i.u.)	1	4.80 *
600 i.u. v. 1200 i.u.	1	1.23 N.S.
Breed x PMSG x Conception Rate Interaction	2	0.10 N.S.
Nutrition x Conception Rate Independence	1	0.004 N.S.

TABLE 4-2: THE INFLUENCE OF BREED OF EWE, DOSE OF PMSG AND LEVEL OF NUTRITION ON CONCEPTION RATE TO ALL SERVICES

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes: Non-Pregnant	Pregnant	Total No. of Ewes	% of Ewes Pregnant
Border-Romney	0	2	34	36	94.4
	600	8	31	39	79.5
	1200	10	28	38	73.7
	All Doses	20	93	113	82.3
Romney	0	1	25	20	96.2
	600	6	24	30	80.0
	1200	4	26	30	86.7
	All Doses	11	75	86	87.2
Both Breeds	0	3	59	62	95.2
	600	14	55	69	79.7
	1200	14	54	68	79.4
Low Nutrition		17	83	100	83.0
High Nutrition		14	85	99	85.9

Test of Independence: G Statistic	d.f.	G
Breed x Conception Rate Independence	1	0.91 N.S.
PMSG x Conception Rate Independence	2	9.40 *
PMSG 0 i.u. v. (600 i.u. and 1200 i.u.)	1	9.40 *
600 i.u. v. 1200 i.u.	1	0.00
Breed x PMSG x Conception Rate Interaction	2	0.98 N.S.
Nutrition x Conception Rate Independence	1	0.31 N.S.

TABLE 4-3: EFFECT OF BREED OF EWE AND PMSG ON CONCEPTION RATE IN EWES RETURNING TO FIRST SERVICE

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes: Non-Pregnant	Pregnant	Total No. of Ewes	% of Ewes Pregnant
Border-Romney	0	2	9	11	81.8
	600	8	13	21	61.9
	1200	10	7	17	41.2
	All Doses	20	29	49	59.2
Romney	0	1	9	10	90.0
	600	6	11	17	64.7
	1200	4	10	14	71.4
	All Doses	11	30	41	73.2
Both Breeds	0	3	18	21	85.7
	600	14	24	38	69.2
	1200	14	17	31	54.8
	All Doses	31	59	90	65.6

Test of Independence: G Statistic	d.f.	G
Breed x Conception Rate Independence	1	1.96 N.S.
PMSG x Conception Rate Independence	2	5.98 N.S.
Breed x PMSG x Conception Rate Interaction	2	1.26 N.S.

TABLE 4-4: INFLUENCE OF BREED OF EWE AND PMSG ON LENGTH OF RETURN TO SERVICE IN EWES RETURNING TO FIRST SERVICE

Classification: Breed of Ewe	Dose of PMSG (i.u.)	Time to Return to Service: (days) 16-20	> 20	Total No. of Ewes	% Returning after 20 days
Border-Romney	0	10	1	11	9.1
	600	17	4	21	19.1
	1200	13	4	17	23.5
	All Doses	40	9	49	18.4
Romney	0	9	1	10	10.0
	600	10	7	17	41.2
	1200	10	4	14	28.6
	All Doses	29	12	41	29.3
Both Breeds	0	19	2	21	9.5
	600	27	11	38	29.0
	1200	23	8	31	25.8
	All Doses	69	21	90	23.3

Test of Independence: G Statistic	d.f.	G
Breed x PMSG x Distribution Independence	7	5.85 N.S.

on the length of time taken for ewes to return to first service. Although none of the effects were significant, PMSG appeared to increase the proportion of ewes returning after 20 days (26-29%) compared to untreated ewes (10%).

Distribution of Lambs Born

1. First mating

Table 4-5 shows the effects of breed of ewe, dose of PMSG and level of nutrition on the distribution of lambs born to all mated ewes and on litter size. In both cases, dose of PMSG was the only effect which was significant ($P < 0.01$). Treatment with gonadotrophin increased numbers of lambs born both to ewes mated ($P < 0.01$) and to ewes lambing ($P < 0.01$). The differences between 600 i.u. and 1200 i.u. PMSG, however, were not significant. Among control ewes there were fewer with twins and none with triplets compared with the treated ewes ($P < 0.01$).

Although the breed effect was not significant the Border-Romney ewes showed an advantage of 10.6% and 7.8% respectively for both of the distributions shown in Table 4-5. Similarly, crossbred ewes had greater litter sizes in response to the higher dose of PMSG than did the Romneys (195.2% v. 168.8%) although the Breed x PMSG interaction did not reach statistical significance.

2. All matings

Table 4-6 summarises information for the various treatments on the distribution of lambs born to all ewes mated and on litter size. PMSG provided the only significant effects in both distributions ($P < 0.01$) increasing lambs born to ewes mated ($P < 0.01$) and to ewes lambing ($P < 0.01$).

TABLE 4-5: EFFECT OF BREED OF EWE, DOSE OF PMSG AND LEVEL OF NUTRITION ON THE DISTRIBUTION OF LAMBS BORN TO FIRST SERVICE

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes Classified According to Lambing Performance — No. of Lambs: 0	1	2	3	Total No. of Ewes	% Lambs Born to: Ewes Mated	Ewes Lambing
Border-Romney	0	11	23	2	0	36	75.0	108.0
	600	21	10	6	2	39	71.8	155.5
	1200	17	6	10	5	38	107.9	195.2
	All Doses	49	39	18	7	113	85.0	150.0
Romney	0	10	15	1	0	26	65.4	106.3
	600	17	7	5	1	30	66.7	153.9
	1200	14	7	7	2	30	90.0	168.8
	All Doses	41	29	13	3	86	74.4	142.2
	0	21	38	3	0	62	71.0	107.3
	600	38	17	11	3	69	69.6	154.8
	1200	31	13	17	7	68	100.0	183.8
Low Nutrition		45	34	17	4	100	80.0	145.5
High Nutrition		45	34	14	6	99	80.8	148.2

Test of Independence: G Statistic	Ewes Mated d.f.	Ewes Mated G	Ewes Lambing d.f.	Ewes Lambing G
Breed x Distribution Independence	1	1.00 N.S.	2	0.60 N.S.
PMSG x Distribution Independence	6	40.29 **	4	34.26 **
0 i.u. v. (600 i.u. and 1200 i.u.)	3	36.11 **	2	31.31 **
600 i.u. v. 1200 i.u.	3	4.18 N.S.	2	2.95 N.S.
Breed x PMSG x Distribution Interaction	6	0.95 N.S.	4	0.86 N.S.
Nutrition x Distribution Independence	3	0.68 N.S.	2	0.68 N.S.

TABLE 4-6: EFFECT OF BREED OF EWE, DOSE OF PMSG AND LEVEL OF NUTRITION ON THE DISTRIBUTION OF LAMBS BORN TO ALL SERVICES

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes Classified According to Lambing Performance — No. of Lambs: 0	1	2	3	Total No. of Ewes	% Lambs Born to: Ewes Mated	Ewes Lambing
Border-Romney	0	2	30	4	0	36	105.7	111.8
	600	8	21	8	2	39	110.3	138.7
	1200	10	13	10	5	38	126.3	171.4
	All Doses	20	64	22	7	113	114.2	138.7
Romney	0	1	22	3	0	26	107.7	112.0
	600	6	18	5	1	30	103.3	129.2
	1200	4	17	7	2	30	123.3	142.3
	All Doses	11	57	15	3	86	111.6	128.0
Both Breeds	0	3	52	7	0	62	106.5	111.9
	600	14	39	13	3	69	107.3	134.5
	1200	14	30	17	7	68	125.0	157.4
Low Nutrition		17	61	18	4	100	109.0	131.3
High Nutrition		14	60	19	6	99	117.2	136.5

Test of Independence: G Statistic	Ewes Mated d.f.	Ewes Mated G	Ewes Lambing d.f.	Ewes Lambing G
Breed x Distribution Independence	3	2.36 N.S.	2	1.45 N.S.
PMSG x Distribution Independence	6	29.30 **	4	19.90 **
0 i.u. v. (600 i.u. and 1200 i.u.)	3	25.95 **	2	16.55 **
600 i.u. v. 1200 i.u.	3	3.35 N.S.	2	3.35 N.S.
Breed x PMSG x Distribution Interaction	3	0.72 N.S.	3	1.25 N.S.
Nutrition x Distribution Independence	6	2.22 N.S.	2	0.83 N.S.

Although non significant, the Border-Romney ewes showed similar advantages over the Romneys as found when lambing to first mating was considered in 1.

Numbers of Corpora Lutea and Lambs Born

1. All ewes

Table 4-7 presents a summary of counts of corpora lutea and the fate of potential lambs. The effects of ovulation rate on the proportion of lambs born per number of corpora lutea for ewes lambing and for ewes mated are shown in Table 4-8. 'Ovum wastage' (or the proportion of ova shed not represented by lambs born) increased with numbers of corpora lutea ($P < 0.001$) when only ewes lambing were considered ('partial ovum wastage') although the effect was less marked when all ewes mated were considered.

Similarly, increasing PMSG dosage reduced the proportion cf corpora lutea represented by lambs born both for ewes lambing ($P < 0.001$) and for ewes mated ($P < 0.05$). These effects are summarised in Table 4-9 and shown diagramatically in Fig. 4-1. Of the ewes pregnant to first mating, Romney ewes (doses of PMSG pooled) had proportionately more lambs born per corpora lutea number ($P < 0.05$) than the crossbreds. When all ewes mated were considered, this advantage was reduced.

2. Ewes with one or two ovulations

Ewes shedding one or two ova were studied separately to investigate the effects of breed of ewe, dose of PMSG and numbers of corpora lutea on ova wastage. This was done to reduce the bias that occurred when all ewes were included since ewes not treated with gonadotrophin did not have more than two lambs.

TABLE 4-7: SUMMARY OF FATE OF 'POTENTIAL LAMBS' IN EWES RELATIVE TO NUMBERS OF CORPORA LUTEA AT LAPAROTOMY

Observation	No. of Corpora Lutea per Ewe:					
	1	2	3	4	5	6+
No. of Ewes	75	73	25	12	8	6
Ewes Pregnant (%)	49	56	68	42	50	83
Ewes Pregnant to First Service						
No. of ovulations	37	82	51	20	20	33
No. of Lambs Born	37	58	36	11	9	9
Litter Size (Mean)	1	1.41	2.12	2.20	2.25	1.80
Litter Size (Range)	-	1-2	1-3	1-3	1-3	1-3
Missing Ova (%)	-	29	29	45	55	73
Ewes with Missing Ova (%)	-	77	72	100	100	100

TABLE 4-8: EFFECT OF NUMBERS OF CORPORA LUTEA AT LAPAROTOMY ON THE PROPORTION OF 'POTENTIAL LAMBS' REPRESENTED AT TERM BY LAMBS BORN

No. of Corpora Lutea	Ewes Lambing Only		All Ewes Mated	
	No. of Ewes	Lambs Born/CL. No.[A] (Mean ± S.E.)	No. of Ewes	Lambs Born/CL. No. (Mean ± S.E.)
1	37	1.00 ± 0.03	75	0.49 ± 0.05
2	41	0.71 ± 0.03	73	0.40 ± 0.05
3	17	0.71 ± 0.05	25	0.48 ± 0.09
4	5	0.55 ± 0.09	12	0.23 ± 0.12
5-8	9	0.34 ± 0.07	14	0.22 ± 0.11

Analysis of Variance

Source of Variation	Ewes Lambing Only		All Ewes Mated	
	d.f.	Mean Squares	d.f.	Mean Squares
Between Numbers of Corpora Lutea	4	1.01 ***	4	0.38 -
Error	104	0.04	194	0.18

[A] Proportion of Corpora Lutea represented by lambs born

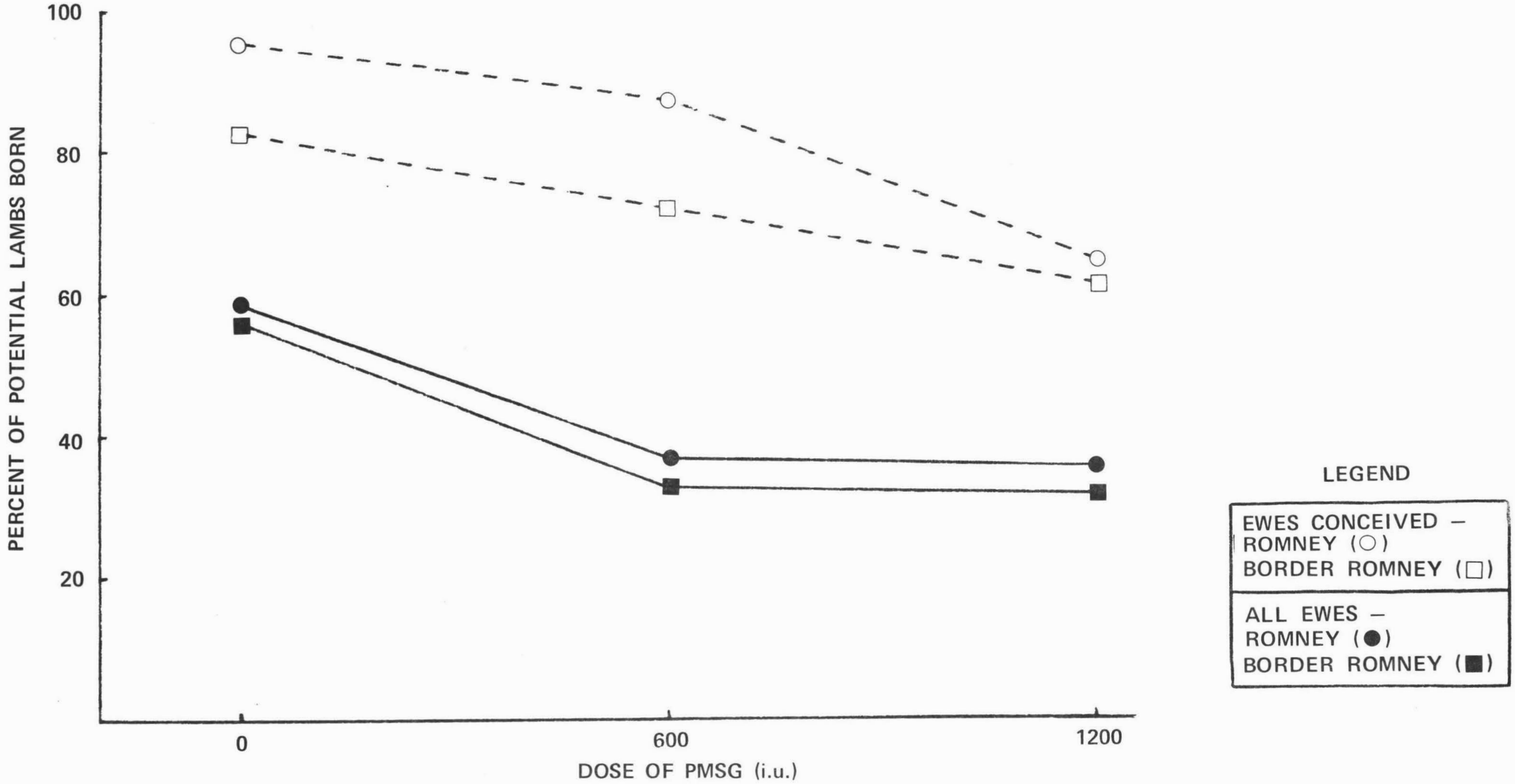
TABLE 4-9: EFFECT OF BREED OF EWE AND DOSE OF PMSG ON THE PROPORTION OF CORPORA LUTEA REPRESENTED BY LAMBS BORN

Classification:		Ewes Lambing Only		All Ewes Mated	
Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes	Lambs Born/CL.No. (Mean ± S.E.)	No. of Ewes	Lambs Born/CL.No. (Mean ± S.E.)
Border-Romney	0	25	0.84 ± 0.03	36	0.58 ± 0.07
	600	18	0.72 ± 0.04	39	0.33 ± 0.07
	1200	21	0.60 ± 0.03	38	0.33 ± 0.07
	All Doses	64	0.72 ± 0.02	113	0.42 ± 0.04
Romney	0	16	0.97 ± 0.04	26	0.60 ± 0.08
	600	13	0.87 ± 0.07	30	0.38 ± 0.08
	1200	16	0.65 ± 0.04	30	0.35 ± 0.08
	All Doses	45	0.83 ± 0.02	86	0.44 ± 0.05
Both Breeds	0	41	0.90 ± 0.03	62	0.59 ± 0.05
	600	31	0.80 ± 0.03	69	0.36 ± 0.05
	1200	37	0.63 ± 0.03	68	0.34 ± 0.05

Analysis of Variance

Source of Variation	Ewes Lambing Only d.f.	Ewes Lambing Only Mean Squares	All Ewes Mated d.f.	All Ewes Mated Mean Squares
Between Breeds (B)	1	0.32 *	1	0.03 N.S.
Between PMSG Doses (P)	2	0.74 ***	2	1.22 *
B x P Interaction	2	0.02 N.S.	2	0.01 N.S.
Error	103	0.06	193	0.18

FIGURE 4–1:–
PERCENTAGE OF POTENTIAL LAMBS BORN TO FIRST SERVICE RELATIVE TO THE DOSE OF PMSG



(a) Single ovulations

Table 4-10 shows the effects of three factors on conception rate and ovum wastage. In this sample, Border-Romney ewes had a 9.3% greater conception rate than Romneys. Crossbred ewes had a similar advantage for ovum wastage but these effects were not significant. Treatment with PMSG reduced ($P < 0.01$) conception rate and increased ovum wastage ($P < 0.01$).

(b) Single- versus double-ovulations

Tables 4-10 and 4-11 summarise conception, lambing and ovum wastage information for ewes shedding one or two ova respectively. More ewes with two corpora lutea conceived to first service ($G = 0.69$) than with one corpus luteum (56.2% v. 49.3%) although this difference was not significant. Similarly, the proportion of ova not represented by lambs was greater for twin ovulating ewes (60.3% v. 50.7%) ($G = 55.1$; $P < 0.01$). There were significant interactions between corpora lutea number and PMSG dose for both conception rate ($G = 8.19$; $P < 0.05$) and ovum wastage ($G = 6.76$; $P < 0.05$). Thus while in ewes with one corpus luteum, increased PMSG dosage reduced conception rates and increased ovum wastage, no such effect was apparent when two corpora lutea per ewe were observed.

(c) Double ovulations

Unilateral twin ovulations occurred more frequently in pregnant Border-Romney ewes than in Romneys (57.5% v. 38.5%; $P < 0.1$). Ewes with two corpora lutea present unilaterally were less likely to conceive than when twin ovulations were bilateral (48.7% v. 63.9%), however, this effect was not significant (Table 4-11).

TABLE 4-10: EFFECT OF BREED OF EWE AND DOSE OF PMSG ON CONCEPTION RATE TO FIRST MATING AND PERCENT CORPORA LUTEA NOT REPRESENTED BY LAMBS BORN IN EWES SHEDDING ONE OVUM

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes	% of Ewes Pregnant	% Corpora Lutea not Represented by Lambs Born
Border-Romney	0	20	75.0	25.0
	600	8	12.5	87.5
	1200	3	33.3	66.7
	All Doses	31	54.8	45.2
Romney	0	22	63.6	36.4
	600	15	33.3	66.7
	1200	7	14.3	85.7
	All Doses	44	45.5	54.6
Both Breeds	0	42	69.1	31.0
	600	23	26.1	73.9
	1200	10	20.0	80.0
Total		75	49.3	50.7

Test of Independence: G Statistic	d.f.	G
Breed x Distribution Independence	1	0.64 N.S.
PMSG x Distribution Independence	2	15.58 **
Breed x PMSG x Distribution Interaction	2	21.72 **

TABLE 4-11: EFFECT OF BREED OF EWE, DOSE OF PMSG AND TYPE OF TWIN OVULATION ON CONCEPTION RATE, 'OVUM WASTAGE' AND LAMBS BORN FOR EWES WITH TWO CORPORA LUTEA

Classification: Dose of PMSG (i.u.)	Type of Ovulation[A]	No. of Ewes	% of Ewes Pregnant	% C.L. Not Represented By Lambs Born[B]	No. of Lambs Born Per: Ewes Mated	Ewes Lambing
0	1	8	62.5	62.5(40.0)	0.75	1.20
	2	12	58.3	62.5(35.7)	0.75	1.29
	Both types	20	60.0	62.5(37.5)	0.75	1.25
600	1	19	42.1	68.4(25.0	0.63	1.50
	2	16	62.5	53.1(25.0)	0.94	1.50
	Both types	35	51.4	61.4(25.0)	0.77	1.50
1200	1	10	50.0	75.0(50.0)	0.50	1.00
	2	8	75.0	31.3(8.3)	1.38	1.84
	Both types	18	61.1	55.6(27.3)	0.89	1.45
All Doses						
Border-Romney	1	27	51.9	66.7(35.7)	0.67	1.29
	2	20	60.0	60.0(33.3)	0.80	1.33
	Both types	47	55.3	63.8(34.6)	0.72	1.31
Romney	1	10	40.0	75.0(37.5)	0.50	1.25
	2	16	68.8	40.6(13.6)	1.19	1.73
	Both types	26	57.7	53.9(20.0)	0.92	1.60
Both Breeds	1	37	48.7	68.9(36.1)	0.62	1.28
	2	36	63.9	51.4(23.9)	0.97	1.48
Total		73	56.2	60.3(29.3)	0.79	1.42

Test of Independence: G Statistic

	Conception Rate d.f.	G	Corpora Lutea Not Represented By Lambs d.f.	G	Litter Size d.f.	G
Breed x Distribution Independence	1	0.04 N.S.	2	3.39 N.S.	1	3.23 -
Type of Ovulation x Distribution Independence	1	1.73 N.S.	2	4.25 N.S.	1	2.52 N.S.
PMSG x Distribution Independence	2	0.62 N.S.	4	2.65 N.S.	2	2.03 N.S.
Breed x Type of Ovulation Independence	1	2.43 N.S.			1	2.82 -
PMSG x Type of Ovulation Independence	2	1.27 N.S.				
Breed x Type of Ovulation x Distribution Interaction	1	0.67 N.S.	2	1.02 N.S.	1	0.47 N.S.
PMSG x Type of Ovulation x Distribution Interaction	2	0.96 N.S.	4	8.30 -	2	7.34 *
Breed x PMSG x Distribution Interaction	2	2.00 N.S.	4	2.24 N.S.	2	0.36 N.S.

[A] Type of ovulation 1 - unilateral twin 2 - bilateral twin

[B] Figures in brackets refer to pregnant ewes only (partial ovum wastage)

PMSG treatment caused a greater incidence of unilateral twin ovulations than was the case for untreated ewes (no PMSG - 40%; 600 i.u. PMSG - 54%; 1200 i.u. PMSG - 56%). Conception rates were reduced in PMSG treated ewes with unilateral twin ovulations although this effect was not apparent in control ewes or when ovulations were bilateral (Table 4-11).

Smaller litter sizes resulted from unilateral twin ovulations compared to bilateral ovulations (1.3 v. 1.5). Overall, the litter size was greatest in Romneys (1.6 v. 1.3; $0.05 < P < 0.1$) and this was largely due to a greater litter size in Romneys with bilateral ovulations compared to similar crossbred ewes (1.7 v. 1.3). Of the ewes losing ova (Table 4-12), 32/56 lost both while 24/56 lost only one ovum ($Chi^2 = 1.14$; N.S.) while of the 41 ewes pregnant, 24 (58.5%) had only one lamb born. Many of the comparisons mentioned did not reach statistical significance, but this may have been due to the limited sample size available for analysis.

(d) Inequality of function of the right and left ovaries and influences on apparent egg loss (data for single and double ovulating ewes)

Of the 75 single ovulations, 52% occurred on the right ovary and there was no relationship between site of ovulation and ovum wastage.

Table 4-12 shows the distribution of ovulations between ovaries and apparent ovum wastage for ewes with two corpora lutea. Thus 58.9% of all ovulations from 73 ewes occurred in the right ovary, i.e. 25 double ovulations from the right ovary and 36 bilateral twin ovulations.

TABLE 4-12: EFFECT OF BREED OF EWE AND DOSE OF PMSG ON SITE OF OVULATION AND OVUM WASTAGE IN DOUBLE OVULATING EWES

Classification: Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes Shedding Ova: Unilateral Left	Unilateral Right	Bilateral	Total No. of Ewes	Corpora Lutea Right Ovary (%)
Border-Romney	0	1	6	9	16	65.6
	600	5	10	9	24	50.4
	1200	3	2	2	7	42.9
	All Doses	9	18	20	47	59.6
	0	0	1	3	4	62.5
	600	1	3	7	11	59.1
	1200	2	3	6	11	54.4
	All Doses	3	7	16	26	57.7
Total		12	25	36	73	58.9

$Chi^2 = 2.32$, N.S.

No. of Ova Lost	No. of Ewes Apparently Losing Ova From: Left Ovary 1	Left Ovary 2	Right Ovary 1	Right Ovary 2	Both Ovaries 1	Both Ovaries 2	Total 1	Total 2
Border-Romney	3	3	7	10	8	8	18	21
Ova Lost (%)	50.0		75.0		60.0		63.8	
Romney	1	2	2	4	3	5	6	11
Ova Lost (%)	83.5		71.4		40.6		53.9	
Both Breeds	4	5	9	14	11	13	24	32
Ova Lost (%)	58.3		74.0		51.4		60.3[A]	

[A] $Chi^2 = 6.53$; $P < 0.05$

Combining the single ovulations on the right ovary (39/75) with the unilateral twin ovulations that occurred on the same side (25/73) means that 89 of the 148 unilateral (single plus twin) ovulations (60.1%) occurred in the right ovary. This effect was, however, not significant.

The unilateral twin ovulations from the right ovary caused greater ovum wastage than for the left which was in turn greater than when ovulations were bilateral ($P < 0.05$).

Weight of Lamb Born per Ewe

The effects of breed of ewe, dose of PMSG and litter size on weight of lamb born per ewe were studied using a selected comparison method outlined in Chapter II. Data for two ewes (one Border-Romney, 1200 i.u. PMSG; one Romney, 0 i.u. PMSG) were not included in the analysis since their lambs were not weighed.

1. PMSG effect

Selected comparisons were made within litter size groups since control ewes did not lamb triplets.

(a) Single- and twin-bearing ewes

Table 4-13 summarises the effects of breed of ewe, dose of PMSG and litter size on weight of lamb born per ewe. Although an increasing dosage of PMSG reduced the mean weight of lamb born, the effect was not significant. In this sample of ewes, however, both the Border-Romney ewes ($P < 0.05$) and ewes lambing singles ($P < 0.001$) had heavier weights of lamb born than Romney or twin-bearing ewes respectively.

TABLE 4-13: EFFECTS OF BREED OF EWE, PMSG AND LITTER SIZE ON WEIGHT OF LAMB BORN PER EWE (Data for ewes lambing singles and twins)

Classification	No. of Ewes	Weight of Lamb Born (kg) (Mean)
Breed of Ewe		
Border-Romney	56	6.30
Romney	41	5.58
Dose of PMSG (i.u.)		
0	40	6.12
600	28	6.02
1200	29	5.69
Litter Size		
Single	67	4.50
Twin	30	7.38

Analysis

Source of Variation	Effect($\hat{B}$)	S.E.[A]	t[B]
Between Breeds (B)	0.72	0.34	2.13 *
Between PMSG Doses (linear) (Pl)	-0.43	0.45	-0.97 N.S.
Between PMSG Doses (quadratic((Pq)	-0.11	0.33	-0.34 N.S.
Between Litter Sizes (L)	2.88	0.33	8.55 ***
B x Pl Interaction	-0.02	0.45	-0.05 N.S.
B x Pq Interaction	-0.10	0.33	-0.32 N.S.
B x P Interaction	0.44	0.34	1.13 N.S.

[A] Error Mean Square = 1.47

[B] d.f. = 96

(b) Triplet-bearing ewes

Increased doses of gonadotrophin reduced the mean weights of lamb born per ewe. Romneys had lighter mean weights of lamb born than crossbred ewes (Table 4-14). These results were not statistically significant probably because of the small numbers of ewes available for analysis.

2. Breed of ewe and litter size effects

Table 4-15 shows the effects of breed of ewe and litter size on weight of lamb born per ewe. Border-Romney ewes had heavier weight of lamb born ($P<0.01$) than the Romneys. Similarly, litter size had significant linear ($P<0.001$) and negative quadratic ($P<0.001$) effects on the variable. A Student-Newman-Keuls test showed that ewes producing triplets had greater weights of lamb born per ewe than ewes with twins ($P<0.05$) or with singles ($P<0.01$). Single-bearing ewes produced a lesser weight of lamb born than ewes lambing twins ($P<0.01$). There were no significant interactions between the main effects.

TABLE 4-14: EFFECTS OF BREED OF EWE AND DOSE OF PMSG ON WEIGHT OF LAMB BORN PER EWE (Data for triplet-lambing ewes

Classification:

Breed of Ewe	Dose of PMSG (i.u.)	No. of Ewes	Weight of Lamb Born (kg) (Mean)
Border-Romney	600	2	9.45
	1200	5	8.32
	Both Doses	7	8.89
Romney	600	1	8.30
	1200	2	7.05
	Both Doses	3	7.68

Analysis

Source of Variation	Effect ($\hat{B}$)	S.E.[A]	t[B]
Between Breeds (B)	1.21	0.89	1.35 N.S.
Between PMSG Doses (P)	1.19	0.89	1.32 N.S.
B x P Interaction	0.06	0.89	0.07 N.S.

[A] Error Mean Square = 1.47

[B] d.f. = 9

TABLE 4-15: EFFECT OF BREED OF EWE AND LITTER SIZE ON WEIGHT OF LAMB BORN PER EWE ACROSS ALL DOSES OF PMSG

Classification: Breed of Ewe	Litter Size	No. of Ewes	Weight of Lamb Born (kg) (Mean)
Border-Romney	Single	39	4.64
	Twin	17	7.96
	Triplet	7	8.89
	All Litter Sizes	63	7.16
Romney	Single	28	4.36
	Twin	13	6.80
	Triplet	3	7.68
	All Litter Sizes	44	6.28
Both Breeds	Single	67	4.50 } ** (Single vs Twin); ** (Single vs Triplet)
	Twin	30	7.38 } * (Twin vs Triplet)
	Triplet	10	8.28

Analysis

Source of Variation	Effect ($\hat{B}$)	S.E.[A]	t[B]
Between Breeds (B)	0.88	0.33	2.67 **
Between Litter Sizes (linear)(Ll)	3.78	0.44	8.54 ***
Between Litter Sizes (quadratic)(Lq)	-0.99	0.32	-3.16 ***
B x Rl Interaction	0.47	0.44	1.C5 N.S.
B x Rq Interaction	-0.42	0.32	-1.34 N.S.

[A] Error Mean Square = 1.47

[B] d.f. = 106

CHAPTER V

PROGESTERONE CONCENTRATION IN PERIPHERAL BLOOD

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PROGESTERONE CONCENTRATION IN PERIPHERAL BLOOD

Ewes in Early Pregnancy (Days 20, 40, 60)

1. Plasma progesterone and numbers of corpora lutea

Table 5-1 summarises the effects of breed and number of corpora lutea on the progesterone concentration in ewes bled on days 20, 40 and 60 of pregnancy. There were no significant interactions between any of the main effects.

Border-Romney ewes had significantly lower progesterone concentrations than Romneys ($P < 0.001$).

Progesterone concentration significantly increased with advancement of pregnancy ($P < 0.001$), there being different mean concentrations at each sampling ($P < 0.01$). A rise in the number of corpora lutea from 1 to 6 was associated with a consistent increase in progesterone levels ($P < 0.001$). The difference in concentration when studied for ewes with 1 or 2 corpora lutea only was significant ($P < 0.01$).

The regression of pre-experimental ewe liveweight (pooled for both breeds) was fitted to the model summarised in Table 5-1 after separate regressions calculated for each treatment group proved non significantly different from a common regression (see Chapter II). The resulting covariance model is summarised in Table 5-2. The amount of variation explained by components of this model ($r^2 = 0.70$) was very similar to that for the analysis of variance model shown in Table 5-1 ($r^2 = 0.68$). The breed effect was greatly reduced when the regression of pre-experimental liveweight on plasma progesterone

TABLE 5-1: EFFECT OF BREED, DAY OF BLEEDING AND NUMBER OF CORPORA LUTEA ON PLASMA PROGESTERONE CONCENTRATION IN EARLY PREGNANCY

Classification	No. of Observations	Plasma Progesterone Concentration	
		Log_e Mean ± S.E.	Antilog (ng/ml)
Breed of Ewe			
Border-Romney	123	1.64 ± 0.03	5.17
Romney	81	1.83 ± 0.04	6.24
Day of Bleeding			
20	68	1.47 ± 0.04 a[A]	4.34
40	68	1.67 ± 0.04 b	5.31
60	68	2.07 ± 0.04 c	7.95
Corpora Lutea No.			
1	54	1.19 ± 0.04) **	3.29
2	63	1.45 ± 0.04)	4.26
3	42	1.68 ± 0.05	5.37
4	18	1.86 ± 0.08	6.42
5	12	2.01 ± 0.09	7.47
6	15	2.23 ± 0.08	9.30

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	1.05	10.02 ***
Between Days (D)	2	3.71	35.57 ***
Between Corpora Lutea Nos. (C)	5	3.32	31.85 ***
B x D Interaction	2	0.02	0.19 N.S.
B x C Interaction	5	0.07	0.72 N.S.
D x C Interaction	10	0.07	0.63 N.S.
B x D x C Interaction	10	0.13	1.25 N.S.
Error	168	0.10	

[A] Means followed by different subscripts are significantly different ($P < 0.01$)

TABLE 5-2: EFFECT OF BREED, DAY OF BLEEDING AND NUMBER OF CORPORA LUTEA ON PLASMA PROGESTERONE CONCENTRATION AFTER COVARIANCE OF EWE LIVEWEIGHT

Classification	No. of Observations	Plasma Progesterone Concentration: $\log_e$ Mean $\pm$ S.E.	Plasma Progesterone Concentration: Antilog (ng/ml)
Breed of Ewe			
Border-Romney	123	1.68 $\pm$ 0.04	5.37
Romney	81	1.78 $\pm$ 0.05	5.93
Day of Bleeding			
20	68	1.46 $\pm$ 0.05	4.31
40	68	1.67 $\pm$ 0.05	5.31
60	68	2.06 $\pm$ 0.05	7.43
Corpora Lutea No.			
1	54	1.15 $\pm$ 0.05	3.16
2	63	1.47 $\pm$ 0.04	4.34
3	42	1.67 $\pm$ 0.05	5.31
4	18	1.87 $\pm$ 0.07	6.49
5	12	2.00 $\pm$ 0.03	7.39
6	15	2.22 $\pm$ 0.10	9.21

Analysis of Covariance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.38	3.79 -
Between Days (D)	2	3.72	37.37 ***
Between Corpora Lutea Nos. (C)	5	3.47	35.02 ***
B x D Interaction	2	0.02	0.19 N.S.
B x C Interaction	5	0.10	1.04 N.S.
D x C Interaction	10	0.07	0.67 N.S.
B x D x C Interaction	10	0.13	1.32 N.S.
Regression of Ewe Liveweight[A] on $\log_e$ Progesterone Concentration	1	0.96	9.69 *
Error	167	0.10	

[A] Pre-experimental and pooled over both breeds ($\hat{B}$ = -0.016) concentration was included in the model (Table 5-2) although the difference between breeds still approached significance ($P < 0.1$).

2. Prediction of numbers of corpora lutea

The analyses of variance (Table 5-1) and covariance (Table 5-2) were used to calculate the estimated blood progesterone means which are summarised in Table 5-3. These means were used to calculate discrimination points for each corpora lutea number grouping within each breed and day of bleeding group (Appendix VI). The number of corpora lutea available were logically grouped in four different ways and ewes were classified using discrimination points according to individual $\log_e$ progesterone concentrations. Table 5-4 shows the success rates of prediction for each breed, day of bleeding, and corpora lutea-classification subgroup using either the analysis of variance (AOV) or analysis of covariance (ACOV) model.

There was little difference between the two models in the accuracy of prediction. This was expected since the difference in variation explained was only 2% as noted in 1 above.

3. Plasma progesterone and litter size

Litter size was related to progesterone concentration ($P < 0.001$) although the variation explained ($r^2 = 0.49$) by the components of the model summarised in Table 5-5 was much less than that when numbers of corpora lutea effects were studied. A comparison among means revealed significant increases ($P < 0.01$) in progesterone concentration of ewes as litter size increased from singles to triplets.

Introducing pre-experimental ewe liveweight as a covariate (Table 5-6) slightly increased the amount of variation explained ($r^2 = 0.50$).

TABLE 5-3: PROGESTERONE CONCENTRATION OF EWES EARLY IN PREGNANCY, CLASSIFIED RELATIVE TO BREED, DAY OF BLEEDING, AND NUMBER OF CORPORA LUTEA

Corpora Lutea No.	No. of Ewes	S.E. AOV[A]	S.E. ACOV[B]	Day of Bleeding 20 — Plasma Progesterone Concentration † (Log_e Mean) AOV	20 ACOV	40 AOV	40 ACOV	60 AOV	60 ACOV
				Romney					
1	8	0.11	0.12	0.99	0.89	1.09	0.99	1.64	1.51
2	9	0.11	0.11	1.45	1.43	1.46	1.44	1.80	1.78
3	4	0.16	0.16	1.27	1.25	1.72	1.69	2.23	2.20
4	3	0.19	0.18	1.69	1.71	1.95	1.97	2.21	2.23
5	2	0.23	0.22	1.77	1.67	1.97	1.88	2.39	2.29
6	1			2.36	2.28	2.30	2.31	2.66	2.59
				Border-Romney					
1	10	0.10	0.10	0.92	0.93	0.98	1.00	1.54	1.55
2	12	0.09	0.09	0.88	0.94	1.25	1.31	1.84	1.90
3	10	0.10	0.10	1.34	1.35	1.48	1.49	2.03	2.04
4	3	0.19	0.18	1.49	1.49	1.84	1.84	1.99	1.99
5	2	0.23	0.22	1.93	2.02	1.91	1.93	2.07	2.16
6	4	0.16	0.16	1.52	1.56	2.06	2.09	2.49	2.52

† Means and standard errors calculated from:

A - the analysis of variance model shown in Table 5-1

B - the analysis of covariance model shown in Table 5-2

TABLE 5-4: ACCURACY OF PREDICTION OF CORPORA LUTEA AND LITTER SIZE GROUP FROM PLASMA PROGESTERONE CONCENTRATION

Grouping	Day of Bleeding							
	20		40		60		All Days	
	AOV[A]	ACOV[B]	AOV	ACOV	AOV	ACOV	AOV	ACOV
Corpora Lutea								
Romney								
1, 2, 3, 4, 5, 6	29.6[C]	40.7	48.1	44.4	40.7	37.0	39.5	40.7
1, 2-3, 4-6	51.9	59.3	77.8	70.0	63.0	59.3	64.2	63.0
1-2, 3-6	66.7	66.7	81.5	81.5	81.5	85.2	76.5	77.8
1, 2-6	74.1	81.5	81.5	85.2	77.8	74.1	77.8	80.3
Border-Romney								
1, 2, 3, 4, 5, 6	29.3	31.7	36.6	39.0	34.2	34.2	33.3	35.0
1, 2-3, 4-6	53.7	51.2	61.0	65.9	48.8	48.8	54.5	55.3
1-2, 3-6	75.6	78.1	70.7	75.6	73.2	68.3	73.2	74.0
1, 2-6	70.7	68.3	75.6	75.6	78.0	78.1	74.8	74.0
Litter Size								
Romney								
1, 2, 3	59.3	48.2	70.4	66.7	44.4	48.2	58.0	54.3
1, 2-3	81.5	70.4	81.5	85.2	59.3	59.3	74.1	71.6
Border-Romney								
1, 2, 3	46.0	54.1	46.0	56.8	64.9	64.9	52.3	58.6
1, 2-3	70.3	73.0	64.9	73.0	75.7	78.4	70.3	74.8

[A] using the analysis of variance model shown in Table 5-1 and Table 5-5

[B] using the analysis of covariance model shown in Table 5-2 and Table 5-6

[C] percentage accuracy

TABLE 5-5: EFFECT OF BREED, DAY OF BLEEDING AND LITTER SIZE ON PLASMA PROGESTERONE CONCENTRATION IN EARLY PREGNANCY

Classification	No. of Observations	Plasma Progesterone Concentration	
		Log_e Mean ± S.E.	Antilog (ng/ml)
Breed of Ewe			
Border-Romney	111	1.57 ± 0.04	4.81
Romney	81	1.72 ± 0.04	5.57
Day of Bleeding			
20	64	1.33 ± 0.05 a[A]	3.78
40	64	1.57 ± 0.05 b	4.81
60	64	2.03 ± 0.05 c	7.62
Litter Size			
1	111	1.35 ± 0.04 a	3.87
2	60	1.56 ± 0.05 b	4.75
3	21	1.85 ± 0.08 c	6.34

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.65	4.32 *
Between Days (D)	2	5.11	33.98 ***
Between Litter Sizes (L)	2	3.86	25.64 ***
B x D Interaction	2	0.18	1.22 N.S.
B x L Interaction	2	0.002	0.01 N.S.
D x L Interaction	4	0.08	0.50 N.S.
B x D x L Interaction	4	0.03	0.22 N.S.
Error	174	0.15	

[A] Means with different subscripts (within classifications) are significantly different ($P < 0.01$)

TABLE 5-6: EFFECT OF BREED, DAY OF BLEEDING AND LITTER SIZE ON PLASMA PROGESTERONE LEVELS IN EARLY PREGNANCY AFTER COVARIANCE OF EWE LIVEWEIGHT

Classification	No. of Observations	Plasma Progesterone Concentration	
		Log_e Mean ± S.E.	Antilog (ng/ml)
Breed of Ewe			
Border-Romney	111	1.61 ± 0.05	5.00
Romney	81	1.70 ± 0.06	5.47
Day of Bleeding			
20	64	1.33 ± 0.06	3.78
40	64	1.59 ± 0.06	4.90
60	64	2.04 ± 0.06	7.69
Litter Size			
1	111	1.36 ± 0.05	3.90
2	60	1.73 ± 0.05	5.64
3	21	1.87 ± 0.08	6.48

Analysis of Covariance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (b)	1	0.28	1.89 N.S.
Between Days (D)	2	4.13	28.11 ***
Between Litter Sizes (L)	2	5.12	34.83 ***
B x D Interaction	2	0.19	1.26 N.S.
B x L Interaction	2	0.01	0.03 N.S.
D x L Interaction	4	0.08	0.54 N.S.
B x D x L Interaction	4	0.03	0.22 N.S.
Regression of Ewe Liveweight[A] on Log_e Progesterone Concentration	1	0.73	4.97 *
Error	173	0.15	

[A] Pre-experimental and pooled over both breeds ($\hat{B}$ = -0.01)

4. Prediction of litter size

Table 5-7 summarises the plasma progesterone means estimated from the analyses of variance (Table 5-5) and covariance (Table 5-6). These means were used to calculate discrimination points for two logical litter size groupings within breed and day of bleeding. The success rate of predicting these litter size groups from $\log_e$ progesterone concentration (for both the AOV and ACOV models) is shown in Table 5-4.

As for corpora lutea, there was little difference between models in accuracy of prediction of litter size groups.

Ewes in Late Pregnancy

1. Plasma progesterone and litter size

Progesterone concentration at day 120 of pregnancy increased with litter size ($P < 0.001$). Ewes producing twins or triplets had greater concentrations of the hormone than ewes with singles ($P < 0.01$) although the difference between ewes producing twins and triplets failed to reach significance (Table 5-8). The interaction between breed and litter size was not significant.

2. Prediction of litter size

Data from Table 5-8 was used to produce discrimination points and these were used to predict litter size from $\log_e$ progesterone concentration. The success rate in determining whether a ewe carried a single, twins or triplets was 57.1% for Romneys and 60.5% for the crossbreds. However, when the prediction was whether ewes carried singles or multiples (twins or triplets), the success rate increased to 71% for both breeds.

TABLE 5-7: PROGESTERONE CONCENTRATION OF EWES EARLY IN PREGNANCY CLASSIFIED RELATIVE TO BREED, DAY OF BLEEDING AND LITTER SIZE

				Day of Bleeding					
				20		40		60	
		S.E.		Plasma Progesterone Concentration† (Log_e Mean)					
Litter Size	No. of Ewes	AOV	ACOV	AOV[A]	ACOV[B]	AOV	ACOV	AOV	ACOV
Romney									
1	15	0.10	0.10	1.19	1.15	1.29	1.26	1.79	1.75
2	9	0.13	0.13	1.16	1.59	1.72	1.70	2.09	2.07
3	3	0.22	0.22	1.58	1.58	1.98	1.98	2.21	2.21
Border-Romney									
1	22	0.08	0.08	0.99	1.02	1.17	1.24	1.70	1.72
2	11	0.12	0.12	1.34	1.37	1.56	1.59	2.05	2.08
3	4	0.19	0.19	1.26	1.30	1.71	1.76	2.35	2.39

† Means and standard errors calculated from:

A - the analysis of variance model shown in Table 5-5

B - the analysis of covariance model shown in Table 5-6

TABLE 5-8: EFFECT OF BREED AND LITTER SIZE ON PLASMA PROGESTERONE CONCENTRATION AT DAY 120 OF PREGNANCY

Classification:			Plasma Progesterone Concentration	
Breed of Ewe	Litter Size	No. of Ewes	Log_e Mean ± S.E.	Antilog (ng/ml)
Border-Romney	1	22	1.54 ± 0.10	4.65
	2	12	2.14 ± 0.14	8.53
	3	4	2.26 ± 0.24	9.55
	All Litter Sizes	38	1.98 ± 0.08	7.24
Romney	1	16	1.74 ± 0.12	5.72
	2	9	2.12 ± 0.16	8.31
	3	3	2.50 ± 0.27	12.18
	All Litter Sizes	28	2.12 ± 0.09	8.33
Both Breeds	1	38	1.64 ± 0.08 a[A]	5.16
	2	21	2.13 ± 0.10 bc	8.42
	3	7	3.38 ± 0.18 c	10.78

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.20	0.91 N.S.
Between Litter Sizes (L)	2	2.56	11.52 ***
B x L Interaction	2	0.10	0.45 N.S.
Error	60	0.22	

[A] Means with different subscripts are significantly different ($P<0.01$)

$r^2 = 0.31$

The reasons why accuracy of prediction did not increase with advancement of pregnancy may be explained by the small amount of variation explained ($r^2 = 0.31$) by components of the model summarised in Table 5-8 for day 120 of pregnancy compared to earlier in pregnancy. When ewe liveweight was introduced as a covariate (Table 5-10) the accuracy of prediction of actual litter size was not increased (Romney 46.4%; Border-Romney 63.2%), nor was the prediction between ewes with singles and multiples improved (Romney 64.3%; Border-Romney 73.7%).

Table 5-9 shows the effects of the regression of weight of lamb born on progesterone concentration ($\hat{B} = 0.17$; $P < 0.001$) when this was included in the analysis. Thus the explained variance increased ($r^2 = 0.44$) while the effect of litter size became non significant. Birthweight within litter size then is a source of considerable variation of progesterone concentration which may reduce the accuracy of prediction of litter size in late pregnancy.

3. Plasma progesterone and breed

Table 5-8 shows that although Romneys had higher blood progesterone levels than the crossbreds this was not significant. The breed comparison (Table 5-10) after including the regression of pre-experimental liveweight of ewes on progesterone concentration ($\hat{B} = -0.03$; $P < 0.001$) showed a non significant advantage of the Border-Romney ewes. This effect may have been due to the breed difference in weight of lamb born (Chapter III). Thus a model including a regression of weight of lamb born on progesterone concentration was studied (Table 5-9). After allowing for variation due to the weight of lamb born ($\hat{B} = 0.17$; $P < 0.001$), Romney ewes had

TABLE 5-9: EFFECT OF BREED AND LITTER SIZE ON PLASMA PROGESTERONE CONCENTRATION AT DAY 120 OR PREGNANCY AFTER COVARIANCE OF WEIGHT OF LAMB BORN PER EWE

Classification:			Plasma Progesterone Concentration	
Breed of Ewe	Litter Size	No. of Ewes	Log_e Mean ± S.E.	Antilog (ng/ml)
Border-Romney	1	22	1.70 ± 0.10	5.48
	2	14	1.83 ± 0.15	6.21
	3	4	1.70 ± 0.26	5.48
	All Litter Sizes	38	1.74 ± 0.11	5.71
Romney	1	16	2.00 ± 0.13	7.39
	2	9	2.03 ± 0.14	7.62
	3	3	2.20 ± 0.26	8.70
	All Litter Sizes	28	2.08 ± 0.10	7.97
Both Breeds	1	38	1.85 ± 0.09	6.36
	2	21	1.93 ± 0.11	6.88
	3	7	1.95 ± 0.20	7.02

Analysis of Covariance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.99	5.39 *
Between Litter Sizes (L)	2	0.02	0.13 N.S.
B x L Interaction	2	0.05	0.30 N.S.
Regression of Weight of Lamb Born on Plasma Progesterone Concentration ($\hat{B}$ = 0.17)	1	2.56	13.99 ***
Error	1	0.18	

$r^2 = 0.44$

TABLE 5-10: EFFECT OF BREED AND LITTER SIZE ON PLASMA PROGESTERONE CONCENTRATION AT DAY 120 OF PREGNANCY AFTER COVARIANCE OF EWE LIVEWEIGHT

Classification:			Plasma Progesterone Concentration	
Breed of Ewe	Litter Size	No. of Ewes	Log_e Mean ± S.E.	Antilog (ng/ml)
Border-Romney	1	22	1.60 ± 0.09	4.94
	2	12	2.24 ± 0.13	9.39
	3	4	2.35 ± 0.22	10.48
	All Litter Sizes	38	2.06 ± 0.09	7.87
Romney	1	16	1.61 ± 0.12	5.00
	2	9	2.04 ± 0.15	7.67
	3	3	2.49 ± 0.25	12.09
	All Litter Sizes	28	2.05 ± 0.11	7.74
Both Breeds	1	38	1.60 ± 0.07	4.97
	2	21	2.14 ± 0.10	8.49
	3	7	2.42 ± 0.17	11.25

Analysis of Covariance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.002	0.01 N.S.
Between Litter Sizes (L)	2	3.02	15.93 ***
B x L Interaction	2	0.11	0.57 N.S.
Regression of Pre-experimental Ewe Liveweight on Plasma Progesterone Concentration ($\hat{B} = -0.03$)	1	2.16	11.36 ***
Error	59	0.19	

$r^2 = 0.42$

significantly greater estimated blood progesterone levels than the crossbreds ($P < 0.05$).

When both ewe liveweight and weight of lamb born regressions on progesterone concentration were included in the model (Table 5-11), both were significant ($P < 0.001$) although breed and litter size effects were non significant. Components of this model provided the best explanation of variation ($r^2 = 0.54$) of those models analysed for late pregnancy. Thus the antagonistic influences of ewe liveweight and weight of lamb born are probably important in a discussion of blood progesterone levels at this stage of pregnancy.

Partial 'Ovum Wastage' and Blood Progesterone Level

The relationship between apparent ovum wastage (corpora lutea number - lambs born) and plasma progesterone concentration was studied using pregnant ewes with either 2 or 3 corpora lutea. This was done in an attempt to reduce problems of confounding corpora lutea number with ovum wastage and blood progesterone level. The results are summarised in Table 5-12.

Progesterone concentrations for days 20 and 40 were used because most ovum wastage probably occurred in early pregnancy.

Double ovulating ewes had greater plasma progesterone levels (on both days) when both corpora lutea were represented by lambs born. The relationship was less clear for ewes with 3 corpora lutea when progesterone levels for Day 20 were considered, although increased concentrations of the hormone were associated with less ovum wastage on Day 40 ($P < 0.1$). The relationship was more apparent on Day 40 than Day 20 for both ovulation rate groups, but the number of ewes available for analysis was small.

TABLE 5-11: EFFECT OF BREED AND LITTER SIZE ON PLASMA PROGESTERONE CONCENTRATION AT DAY 120 OF PREGNANCY AFTER COVARIANCE OF PRE-EXPERIMENTAL EWE LIVEWEIGHT AND WEIGHT OF LAMB BORN PER EWE

Classification:			Plasma Progesterone Concentration	
Breed of Ewe	Litter Size	No. of Ewes	Log_e Mean ± S.E.	Antilog (ng/ml)
Border-Romney	1	22	1.75 ± 0.09	5.76
	2	12	1.93 ± 0.14	6.89
	3	4	1.81 ± 0.24	6.11
	All Litter Sizes	38	1.83 ± 0.10	6.24
Romney	1	16	1.86 ± 0.12	6.43
	2	9	1.96 ± 0.13	7.09
	3	3	2.20 ± 0.24	9.03
	All Litter Sizes	28	2.00 ± 0.10	7.44
Both Breeds	1	38	1.81 ± 0.08	6.09
	2	21	1.94 ± 0.10	6.99
	3	7	2.01 ± 0.18	7.45

Analysis of Covariance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	0.25	1.62 N.S.
Between Litter Sizes (L)	2	0.08	0.51 N.S.
B x L Interaction	2	0.08	0.55 N.S.
Regression of Ewe Liveweight on Plasma Progesterone Concentration ($\hat{B}$ = -0.03)	1	1.95	12.78 ***
Regression of Weight of Lamb Born on Plasma Progesterone Concentration ($\hat{B}$ = 0.16)	1	2.35	15.42 ***
Error	58	0.15	

$r^2 = 0.54$

TABLE 5-12: RELATIONSHIP BETWEEN NUMBER OF LAMBS BORN AND PLASMA PROGESTERONE CONCENTRATION IN EWES 20 OR 40 DAYS PREGNANT THAT SHED TWO OR THREE OVA

Classification: No. of Corpora Lutea	No. of Lambs Born per Ewe	No. of Ewes	Plasma Progesterone Concentration Log_e Mean ± S.E. (Antilog ng/ml)[A] Day 20	Day 40
2	1	12	1.01 ± 0.14(3.00)	1.25 ± 0.09(3.49)
	2	9	1.29 ± 0.16(3.63)	1.46 ± 0.10(4.31)
3	1	5	1.33 ± 0.11(3.78)	1.40 ± 0.12(4.06)
	2	4	1.42 ± 0.12(4.14)	1.48 ± 0.14(4.40)
	3	4	1.31 ± 0.12(3.17)	1.87 ± 0.14(6.48)

Analyses of Variance

Source of Variation	d.f.	Day 20 Mean Squares	Day 40 Mean Squares
Ewes with Two Ovulations			
Between Litter Size	1	0.41 N.S.	0.22 N.S.
Error	19	0.24	
Ewes with Three Ovulations			
Between Litter Size	2	0.02 N.S.	0.27 -
Error	10	0.06	0.07

[A] Detransformed mean in brackets

CHAPTER VI

PRE- AND POST-NATAL LAMB GROWTH

CHAPTER VI

PRE-AND POST-NATAL LAMB GROWTH

Data on gestation length and birth weight were available for 107 lambs born to first mating and 200 born to all services. The weaning weight records were available from 170 lambs.

Gestation Length

1. Single- and twin-bearing ewes

PMSG effects on gestation length were studied using ewes producing singles and twins since ewes not injected with PMSG did not have triplets (Table 6-1). The gonadotrophin appeared to have no real effect on gestation length. The gestation period of Romney ewes was about one day longer than the crossbreds ($P < 0.01$). There was, however, an interaction between breed and birth rank effects. Thus, while Border-Romney ewes with twins had shorter pregnancies than ewes producing singles, the reverse was true with Romneys ($P < 0.05$). Over both breeds, however, the effect of birth rank was not significant.

2. All ewes

The effects of breed and birth rank are summarised in Table 6-2. Romney lambs were carried slightly longer than the crossbreds but the effect was not significant. Similarly, the apparent reduction in gestation length with increased birth rank failed to reach significance.

3. Effect of sex of lamb

Table 6-3 shows the effects of breed and sex of single-born lambs on gestation length. Although male lambs were carried slightly longer than females, the effect was not significant. Over both

TABLE 6-1: EFFECT OF BREED, DOSE OF PMSG AND BIRTH RANK ON GESTATION LENGTH - DATA FOR EWES LAMBING SINGLES AND TWINS TO FIRST MATING

Classification: Breed of Ewe	Birth Rank	No. of Ewes	Gestation Length (Days) (Mean)
Border-Romney	Singles	39	146.6
	Twins	17	145.5
	Both Birth Ranks	56	146.1
Romney	Singles	28	146.9
	Twins	13	147.8
	Both Birth Ranks	41	147.3
Both Breeds	Singles	67	146.8
	Twins	30	146.6
Dose of PMSG (i.u.)			
0		40	146.7
600		28	147.0
1200		29	146.4

Analysis

Source of Variation	Effect ($\hat{B}$)	S.E.[A]	t[B]
Between Breeds (B)	1.29	0.46	2.85 **
Between Birth Ranks (R)	0.12	0.46	0.26 N.S.
Between PMSG Doses (linear) (Pl)	-0.27	0.70	-0.39 N.S.
Between PMSG Doses (quadratic) (Pq)	-0.40	0.44	-0.91 N.S.
B x R Interaction	0.99	0.46	2.17 *
B x Pl Interaction	0.10	0.70	0.14 N.S.
B x Pq Interaction	0.10	0.44	0.23 N.S.

[A] Error Mean Square = 2.72

[B] d.f. = 96

TABLE 6-2: EFFECT OF BREED AND BIRTH RANK ON GESTATION LENGTH ACROSS ALL DOSES OF PMSG - DATA FOR EWES LAMBING TO FIRST MATING

Classification:

Breed of Ewe	Birth Rank	No. of Ewes	Gestation Length (Days) (Mean)
Border-Romney	Single	39	146.6
	Twin	17	145.5
	Triplet	7	146.7
	All Litter Sizes	63	146.3
Romney	Single	28	146.9
	Twin	13	147.8
	Triplet	3	145.8
	All Litter Sizes	44	146.8
Both Breeds	Single	67	146.8
	Twin	30	146.6
	Triplet	10	146.2

Analysis

Source of Variation	Effect ($\hat{B}$)	S.E.[A]	t[B]
Between Breeds (B)	0.56	0.45	1.24 N.S.
Between Birth Ranks (linear) (Rl)	-0.56	0.61	0.92 N.S.
Between Birth Ranks (quadratic) (Rq)	0.16	0.34	0.47 N.S.
B x Rl Interaction	0.50	0.61	0.99 N.S.
B x Rq Interaction	1.14	0.34	3.38 **

[A] Error Mean Square = 2.72

[B] d.f. = 106

TABLE 6-3: EFFECT OF BREED AND SEX OF LAMB ON GESTATION LENGTH AND BIRTH WEIGHT FOR SINGLE-BORN LAMBS

Classification:

Breed of Ewe	Sex of Lamb	No. of Lambs	Gestation Length (Days) (Mean ± S.E.)	Birth Weight (kg) (Mean ± S.E.
Border-Romney	Male	25	146.2 ± 0.36	5.09 ± 0.15
	Female	27	146.2 ± 0.35	4.54 ± 0.14
	Both Sexes	52	146.2 ± 0.25	4.82 ± 0.10
Romney	Male	28	147.2 ± 0.34	4.56 ± 0.14
	Female	22	146.5 ± 0.39	4.65 ± 0.16
	Both Sexes	50	146.8 ± 0.26	4.60 ± 0.10
Both Breeds	Male	53	146.7 ± 0.25	4.82 ± 0.10
	Female	49	146.4 ± 0.26	4.60 ± 0.11

Analysis of Variance

Source of Variation	d.f.	Gestation Length Mean Squares	Birth Weight Mean Squares
Between Breeds (B)	1	10.70 -	1.16 N.S.
Between Sexes (S)	1	2.41 N.S.	1.34 N.S.
B x S Interaction	1	3.47 N.S.	2.50 *
Error	98	3.30	0.54

sexes Romney singles were carried over half a day longer than crossbred singles ($P < 0.1$).

Table 6-4 summarises the effects of breed and classes of twin birth on gestation length. Twin males were carried longer than either mixed sexed twins or twin females ($P < 0.01$) although the difference between the latter two classes of twins was not significant. Romney ewes producing twins had gestation lengths two days longer than similar crossbred ewes ($P < 0.001$).

Birth Weight

1. Single lambs

The influences of breed of ewe and sex of lamb on lamb birth weight are shown in Table 6-3. For this sample the crossbred lambs were heavier than Romneys although the effect was not significant. There was a significant breed by sex interaction ($P < 0.05$). Thus in this group of lambs, male crossbred lambs were heavier at birth than females while the reverse was the case with lambs born to Romney ewes.

2. Twin lambs

Table 6-5 summarises the effects of breed of ewe and class of twin birth on lamb birth weight. Twins born to crossbred ewes were heavier at birth than lambs from Romneys ($P < 0.01$).

The class of twin birth had a significant influence on lamb birth weight ($P < 0.05$). A comparison among means showed that significant differences in birth weight ($P < 0.05$) occurred between female lambs born as twins to females compared to male lambs twin to males and males twin to females. There was no significant difference in birth weights of male lambs depending on whether they were co-twin to male or female lambs. This was also true of female lambs.

TABLE 6-4: EFFECT OF BREED AND CLASS OF TWIN-BIRTH ON GESTATION LENGTH

Classification:

Breed of Ewe	Class of Twin-Birth	No. of Ewes	Gestation Length (Days) (Mean ± S.E.)
Border-Romney	Male - Male	6	146.2 ± 0.34
	Female - Female	4	144.8 ± 0.42
	Mixed Sex Twins	7	145.8 ± 0.32
	All Classes	17	145.6 ± 0.20
Romney	Male - Male	5	149.0 ± 0.37
	Female - Female	4	147.8 ± 0.42
	Mixed Sex Twins	8	147.1 ± 0.29
	All Classes	17	148.0 ± 0.20
Both Breeds	Male - Male	11	147.6 ± 0.25 a[A]
	Female - Female	8	146.3 ± 0.29 b
	Mixed Sex Twins	15	146.5 ± 0.22 b

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	23.45	33.83 ***
Between Classes (C)	2	1.78	2.56 -
B x C Interaction	2	1.27	1.82 N.S.
Error	28	0.69	

[A] Means followed by different subscripts are significantly different ($P < 0.01$)

TABLE 6-5: EFFECT OF BREED AND CLASS OF TWIN-BIRTH ON BIRTH WEIGHT

Classification: Breed of Ewe	Class of Twin-Birth	No. of Lambs	Birth Weight (kg) (Mean ± S.E.)
Border-Romney	Male - Male	12	4.23 ± 0.23
	Male - Female	4	4.21 ± 0.39
	Female - Female	8	3.55 ± 0.28
	Female - Male	10	3.48 ± 0.25
	All Classes	34	3.87 ± 0.13
Romney	Male - Male	10	3.78 ± 0.25
	Male - Female	8	3.78 ± 0.28
	Female - Female	8	2.84 ± 0.28
	Female - Male	8	3.60 ± 0.28
	All Classes	34	3.50 ± 0.13
Both Breeds	Male - Male	22	4.00 ± 0.17 a[A]
	Male - Female	12	3.99 ± 0.23 a
	Female - Female	16	3.19 ± 0.20 b
	Female - Male	18	3.54 ± 0.18 ab

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	2.27	3.73 -
Between Classes (C)	3	2.37	3.90 *
B x C Interaction	3	0.52	0.86 N.S.
Error	60	0.61	

[A] Means with different subscripts are significantly different ($P < 0.05$)

3. All birth ranks

Table 6-6 shows the effects of breed, birth rank and sex on birth weight.

Crossbred lambs were heavier than the Romneys ($P < 0.001$) and males heavier than females at birth by about the same margin ($P < 0.01$). Similarly there was a significant inverse relationship between birth rank and weight at birth ($P < 0.001$).

Weaning Weight and Daily Liveweight Gain

Lamb growth was studied from birth using liveweight at weaning and daily liveweight gain to weaning.

There were only 20 lambs born as triplets available for study and these were analysed separately to avoid unfilled rearing rank subclasses had they been included with data from lambs of other birth ranks.

1. Single and twin lambs

Weaning weights were studied after the application of the regression of age of lamb at weaning on weight at weaning. This regression ($\hat{B} = 0.13$) was significant ($P < 0.001$) and adjusted weaning weights to a mean of 99.25 days. The effects of ewe breed, lamb sex and rearing rank on age adjusted weaning weight and on daily liveweight gain are shown in Table 6-7 for single- and twin-born lambs.

Lambs born to Border-Romney ewes grew faster ($P < 0.1$) and were nearly 3 kg heavier at weaning than those born to Romneys ($P < 0.05$). Similarly, male lambs (castrated) grew faster than females ($P < 0.05$) and were more than 3 kg heavier at weaning ($P < 0.01$).

TABLE 6-6: EFFECT OF BREED, BIRTH RANK AND SEX ON BIRTH WEIGHT - DATA FOR ALL LAMBS

Classification	No. of Lambs	Birth Weight (kg) (Mean ± S.E.)
Breed of Ewe		
Border-Romney	113	3.92 ± 0.07
Romney	87	3.56 ± 0.08
Birth Rank		
Single	102	3.71 ± 0.08 a[A]
Twin	68	3.67 ± 0.09 b
Triplet	30	2.82 ± 0.14 c
Sex		
Male	101	3.91 ± 0.08
Female	99	3.56 ± 0.08

Analysis of Variance

Source of Variation	d.f.	Mean Squares	F
Between Breeds (B)	1	6.52	11.49 ***
Between Birth Ranks (R)	2	43.33	76.40 ***
Between Sexes (S)	1	5.59	9.85 **
B x R Interaction	2	0.26	0.46 N.S.
B x S Interaction	1	0.02	0.04 N.S.
R x S Interaction	2	0.97	1.70 N.S.
B x R x S Interaction	2	1.04	1.84 N.S.
Error	188	0.57	

[A] Means followed by different subscripts are significantly different ($P < 0.01$)

TABLE 6-7: EFFECT OF EWE BREED, LAMB SEX AND REARING RANK OF SINGLE- AND TWIN-BORN LAMBS ON WEANING WEIGHT AND WEIGHT GAIN PER DAY

Classification	No. of Lambs	Weaning Weight[A] (kg) (Mean ± S.E.)	Weight Gain Per Day (kg/day) (Mean ± S.E.)
Breed of Ewe			
Border-Romney	83	25.80 ± 0.73	0.216 ± 0.004
Romney	67	23.03 ± 0.88	0.197 ± 0.004
Sex of Lamb			
Male	74	26.13 ± 0.88	0.221 ± 0.004
Female	76	22.70 ± 0.73	0.192 ± 0.004
Rearing Rank			
Single Reared as Single	92	27.41 ± 0.37 a	0.232 ± 0.004 } * (vs Twin Reared as Single); ** (vs Twin Reared as Twin)
Twin Reared as Single	6	23.00 ± 1.60 b	0.197 ± 0.014 } * (vs Single Reared as Single); N.S. (vs Twin Reared as Twin)
Twin Reared as Twin	52	22.84 ± 0.51 b	0.189 ± 0.005 } ** (vs Single Reared as Single); N.S. (vs Twin Reared as Single)

Analysis of Variance

Source of Variation	d.f.	Weaning Weight Mean Squares	d.f.	Weight Gain Mean Squares
Between Ewe Breeds (B)	1	71.65 *	1	0.0034 -
Between Sexes (S)	1	110.30 **	1	0.0080 *
Between Rearing Ranks (R)	2	327.37 ***	2	0.0301 ***
B x S Interaction	1	0.11 N.S.	1	0.0003 N.S.
B x R Interaction	2	11.94 N.S.	2	0.0008 N.S.
S x R Interaction	2	21.28 N.S.	2	0.0015 N.S.
B x S x R Interaction	2	5.10 N.S.	2	0.0008 N.S.
Regression of Age of Lamb on Weaning Weight ($\hat{B} = 0.13$)	1	198.05 ***	-	-
Error	137	12.25	138	0.0012

[A] Adjusted to a mean age of 99.25 days at weaning

Means followed by different subscripts are significantly different ($P < 0.01$)

Rearing rank had a significant effect on both daily weight gain ($P < 0.001$) and weaning weight ($P < 0.001$). Thus singles reared as singles grew faster than either twins reared as singles ($P < 0.05$) or twins reared as twins ($P < 0.01$) although the rearing rank of twin-born lambs had no significant effect on daily growth rate. Similarly, singles reared as singles were more than 4 kg heavier at weaning than twins reared as singles ($P < 0.01$) and about 4.5 kg heavier than twins reared as twins ($P < 0.01$). Rearing rank had no appreciable effect on weaning weight of lambs born as twins.

There were no significant interactions between any of the main effects.

2. <u>Triplet lambs</u>

Table 6-8 presents the effects of breed of ewe and rearing rank of triplets on age-adjusted weaning weight and daily weight gain.

The regression of age at weaning on weaning weight ($\hat{B} = 0.52$) approached significance ($P < 0.1$) and weaning weights tested were adjusted to a mean age of 104.10 days.

The very small numbers of triplet-born lambs reared either as twins or singles probably explains the greater weaning weights ($P < 0.1$) and growth rates ($P < 0.1$) shown for Romneys compared to the crossbreds. The interaction between breed and rearing rank ($P < 0.1$) should also be treated with caution.

Lambs born as triplets and reared as either twins or singles grew significantly faster ($P < 0.05$) and were about 3.5 kg heavier at weaning ($P < 0.1$) than those reared as triplets.

TABLE 6-8: EFFECT OF EWE BREED AND REARING RANK OF TRIPLET-BORN LAMBS ON WEANING WEIGHT AND WEIGHT GAIN PER DAY

Classification: Breed of Ewe	Rearing Rank	No. of Lambs	Weaning Weight[A] (kg) (Mean ± S.E.)	Weight Gain Per Day (kg/day) (Mean ± S.E.)
Border-Romney	Triplet	12	19.93 ± 0.93	0.159 ± 0.008
	Single or Twin	3	20.18 ± 1.99	0.171 ± 0.017
	All Rearing Ranks	15	20.05 ± 1.04	0.165 ± 0.007
Romney	Triplet	3	19.89 ± 1.85	0.163 ± 0.017
	Single or Twin	2	26.83 ± 2.31	0.225 ± 0.020
	All Rearing Ranks	5	23.36 ± 2.07	0.194 ± 0.013
Both Breeds	Triplet	15	19.91 ± 1.04	0.161 ± 0.007
	Single or Twin	5	23.50 ± 2.08	0.198 ± 0.013

Analysis of Variance

Source of Variation	d.f.	Weaning Weight Mean Squares	d.f.	Weight Gain Mean Squares
Between Breeds (B)	1	31.94 -	1	0.0027 -
Between Ranks (R)	1	40.72	1	0.0043 *
B x R Interaction	1	32.08	1	0.0020 N.S.
Regression of Age of Lamb on Weaning Weight ($\hat{B}$ = 0.52)	1	33.95 -	-	-
Error	15	10.23	16	0.0008

[A] Adjusted to a mean age of 104.10 days at weaning

Fig. 6-1 and Fig. 6-2 show 2 year-old crossbred and Romney ewes respectively with lambs born and reared as triplets at about 100 days of age.

Fig. 6-1:- 2 YEAR-OLD BORDER-ROMNEY EWE WITH SOUTHDOWN-SIRED TRIPLET LAMBS AT ABOUT 100 DAYS OF AGE

Fig. 6-2:- 2 YEAR-OLD ROMNEY EWE WITH SOUTHDOWN-SIRED TRIPLET LAMBS AT ABOUT 100 DAYS OF AGE

CHAPTER VII

DISCUSSION

CHAPTER VII

DISCUSSION

Induction and Synchronisation of Oestrus

Progestagen treatment of maiden 2 year-old ewes caused a good proportion to show oestrus (80%) within 7 days and even more were marked at the next cycle (96%). Other New Zealand work has shown a similar occurrence of 'silent' heat. Thus Cumming (1965) noted 32-38% silent oestrus in mature Romney ewes after daily progesterone injections commencing in late February and Clarke (1973) reported 18% silent oestrus (at expected first heat) after progestagen sponge treatment in mid breeding season. Similarly, Larsen (1971) with mature and 2 year-old Romneys treated with progestagen pessaries in March cited figures of 7% and 20% silent heats respectively at expected first heat.

Ovulation had occurred in all ewes at both expected first and second heat whether they had been mated or not and this supports the results of Larsen (1971). The depressed behavioural response at the oestrus immediately following pessary removal may be due to an inadequate progestagen priming of the reproductive system of ewes that had not previously experienced a silent heat early in the breeding season. Modification of sponge preparation may have improved oestrous response (Gordon, 1972). Ovulation and associated endogenous progesterone production before the expected second heat probably caused the improved oestrous activity at the latter time.

Border-Romney ewes had fewer silent heats than Romneys ($P<0.05$) immediately after progestagen treatment. This may indicate a lower threshold in the central nervous system to progestagen priming shown by the crossbred ewes although this would not support the results of Larsen (1971).

Ewes were synchronised in heat over a period of 2 days after sponge removal and this was essentially maintained at next oestrus. Most ewes experiencing silent heats initially were also synchronised at "second" oestrus and more ewes were mated over a 3-day period at this time than immediately after progestagen treatment (152 v. 144). Similar findings in 5- to 7-year-old ewes have been reported by Edey and Thwaites (1966). Other workers have found that the second synchronised cycle is convenient both for artificial insemination (Robinson et al., 1967) and ovum transfer (Larsen, 1971). More recent work has shown that progestagen synchronisation of oestrus remains effective for 3 oestrous cycles and that laparotomy at each of these cycles does not markedly affect the degree of synchronisation (Clarke, 1973).

Border-Romney ewes that showed heat appeared to overcome the progestagen inhibition and came into heat earlier than Romneys. A similar effect was reported by Larsen (1971). This effect might be anticipated given the higher natural fecundity of the first-cross Border-Romney ewes (Clarke, 1962; Larsen, 1971) and the suggestion that more fecund breeds have a greater ability to overcome inhibitory mechanisms (Land, 1971, 1973).

Treatment with PMSG did not significantly affect synchronisation at second heat, although the onset of oestrus was earlier than in control ewes. This result contrasts with that of Clarke (1973) who found that PMSG injected immediately after progestagen treatment caused a greater dispersion of oestrus in ewes at the second cycle compared to control animals. Since PMSG was injected at mid cycle in the present work, it appears that the timing of gonadotrophin treatment may be important. Alternatively, the more extreme super-ovulatory response obtained by Clarke (1973) resulting in excessive populations of corpora lutea and follicles in the ovaries of stimulated animals may account for the difference from the present results.

Cycle Length

Higher levels of feeding were associated with shorter oestrous cycles, an effect also noted by Wallace (1954). This may be related to increased plasma progesterone levels and slower maturation of follicles after regression of the corpus luteum in less well fed sheep (Lamond et al., 1972). PMSG given during the follicular phase of the oestrous cycle reduced cycle lengths by an average of about half a day. Similar reductions have been reported by Warwick and Casida (1943), Robinson (1951) and Cumming and McDonald (1967), although other reports note an inconsistent or no effect with the drug (e.g., Wallace, 1954; Larsen, 1971).

Administering PMSG on day 12 rather than day 13 significantly shortened the cycle, a result also noted by Cumming and McDonald (1967) although other workers have found no such effect (Wallace, 1954; Tervit, 1967; Larsen, 1971).

Since level of feeding, PMSG administration and day of injection may each affect cycle length, then all should be considered in programmes to synchronise breeding where precise control of onset of oestrus is required, as in the application of egg transfer techniques.

Ovarian Response

Ovulation rate in Border-Romney ewes was higher than in Romneys (0.24 corpora lutea per ewe). This result may be compared with the differences of 0.06, 0.12, 0.25, 0.24, and 0.31 ovulations per ewe reported for ewe lambs (Lang and Hight, 1967), ewe lamb singles and twins (Hight et al., 1973), 2 year-old ewes (Larsen, 1971) and mature ewes (Allison, 1968), respectively.

PMSG treatment caused a greater ovulation response in crossbred ewes than in Romneys. The effect was seen mainly in ewes treated with the highest dose of the drug. Litter size after PMSG injection was also higher in Border-Romney than in Romney ewes, although the difference between breeds at each dose level was much less than that observed for ovulation rate.

Several reports have also shown greater ovulation response to PMSG in naturally more-fecund strains (Bindon et al., 1971; Trounson and Moore, 1972) and breeds (Bradford et al., 1971) than in less-prolific sheep. Newton et al. (1970), however, concluded that that the dose of PMSG required for successful superovulation (as measured by increased litter size) was higher for breeds of greater average litter size. Similarly, Yuzlikaev (1973) reported higher lambing responses to PMSG from ewes producing either no lambs or singles the previous season compared to twin-bearing ewes. Smith (1975) however, obtained greater responses from those ewes having better rather than poorer previous lambing records. Other workers have noted an effect of breed of ewe on the ovulation response to PMSG together with a positive breed and level of PMSG interaction (Laster et al., 1974). In the latter work, however, there appeared to be little consistent relationship between the natural ovulation rates of the different breeds and their mean responses to PMSG.

Border-Romney ewes ovulated a slightly greater proportion (62.6% v. 58.2%) of follicles although the effect was not significant. Bradford et al. (1971) noted that although Southdown ewes treated with PMSG may have a total follicular response that is similar to Finnish Landrace ewes, the former breed had a lower proportion of follicles ovulated. This effect could be due to a smaller number of follicles that are competent to ovulate. In mice, follicular fluid from large follicles may contain substances that are able to depress growth initiation of other follicles (Peters et al., 1973). Workers have described the existence of tissue-specific antimitotic messenger ('chalone') systems for the approximately 20 tissues studied in several species (Bullough, 1975). There may be breed differences in the potency or quantity of such substances which may help explain breed of ewe differences in ovulation rates and proportion of follicles ovulated.

It is not clear whether the present results were due to differences in: 'ovarian sensitivity' to PMSG (McLaren, 1962); endogenous levels of pituitary gonadotrophin supplementing the PMSG (Lamond and Emmens, 1969; Lamond and Bindon, 1966a, b); or to a combination of the two as suggested by Trounson and Moore (1972) and Allison (1975). There have been several reports showing a positive relationship between plasma concentrations of LH and prolificacy both within a breed (Bindon, 1973; Bindon and Turner, 1974) and between breeds (Thimonier et al., 1972). Although studies have not been reported in sheep, Bindon and Pennycuik (1974) have demonstrated in mice that differences in ovarian sensitivity do represent part of the response to selection for ovulation rate. Thus although more detailed work is required with sheep, it is likely that breed or strain differences in ovulatory response to PMSG may be related to a combined effect that includes aspects of ovarian sensitivity and levels of endogenous LH.

Injection of PMSG also increased the proportion of follicles ovulated in ewes compared to untreated ewes. Several possible reasons for this include:

1. The LH moeity in PMSG may contribute to luteinisation of follicles and to their ovulation (Williams, 1945) although the extent to which this occurs in sheep is not clear. The effectiveness of this ovulatory property of PMSG may depend on the batch or preparation used (Clarke, 1973).

2. PMSG may itself stimulate the direct release of endogenous LH from the pituitary (Clarke, 1973).

The positive quadratic shape of the present dose-response curves closely resembles that found by Robinson (1951) over the range of PMSG doses 0 i.u. to 1200 i.u. The great variability in response between ewes to the gonadotrophin reported by Robinson (1951) was also noted.

The dose-response curves for the present 2 year-old ewes were generally less steep than those reported from other New Zealand work with mature Romney ewes (Wallace, 1954; Allison (1973, 1975). The difference in slope may be due to an age effect, although this has not been consistently reported. Thus Robinson (1951) noted that lambs show a lower response to PMSG than mature ewes. Similarly, Averill (1958) obtained consistently steeper dose-response regressions for mature Border Leicester and Welsh Mountain ewes than for 2 year-old ewes, although the effect was not significant. Conversely, Bradford et al. (1971) reported similar ovarian responses to PMSG in mixed-age ewes and 6 month-old Finnish Landrace lambs. Gordon (1963) also concluded that age of ewe is not responsible for any real variation in response to treatment. Besides an age effect, variables such as the potency of the gonadotrophin used could also explain differences in dose-responses between different workers (Laster et al., 1974).

The day of PMSG injection has been shown to influence response to the drug (Neville, 1966) but both ovulation rate and total follicular response were independent of whether PMSG was injected on day 12 or 13 of the oestrous cycle in the present trial. The latter results support those of Robinson (1951), Wallace (1954), Cumming (1965), Bindon et al. (1971) and Larsen (1971).

At the levels of feeding in this trial, no effect of nutrition was noted on natural ovulation rates or response to PMSG treatment. Although significant liveweight differences in these 2 year-old ewes were established, it was intended to induce greater differences. This was impractical owing to dry soil conditions resulting in poor pasture growth which limited weight gain. There was also a need to avoid facial eczema and ryegrass staggers and work by Keogh (1975) suggested that excessive forced grazing of the low plane group would increase the incidence of these conditions.

Where satisfactory levels of feeding are possible close to mating, the 'dynamic and static effects' of flushing have been well documented (Coop, 1966) and ovulation responses to PMSG may be greater (Allison, 1973, 1975; Hedges and Reardon, 1973). If improved nutrition cannot be supplied using pasture alone as in a dry autumn, then supplementing intake of ewes with concentrates may be of value. However, Western Australian work with high energy cereal grains (Lightfoot and Marshall, 1974; Reeve et al., 1975) and Whatawhata work with lucerne : maize meal nuts (Moore and Hight, 1973) has been disappointing. However, prolonged feeding (83 days) causing a 7 kg difference in liveweight with such supplements has raised lambing performance by 10% (LB/EP)* (Moore, 1975). Lupin grain (containing 28-33% protein) was successful in improving ovulation rates following short-term feeding of ewes on both adequate levels of pasture (4000 kg dry matter/ha) (Reeve et al., 1975) and on limited grazing (Marshall and Lightfoot, 1974). Similarly, Knight et al. (1975) and Lightfoot and Marshall (1975) reported that short-term supplementation with lupin grain increased both the number of ewes lambing and the number of twin births without greatly affecting bodyweight. There is some evidence that the ovulation response to lupin grain supplementation may depend on seasonal factors (Rizzoli et al., 1975). The use of supplements at about mating of ewes requires more detailed investigation.

No consistent relationship was found between either liveweight at the time of PMSG injection, or the change in liveweight before injection, and the number of ovulations. This may have been due to a combination of insufficient ewe numbers and the statistical problem of relating continuous and discrete variables. Cockrem (1965)

* Lambs born per ewes present at lambing

stated that the ideal method of analysis to relate these types of variables has yet to be arrived at, if it is indeed possible. The present results support those from other studies in 2 year-old ewes (Allison, 1973, 1975). However, there is some evidence of a possible relationship between ewe liveweight and ovarian response to PMSG (e.g. Guerra et al., 1971; Killeen, 1972).

In the nonbreeding season, better feeding causing heavier liveweights has been associated with greater ovarian responses to a constant dose of PMSG following progestagens (Keane, 1973). In the same study, body condition was found to have little effect on ovarian response to PMSG but the influence of this parameter requires more detailed work before meaningful conclusions can be reached.

The incidence of cystic ovaries in the present ewes was about that expected from the findings of Cumming and McDonald (1967), although it was far lower than that reported for similar dose levels by Bradford et al., 1971).

The variability in ovulation response between experiments, between breeds within experiments and between ewes within breeds, underline the need for caution in making or using any general recommendations about PMSG dosage (Bradford et al., 1971).

Uterine Capacity

1. Pregnancy in ewes

The conception rate to first service was reduced about 16% after PMSG treatment. This effect has also been noted by Robinson (1951) and Allison (1973, 1975) although other workers have reported no real decrease after PMSG administration (Wallace, 1954;

Gordon, 1963; Tait, 1971; Laster et al., 1974). Whether the present result was due to an interaction between dose of PMSG and the effects of laparotomy is not known. The stress of laparotomy shortly before or after ovulation in the ewe can result in a lower conception rate (Lamond, 1963; Packham and Triffit, 1966; Cutten, 1970) or increased luteolysis (Holst et al., 1973). Other workers have reported only minor effects of laparotomy (Alliston and Ulberg, 1961; McDonald, 1969).

An increased conception rate might have been expected after PMSG treatment since multiple ovulating ewes often become pregnant more readily than ewes shedding a single ovum (Dolling and Nicolson, 1967; Hulet and Foote, 1967; Killeen, 1967) although this is not always the case (Edey, 1970). Further, ova shed from superovulated sheep have normal levels of viability (Hunter et al., 1955; Averill, 1958) and PMSG appears to have little effect on fertilisation rates (with up to about 10-12 ovulations) (Cumming and McDonald, 1967), or on ovum survival after egg transfer (Moore et al., 1960).

Proportionately fewer ewes lambed to later services if initially treated with PMSG. This "carry-over" effect was probably related to an increased level of embryonic death as indicated by the greater incidence of long returns to service (intervals to next service of more than 20 days have been related to embryonic death (Edey, 1967; Dooley et al., 1974)). Other work has also shown that ewes are less likely to conceive when remated after an extended return cycle than after a normal return cycle (Edey, 1972; Blockey et al., 1975; MacKenzie and Edey, 1975). This reduced fertility following embryonic death may be due to impaired sperm transport (O'Shea et al., 1974). The present carry-over effect of PMSG on conception rate was likely mediated through the higher ovulation rate and associated ovum wastage (discussed below), rather than any direct residual effect of the drug. With mature Romneys, Allison (1975) noted that ewes not pregnant to first service after PMSG treatment had normal intervals to service and high levels of fertility at this time. This indicates failure before rather than after implantation begins (Edey, 1967). However, since the ewes were slaughtered 22-24 days after mating, there is a need for further study in ewes allowed to lamb of a possible carry-over effect of PMSG on conception rates. The present results support those of Newton et al. (1968) who found that ewes not pregnant to first mating after progestagen-PMSG treatment may suffer reduced conception rates at the next service. PMSG can reduce pregnancy rates without progestagen pretreatment (Robinson, 1951) while fertility after progestagen synchronisation alone is normal at second oestrus (Robinson, 1967). Thus it seems likely that any carry-over effect on conception rates is due to effects of the gonadotrophin rather than to a combination of treatments.

2. Numbers of corpora lutea and lambs born

As the dose of PMSG increased the percentages of potential lambs born was reduced in both ewes mated and ewes lambing. The Border-Romney ewes had a proportionately greater wastage of potential lambs (or corpora lutea) than the Romneys. Both the PMSG and the breed effects may be explained by the increased percentage of loss associated with increasing numbers of corpora lutea. The magnitude of this loss in pregnant ewes was similar to those reported by Wallace (1954) and Allison (1975) over the same range of ovulation rates. An increasing proportion of ewes which lost a part of the total complement of ova shed as ovulation rate increased was also noted by these workers and in the present work.

Despite the greater ovum wastage with greater numbers of corpora lutea, litter size increased with up to 5 ovulations as was reported by Wallace (1954). Litter sizes increased with higher PMSG doses but uterine capacity became a limiting factor since no more than 3 lambs were born to any one ewe irrespective of whether ewes had more than 3 corpora lutea of pregnancy. Thus the mean maximum capacity for 2 year-old ewes of both genotypes as indicated by ewes shedding 3 or more ova was between 2.0 and 2.3 lambs born. This corresponds closely with figures cited by Allison (1975) for mature Romney ewes of 2.0 to 2.5. Uterine capacity of the younger maiden ewes in this trial may be slightly less than for more mature ewes. An age or parity effect is suggested from the results of Keane (1974) who reported a likely uterine capacity of only one foetus per ewe for 8 month-old Suffolk-cross ewe lambs receiving progestagen-PMSG treatment.

Litter size after PMSG injection tended to be higher in Border-Romney than in Romney ewes, but the difference between breeds at each dose level was much less than observed for ovulation rate. Using Border-Romney and Romney 2 year-old ewes transplanted with 3 fertilised eggs each, Larsen (1971) noted a similar difference in litter size between breeds (0.26) to that of the present study for ewes having equivalent ovulation rates. Both investigations clearly indicate that uterine capacity exceeds the natural ovulation rate and is greater in the Border-Romney.

The uterine environment of different breeds after PMSG treatment appears related to natural fertility levels (Robinson, 1951), but it has also been reported that given equal ovulation rates, breeds of inherently low fertility may produce multiple births as readily as more fertile breeds (Wallace, 1954; Palsson, 1956; Gordon, 1958). Similarly, following egg transfer studies, Lawson and Rowson (1972) concluded that ovulation rate was a more important source of between-breed variation in fecundity than were effects of uterine capacity. Thus transfer of 5 ova to ewes increased lambing rates in all breeds except the more naturally fecund where natural ovulation rate was more closely related to uterine capacity. Moore (1968) however, showed that more fecund Border Leicester ewes each receiving 3 fertilised eggs had more triplets and less single lambs than Merino ewes receiving similar treatment.

While there are indications from the present and other work at Massey University that Border-Romney ewes have a greater uterine capacity than Romney ewes, the greatest limitation to potential reproductive performance in both breeds is the inadequate ovulation rate. Hence management methods which increase ovulation rates and selection of ewes with a propensity for higher ovulation rates should be emphasised.

Using the weight of lamb born per ewe as a measure of uterine capacity, crossbred ewes were superior to Romneys at all litter sizes ($P < 0.01$). This observation supports that of Larsen (1971).

Weight of lamb born per ewe increased with litter size although the increase in weight between ewes carrying singles and those carrying twins (2.9 kg) was greater than when the comparison was between triplet- and twin-bearing ewes (0.9 kg). Uterine capacity in terms of weight of lamb born then appears to be reached in both breeds when triplets are carried. The mean maximum capacity for Border-Romney 2 year-old ewes with triplets is about 8.9 kg while that for Romneys is more than a kilogram lighter at about 7.7 kg of lamb born per ewe.

The influence of PMSG on weight of lamb born was studied in ewes producing singles or twins (no control ewes had triplets). The drug appeared to have a depressive effect on the weight of lamb born per ewe but this was not significant. Similarly for the triplet-bearing ewes the weight of lamb born per ewe declined with the higher dose of PMSG although the effect was not statistically significant.

The survival of ova in ewes treated with PMSG was examined in those sheep which shed one or 2 ova (no control ewes exceeded 2 ovulations). The results for pregnant ewes shedding 2 ova support those of Wallace (1954) who noted that in pregnant ewes, ova produced after PMSG treatment, when ovulated in similar numbers, are no more likely to fail to develop than naturally ripened ova. However, an ovum from a uniovular ewe had a greater chance of survival if the animal had not been injected with PMSG which also agrees with data presented by Wallace (1954). It is not clear whether this effect of PMSG occurred mainly at the time of fertilisation or at later stages of embryo development. These PMSG-treated, uniovular ewes may be atypical, since they appear not to have responded to the drug.

Ewes with 2 corpora lutea had higher levels of ovum wastage ($P < 0.01$) and higher conception rates (non significant) than ewes shedding one ovum. This is in agreement with results of Dolling and Nicolson (1967); Killeen (1967); Allison (1975); MacKenzie and Edey (1975). Such findings might be expected since in single-ovulating sheep the loss of one ovum ends pregnancy, but a ewe with 2 corpora lutea can lose one egg with the possibility of further and greater percentage loss later (Edey, 1967). However, inconsistent results have also been reported (Edey, 1970).

Of the 41 pregnant ewes with 2 ovulations 24 (58.5%) produced one lamb each. This result agrees with Casida et al. (1966) and Quinlivan et al. (1966) who found that about half of the ewes with 2 corpora lutea, and which were pregnant, had only one lamb at slaughter 140 days after mating. Allison (1975) however, reported that 27.9% of ewes with double ovulations had only one embryo at slaughter 22-24 days post mating. Greater ovum loss may occur after this time although there is evidence that little embryonic mortality takes place after about day 30 of pregnancy (Robinson, 1951; Quinlivan et al., 1966). Hence Allison (1975) suggested the need for more research using laparoscopic techniques to record the number of ovulations in ewes which are allowed to lamb.

Although more double ovulating ewes lost both ova than those losing only one ovum (57.1% v. 42.9%) the effect was not significant. These results suggest the possibility that the loss was not at random but the sample was too small to investigate the hypothesis proposed by Edey (1966). This hypothesis was that the development of an unfavourable uterine environment leads to total rather than partial loss of embryos that originated from multiple ovulations. Results of MacKenzie and Edey (1975) support this contention.

The present work indicates greater ovum wastage, lower conception rates and reduced litter sizes for ewes having unilateral rather than bilateral double ovulations. Similar results have been noted previously (e.g. Bair and Russe, 1968; Doney et al., 1973). There is also evidence that transuterine migration occurs more frequently in ewes with unilateral rather than bilateral twin ovulations (Boyd et al., 1944; Casida et al., 1966; Scanlon, 1972; Doney et al., 1973). Earlier work suggested that such transuterine migration was associated with an increased level of embryonic mortality (Casida et al., 1966). There was also a suggestion that the viability of a sheep embryo was reduced by location in a uterine horn without a corpus luteum on the adjacent ovary (Doney et al., 1973). Despite this, strong evidence exists to suggest that the transuterine migration observed when both corpora lutea are present on a single ovary actually enhances embryo survival (Scanlon, 1972; Sittman, 1972; Doney et al., 1973). The distributive embryonic migration may spread the products of pregnancy more evenly throughout the uterus and reduce overcrowding. This theory is supported by results from ovum transfers in cattle where Rowson et al. (1971) found that the number of cotyledons to which the conceptuses were attached was usually much greater when pregnancies were bilateral and losses due to overcrowding were often less.

Over both breeds the incidence of both types of double ovulation was similar. This result contrasts with that of Doney et al. (1973) who reported consistently more unilateral than bilateral double ovulations. There may be a breed effect, however, since in the present work, pregnant Border-Romney ewes had more unilateral twin ovulations (57%) than the Romneys (38%) ($P < 0.1$). This finding may have been partly responsible for the greater ovum survival noted in pregnant Romney compared to Border-Romney ewes. Other reports have noted breed differences in the rate of distributive embryo migration in unilateral twin ovulators which was associated with differences in embryo mortality (Doney et al., 1973). Although only limited observations were made in the present trial, it appeared that while Border-Romney sheep had slightly less ovum wastage associated with unilateral twin ovulations, Romneys suffered less wastage when ovulations were bilateral. Similarly, although more prolific, the Border-Romney ewes had a less symmetrical distribution of twin ovulations between ovaries compared to the Romneys. Studies with breeds of greater variation in fecundity have shown that the Finnish Landrace sheep had the most symmetrical distribution of multiple ovulations between ovaries within sheep (Bradford et al., 1971). These workers suggested that the process of ovulation was more closely regulated in the Finn than in the other breeds (Welsh Mountain and Border Leicester). Hence more extensive studies are required to clarify the processes controlling fecundity.

When all ovulations were considered, more corpora lutea were observed on the right (56.7%) than the left ovary ($P < 0.05$). A study of single and unilateral twin ovulations also showed that the right ovary was more active (59.7% of unilateral ovulations) although the effect did not reach significance. This evidence supports that reviewed by Edey (1969) but inconsistencies are evident (Edey, 1966). Ova shed from the right ovary have been reported to suffer less wastage than those shed from the left ovary (Casida et al., 1966) but this was not confirmed in the present work.

Progesterone Level and Reproductive Phase

1. Effects of the stage of pregnancy and breed of ewe on progesterone level

The progesterone concentration in the ewes of each breed rose slightly from day 20 to day 60 of pregnancy. From day 60 to day 120 blood progesterone levels increased nearly two-fold. This pattern of progesterone production and the absolute values produced in 2 year-old ewes is similar to other work for ewes with similar numbers of corpora lutea or lambs born per ewe (Bassett et al., 1969; Fylling, 1970; McNatty et al., 1972; Sarda et al., 1973). From work reported by McNatty et al. (1972) it is likely that in these 2 year-old ewes, progesterone concentrations were approaching a maximum at day 120 of pregnancy. There is evidence that in older ewes, 2 peaks of progesterone occur after 100 days of pregnancy (McNatty et al., 1972; Sarda et al., 1973). Blood samples were taken every 20 days from mating until lambing in the present work, but these were not all analysed. Hence the magnitude and timing of peaks of progesterone concentration could not be monitored.

In early pregnancy, Romney ewes had greater blood progesterone levels than the crossbreds ($P < 0.05$). The main component of this 'breed' effect appeared due to differences in liveweight between Romneys and Border-Romneys. The difference between breeds not explained by ewe liveweight approached significance ($P < 0.1$) which indicates that Romneys may have greater blood progesterone levels than the crossbreds independent of liveweight. Bindon et al. (1971) reported significantly greater concentrations of plasma progesterone early in pregnancy in uniovular Merino ewes from a strain that had been selected for a high incidence of multiple births compared to similar ewes from a strain selected for a low incidence of multiple births. This evidence might indicate a higher blood progesterone level in ewes from a more fecund genotype although the present results do not support this. More detailed work with a greater number of breeds or strains is required to determine whether a relationship does exist between the genotype of the ewe and plasma progesterone level in early pregnancy.

Heavier ewes had lower levels of blood progesterone ($P < 0.05$). Other workers have noted higher blood progesterone levels in light ewes compared to heavier ewes following differential feeding (Cumming et al., 1971; Lamond et al., 1972). The present result may be related to a greater body pool for progesterone in heavier ewes or to an increased extravascular pool for the hormone due to greater content of body fat in heavier ewes as suggested by Lamond et al. (1972). The present ewes were not condition scored and the relationship between this measure and ewe liveweight was not known.

2. Fecundity and progesterone level

The number of corpora lutea (1 to 6) and peripheral plasma progesterone levels in early pregnancy were positively associated. A similar relationship was noted following PMSG treatment for ovarian vein progesterone levels by Short (1960, 1961) and for peripheral plasma levels by Thorburn et al. (1969) and Bindon et al. (1971).

The blood progesterone level was significantly greater in ewes with two corpora lutea compared to uniovular ewes. This supports work by Cumming et al. (1971) although the majority of reports note little value from the use of blood progesterone levels in the determination of whether ewes had one or two corpora lutea (Bindon *et al*., 1971; Robertson and Sarda, 1971; Lamond and Gaddy, 1972).

Litter size had a significant effect on progesterone concentration at both early pregnancy and at day 120 after mating. Ewes producing multiple births had greater blood progesterone levels than single-bearing ewes. This supports Australian work cited by Russel and Foot (1971) which reported plasma progesterone concentrations of twin-bearing ewes about twice those of single-bearing ewes. Gadsby *et al*. (1972) and Thompson and Wagner (1974) also reported significantly elevated blood progesterone levels in ewes carrying multiple foetuses compared to ewes with singles. There have been several reports, however, of a poor relationship between plasma progesterone levels of ewes and foetal numbers (Bassett *et al*., 1969; McNatty *et al*., 1972; Stabenfeldt *et al*., 1972; Sarda *et al*., 1973).

The success rate of classifying ewes into corpora lutea number or litter size groups on the basis of plasma progesterone levels generally increased from day 20 to day 40 after mating with little additional success obvious at day 60 of pregnancy. Correcting the data for ewe liveweight accounted for slightly more of the variation although this did not greatly affect the accuracy of prediction. There was little difference between breeds in the success of prediction. Exact prediction of the number of corpora lutea in ewes yielded rather poor results while exact prediction of litter size was only slightly more successful. Gadsby *et al*. (1972) also reported that classification of ewes according to actual litter size later in pregnancy, was unsuccessful. In the present work, diagnoses were more successful if based on whether ewes had one or more than one ovulation (70% to 80% accurate); a single or multiple birth (60% to 70% accurate). There appear to be no other reports where workers have attempted to predict the likely corpora lutea or litter size grouping of ewes using peripheral plasma progesterone concentrations early in pregnancy.

Accuracy of prediction of whether a ewe would produce a single, twin or triplet increased to about 60% when plasma progesterone levels at day 120 of pregnancy were used. Prediction was 71% accurate for both breeds when the criterion was whether ewes would produce singles or multiples. Including ewe liveweight as a covariate did not increase the accuracy of prediction of litter-size. Gadsby et al. (1972) with Finn and Finn-cross ewes reported a success rate of about 65% in classifying ewes according to litter-size groups on the basis of blood progesterone levels 91 to 105 days after mating. These workers included 'dry' ewes in their work whereas only ewes not returning to the ram were included in the present analysis. Similarly, Russel and Foot (1971) used an arbitrarily selected progesterone concentration less than 48 days from lambing to distinguish between single- and twin-bearing ewes with an overall accuracy of about 82%. The success rates of these reports are reasonably high, but this may have been due to the standardised and controlled conditions operating in each trial.

The above results may be compared with those from other techniques of litter size determination. Thus Hulet and Shupe (1973) using recto-abdominal palpation of the foetus (Hulet, 1972) between 91-118 days after breeding were about 70% accurate differentiating between single- and multiple-bearing pregnancies. Ackerley and Welsh (1974) using a similar technique reported that with mixed-age ewes from 60-110 days post-mating, a success rate of more than 80% is possible with experienced operators. English workers have reported an overall accuracy of predicting single from multiple pregnancies of about 70% in ewes 40 to 90 days pregnant although at least 34/167 ewes aborted and 5 ewes died following diagnosis (Turner et al., 1975). These workers concluded that the method was neither safe nor accurate enough to justify any saving there may have been in more efficient food usage.

The use of more expensive and complex equipment such as the ultrasonic Doppler instrument has given accuracies of litter-size prediction 63-84 days after mating of 53% increasing to 82% after 3 years of experience (Fraser et al., 1971). The results from ultrasonic methods can be extremely variable between operators however (Richardson, 1972). X-ray methods may give very accurate results (Braden and Baker, 1972) although this accuracy may depend on radiographical experience (Richardson, 1972).

A simple but reliable method of diagnosing multiple-bearing pregnancy would enable the feeding of pregnant ewes to an optimal level of nutrition during the last half of gestation (Richardson, 1972). An overall accuracy of prediction of multiple-bearing pregnancy for practical use should be more than about 70% according to Hulet and Shupe (1973). On this basis, the use of blood progesterone levels at day 120 of pregnancy appears to be of marginal value since about 30% of ewes were wrongly diagnosed as either having single- or multiple-bearing pregnancies. This accuracy, however, is similar to that reported for other methods used to determine litter size in pregnant ewes. Methods using plasma progesterone level are unlikely to increase the incidence of abortion in ewes but the number of animals examined is likely to be much less than the potential of 200 ewes per hour reported for the rectal palpation technique (Hulet, 1972). Thorburn <u>et al</u>. (1969) were able to process 60-70 blood samples per day and bulk handling of samples would greatly increase throughput.

Once the progesterone concentration is known for a ewe then the method does not depend on the experience of the operator as do the other methods that have been reported. The bleeding of ewes and methods of determining progesterone concentrations, however, require experienced personnel and expensive laboratory resources. Other body fluid (e.g. saliva) might also be sampled for progesterone analysis. A positive relationship between blood and milk levels of progesterone has been reported for pregnant cows (Laing and Heap, 1971).

It is concluded that while the accuracy of prediction was comparable to other techniques, this method is not considered to be sufficiently accurate, simple or cheap enough for widespread use to increase efficiency of feed usage by the flock. There may, however, be a limited application of such a method for research purposes such as the diagnosis of successful superovulation of donor ewes treated with PMSG for egg transfer work.

3. <u>Relationship of weight of lamb born, ewe liveweight and ovum survival with progesterone level</u>

Weight of lamb born per ewe was positively and significantly related to plasma progesterone concentrations ($\hat{B} = 0.19$; $P < 0.001$).

This finding supports that of Russel and Foot (1971). Thompson and Wagner (1974) suggested that progesterone production late in pregnancy may be related to placental mass as well as to the weight of lamb born. Bedford _et al_. (1972) also reported a good relationship between foetal weight and plasma progesterone levels after day 100 of pregnancy. These workers and others (Thompson and Wagner, 1974) have suggested that the relationship may be related to the weight of cotyledons or increasing uterine volume associated with foetal growth. Other reports, however, have failed to show that the birthweight (Sarda _et al_., 1973) or placental development (Alexander and Williams, 1966) were related to progesterone levels in the blood during late pregnancy.

Whatever the mechanism, the present results would suggest that the variation in blood progesterone due to lamb birthweight may contribute to the inability to accurately determine litter size using plasma concentrations of this hormone. This was indicated by a 13% increase in the variation explained when weight of lamb born was included in the analysis of variance shown in Table 5-9.

The differences in plasma progesterone levels between Romneys and crossbred ewes at day 120 of pregnancy were not significant. After covariancing ewe liveweight, however, Border-Romney ewes showed slightly greater progesterone levels. This appeared due to a greater weight of lamb born to the ewes since the advantage was reversed when weight of lamb born was also included in the analysis. Thus the antagonistic effects of ewe liveweight and weight of lamb born per ewe appear to be major contributors to differences in blood progesterone levels between Romney and Border-Romney ewes in late pregnancy.

Lower levels of blood progesterone in early pregnancy appeared to be associated with reduced ovum survival in ewes with either two or three ovulations. The number of ewes studied was small but the relationship was better at day 40 rather than day 20 of pregnancy. Other workers have also reported that lower embryonic mortality is often associated with greater endogenous levels of progesterone in early pregnancy (Cumming et al., 1971; Trounson and Moore, 1973, 1974; Cumming et al., 1974). This effect may be mediated through the relationship between blood levels of progesterone and rapid pre-implantation embryo growth observed by Bindon (1971a, b) who also noted increased embryonic survival with increasing progesterone levels very early in pregnancy.

The greater level of embryonic mortality following superovulation noted in the present work is unlikely to be due to an inadequate progesterone concentration given the results of Short (1960). In some of the superovulated ewes progesterone levels were increased to levels well above those considered to be within the normal physiological range. It is not clear whether these very high levels of progesterone adversely affect embryo survival and a technique using ovum transfer to superovulated ewes would be a satisfactory method of testing this.

Pre- and Post-Natal Lamb Growth

Litter size and gestation length appeared inversely related when all litter sizes and both Romney and Border-Romney ewes were considered. Within each breed, however, a relationship between litter size and gestation length was not apparent. Other reports also conflict and while Forbes (1967) showed that single lambs were carried longer *in utero* than twins with the latter carried longer than triplets, many workers have failed to establish such a relationship (Terrill, 1944; Boshier et al., 1969; Larsen, 1971; Karihaloo and Combs, 1971a).

The small number of ewes analysed within breed and litter size coupled with the small variation of gestation length probably explains the lack of statistically significant differences.

PMSG had no effect on the length of pregnancy when analysed for single- and twin-bearing ewes.

Single lambs averaged more than a kilogram heavier at birth than twin lambs which in turn averaged 0.9 kg more than lambs born as triplets ($P < 0.05$). Many other workers have also noted this inverse relationship between litter size and lamb birthweight (e.g. Larsen, 1971; Bradford et al. 1974). Whether this effect is solely due to competition between foetal and maternal tissue for a limited pool of nutrients as proposed by Hammond (1944) and Hunter (1956) is not clear. Placental development may be important since lamb birthweight has been correlated with the weight of cotyledons in late pregnancy (Alexander, 1964). Thus a limited placental size of multiple lambs may limit foetal growth of such lambs. There was no significant interaction between breed and litter size for lamb birthweight, however.

Single male lambs were carried an average of about half a day longer than single female lambs although the effect was not significant and was only apparent in Romneys. Similarly, males twin to males for both breeds were born on average more than one day after either females born co-twin to females or mixed-sexed twins ($P < 0.01$). These findings support those of Dickinson et al. (1962). Similarly, Bradford et al. (1974) observed that male lambs prolonged gestation by up to one day although these workers showed that this effect diminished as litter size increased.

Coupled with longer gestations, male single lambs were slightly (if non significantly) heavier at birth than female singles. When all ranks were considered, male lambs were on average about one third of a kilogram heavier than their female contemporaries ($P < 0.01$). The discussion of the differences in birthweight due to class of twin birth is more complex, however. Whether co-twin to males or females, male twin lambs were heavier at birth than female lambs ($P < 0.05$). This may be due to a greater ability to compete for a limited maternal pool of nutrients by males compared to females or to a greater placental size which provides a greater nutrient supply to males compared to females. The birthweight advantage of twin males over twin females was greater (0.8 kg) when like-sexed litters rather than unlike-sexed litters (0.5 kg) were compared. The present results did not support the conclusion of other workers that the prenatal growth of twin lambs is influenced not only by the sex of the lamb but by the sex of its co-twin (Donald and Purser, 1956; Larsen, 1971; Burfening, 1972; Terrill, 1972).

Over all birth ranks, Romney ewes carried lambs about half a day longer than Border-Romney ewes although the effect was not significant. Romney singles ($P < 0.1$) and twins ($P < 0.001$) were carried 0.5 day and more than 2 days longer than Border-Romneys, respectively. In the small sample of triplet-bearing ewes studied, the crossbred ewes had gestation lengths of about half a day longer than the Romneys. Larsen (1971) also noted that single lambs were carried longer (about one day) in Romney ewes compared to Border-Romney ewes and a similar breed difference was noticed when all birth ranks were considered.

Although gestation lengths were generally shorter, crossbred ewes on average had heavier lambs at birth (0.4 kg) than Romneys ($P < 0.001$). This was true for all birth ranks and there was no evidence of an interaction between breed of dam and birth rank of the lamb. In previous work with animals of the same flock it was noted that single lambs out of Border-Romney ewes were on average 8% heavier at birth than lambs born to Romney ewes (Larsen, 1971). The same study, however, failed to show a breed of ewe difference when all birth ranks were considered.

Since all ewes in the present work were mated with Southdown sires and there was no transfer of ova between ewe breeds, the separate influences of maternal genotype and lamb genotype on lamb birthweights could not be compared as in other investigations (e.g. Hunter, 1956; Dickinson et al., 1962; Larsen, 1971). It is not clear then whether the lambs from the Border-Romney ewes were heavier at birth because the maternal environment of these ewes was better than that of the Romneys (Larsen, 1971). The alternative explanation of the difference is that lambs born to Border-Romney ewes were genetically capable of more rapid pre-natal growth than Southdown x Romney crossbred lambs. The latter explanation is favoured by workers utilising a large difference between the maternal and foetal genotype for size (Hunter, 1956; Dickinson, 1962). Discussion of data on post-natal lamb growth will be confined to lambs born as either singles or twins (only 20 triplet-born lambs were available for study and some sub class numbers were small).

The age of lamb at weaning had a significant influence on weaning weight ($P < 0.001$) of single- and twin-born lambs. The regression of age of lamb on weaning weight ($\hat{B} = 0.13$) was similar to the adjustment used in the National Flock Recording Scheme ($\pm$ 0.136 for every day under or over 100 days of age at weaning) and which was based on data derived by Ch'ang and Rae (1961, 1970).

Single lambs grew 0.035 kg/day faster ($P < 0.05$) and were about 4.4 kg heavier at weaning ($P < 0.01$) than twin-born lambs reared as singles and weaned at about 99 days of age. This is in agreement with other work with mixed-age ewes at Massey by Ch'ang and Rae (1970) which cited an equivalent difference in weaning weight of 4.2 kg between these birth ranks. The greater weaning weight of single lambs compared to twin-born lambs ($P < 0.05$) is likely to be partly due to their heavier birthweight and partly to their greater intake of milk (Barnicoat *et al.*, 1949).

Although few twin lambs were reared as singles these were, on average, slightly (although not significantly) heavier than twin-reared lambs (0.16 kg). This supports Ch'ang and Rae (1970) who reported an advantage of 2.9 kg at weaning in favour of twins reared as singles compared to twin-reared lambs. This difference between these rearing ranks is probably due to the greater amount of milk available to the twin reared singly (Ch'ang and Rae, 1961).

Male (wether) lambs grew faster ($P < 0.05$) and were 3.4 kg heavier at weaning on average ($P < 0.01$) than ewe lambs when the effects of sex were studied in single- and twin-born lambs. The weaning weight difference between lamb sexes was greater than the 1.4 kg reported by Ch'ang and Rae (1961) for mixed-age Romney ewes. The present sex difference was also greater than for other comparisons between entire ram and ewe lamb weaning weights reported in New

Zealand for Romney and F_1 Border-Romney lambs (Larsen, 1971; Ch'ang and Rae, 1961) although overseas workers have noted greater weaning weight differences between ram and ewe lambs (Hazel and Terrill, 1945).

Lambs born to Border-Romney ewes grew faster ($P < 0.001$) and were 2.8 kg heavier at weaning ($P < 0.001$) than similar lambs born to Romney ewes when these effects were investigated in single- and twin-born lambs corrected for rearing rank and age at weaning. There was no evidence of a breed of ewe times rearing rank interaction for growth rate or weaning weight. The weaning weight advantage shown by lambs born to crossbred ewes was greater than the 2 kg per lamb reported by Larsen (1971) for Romney and Border-Romney lambs born to Romney or Border-Romney ewes. The present comparison more closely supports the results of a comparison of Romney and Border-Romney ewes for export lamb production which found an advantage of 2.2 to 4.4 kg in favour of progeny of crossbred ewes (Coop and Clarke, 1965). Using egg transfer methods, Larsen (1971) concluded that both the maternal and lamb genotype influences were important; the design of the present trial did not allow determination of the relative importance of these effects. It may be, however, that the use of early maturing sire breeds such as the Southdown allowed greater expression of lamb genotype differences in weaning weight than if Romney or Border-Romney sires were used.

Young Border-Romney ewes produce more milk than Romneys whether suckling single or twin lambs (Coop and Drew, 1963) although genetic differences in milk quality appear far less important in their effects on lamb growth rate (Barnicoat et al., 1957).

Southdown rams mated to Border-Romney ewes produced larger lambs at birth than when Romney ewes were involved and whether this was related to weaning weight through a difference in the ability of lambs to obtain milk (Moore, 1966; Langlands, 1972, 1973) or to a difference in the ability to grow (Ch'ang and Rae, 1961) was not clear.

SUMMARY

Differences in the reproductive phase between Romney and Border-Romney 2 year-old ewes were studied after progestagen synchronisation and treatment with PMSG. Progestagen treatment of crossbred ewes caused fewer silent heats and earlier synchronisation of heat than for Romney ewes. Border-Romney ewes also had greater natural ovulation rates and ovarian responses to PMSG resulting in a higher proportion of multiple births.

Uterine capacity measured in terms of numbers and weight of lamb born was greatest in crossbred ewes but exceeded the natural ovulation rate of both breeds. Breeding or management techniques resulting in greater ovulation rates are therefore likely to directly increase the number of lambs born.

Ovulation rates and litter sizes were substantially increased after treatment of ewes with PMSG. Considerable variation in response to the drug existed, however, and conception rates to all services were reduced. Such limitations reduce the widespread application of this technique by farmers.

Compared to Romney ewes, lambs born to Border-Romney ewes were heavier at birth and grew more rapidly to weaning. It is likely that this more rapid post-natal growth is at least partially due to a greater milk yield by the crossbred ewes and this warrants further investigation.

Methods using plasma progesterone levels either early or later in pregnancy aided identification of ewes with either single- or multiple-bearing pregnancies, but the accuracy was no better than

other methods currently available. There is a need for an accurate, simple and cheap method of identifying single- and twin-bearing ewes early in pregnancy to allow more efficient use of feed for sheep.

R E F E R E N C E S

REFERENCES

Ackerley, J.G. and Welsh, R.A.S. (1974) Diagnosing pregnancy in ewes by rectal palpation. Proc. N.Z. Soc. Anim. Prod. 34: 55.

Alexander, G. (1956) The influence of nutrition upon duration of gestation in sheep. Nature, Lond., 178: 1058.

Alexander, G. (1964) Studies on the placenta of the sheep. Effect of surgical reduction in the number of caruncles. J. Reprod. Fert., 7: 307.

Alexander, G. and Williams, D. (1966) Progesterone and placental development in the sheep. J. Endocr., 34: 241.

Alexander, G. and Williams, D. (1971) Heat stress and development of the conceptus in domestic sheep. J. Agric. Sci., 76: 53.

Allen, D.M. and Lamming, G.E. (1961) Nutrition and reproduction in the ewe. J. Agric. Sci., 56: 69.

Allison, A.J. (1968) The influence of liveweight on ewe fertility. M. Agric. Sci. Thesis, Lincoln College.

Allison, A.J. (1973) The effect of liveweight on the ovarian response and fertility of ewes treated with PMSG. Proc. N.Z. Soc. Anim. Prod., 33: 114.

Allison, A.J. (1975) Effect of nutritionally induced liveweight differences on the ovarian response and fertility in ewes treated with pregnant mare's serum gonadotrophin. N.Z. J. Agric. Res., 18: 101.

Allison, A.J. and McNatty, K.P. (1972) Levels of progesterone in peripheral blood plasma of Romney and Merino ewes during the oestrous cycle. N.Z. J. Agric. Res., 15: 825.

Allison, A.J. and Robinson, T.J. (1970) The effect of dose level of intravaginal progestagen on sperm transport, fertilisation and lambing in the cyclic Merino ewe. J. Reprod. Fert., 22: 515.

Alliston, C.W. and Ulberg, L.C. (1961) Pregnancy loss in sheep. J. Anim. Sci., 20: 608.

Averill, R.L.W. (1958) The production of living sheep eggs. J. Agric. Sci., 50: 17.

Baier, W. and Russe, I. (1968) Embryonic mortality in sheep after double ovulation. Proc. VI Int. Congr. Anim. Reprod., Paris, 1: 397.

Barnicoat, C.R., Logan, A.G. and Grant, A.I. (1949) Milk secretion studies with New Zealand Romney ewes. Parts I and II. J. Agric. Sci., 39: 44.

Barnicoat, C.R., Murray, P.F., Roberts, E.M. and Wilson, G.S. (1957) Milk secretion studies with New Zealand Romney ewes. Parts V-XI. J. Agric. Sci., 48: 9.

Bassett, J.M., Oxborrow, T.J., Smith, I.D. and Thorburn, G.D. (1969) The concentration of progesterone in the peripheral plasma of the pregnant ewe. J. Endocr., 45: 449.

Bastiman, B. (1972) The effect of ewe condition at tupping on lambing performance. Exptal. Husb., 22: 22.

Bedford, C.A., Challis, J.R.G., Harrison, F.A. and Heap, R.B. (1972) The role of oestrogens and progesterone in the onset of parturition in various species. J. Reprod. Fert. Suppl., 16: 1.

Bellows, R.A., Pope, A.L., Meyer, R.K., Chapman, A.B. and Casida, L.E. (1963) Physiological mechanisms in nutritionally induced differences in ovarian activity of mature ewes. J. Anim. Sci., 22: 93.

Bennett, D., Axelson, A. and Chapman, H.W. (1964) The effect of nutritional restriction during early pregnancy on the number of lambs born. Proc. Aust. Soc. Anim. Prod., 5: 70.

Bindon, B.M. (1971a) The role of progesterone in implantation in the sheep. Aust. J. Biol. Sci., 24: 149.

Bindon, B.M. (1971b) Role of progesterone in implantation in the sheep. J. Reprod. Fert., 24: 146.

Bindon, B.M. (1973) Genetic differences in plasma LH of the pre-pubertal lamb. J. Reprod. Fert., 32: 347.

Bindon, B.M., Ch'ang, T.S. and Turner, Helen Newton (1971) Ovarian response to gonadotrophin by Merino ewes selected for fecundity. Aust. J. Agric. Res., 22: 809.

Bindon, B.M. and Pennycuik, P.R. (1974) Differences in ovarian sensitivity of mice selected for fecundity. J. Reprod. Fert., 36: 221.

Bindon, B.M. and Turner, H.N. (1974) Plasma LH of the prepubertal lamb: a possible early indicator of fecundity. J. Reprod. Fert., 39: 85.

Blockey, M.A. de B., Parr, R.A. and Restall, B.J. (1975) Wastage of ova in young Merino ewes. Aust. Vet. J., 51: 298.

Boshier, D.P., Martin, C.A. and Quinlivan, T.D. (1969) Foetal mass and gestation length in sheep. N.Z. J. Agric. Res., 12: 575.

Bowman, J.C. (1967) Genetic variation of body weight in sheep. in "Growth and development of mammals", eds Lodge, G.A. and Lamming, G.E., Butterworths, Lond.

Boyd, J.D., Hamilton, W.J. and Hammond, J. (Jr) (1944) Transuterine ("internal") migration of the ovum in sheep and other mammals. J. Anat., (Lond.), 78: 5.

Braden, A.W.H. and Baker, A.A. (1973) Reproduction in sheep and cattle. In "The pastoral industries of Australia". Eds G. Alexander and O.B. Williams, Sydney University Press.

Braden, A.W.H., Lamond, D.R. and Radford, H.M. (1960) The control of the time of ovulation in sheep. Aust. J. Agric. Res., 11: 389.

Bradford, G.E. (1972) Genetic control of litter size in sheep. J. Reprod. Fert. Suppl., 15: 23.

Bradford, G.E., Hart, R., Quirke, J.F. and Land, R.B. (1972) Genetic control of the deviation of gestation in sheep. J. Reprod. Fert., 30: 459.

Bradford, G.E., Quirke, J.F. and Hart, R. (1971) Natural and induced ovulation rate of Finnish Landrace and other breeds of sheep. Anim. Prod., 13: 627.

Bradford, G.E., Taylor, S., Taylor, C.S., Quirke, J.F. and Hart, R. (1974) An egg transfer study of litter size, birth weight and lamb survival. Anim. Prod., 18: 249.

Bullough, W.S. (1975) Mitotic control in adult mammalian tissues. Biol. Rev., 50: 99.

Burfening, P.J. (1972) Prenatal and postnatal competition among twin lambs. J. Brit. Soc. Anim. Prod., 15: 61.

Carter, A.H. (1968) Lamb survival and growth rates. Proc. Ruakura Fmrs. Conf. p.65.

Carter, A.H., Kirton, A.H. and Sinclair, D.P. (1974) Sires for export lamb production. 1. Lamb survival, growth rate, and wool production. Proc. Ruakura Fmrs. Conf. p.20.

Casida, L.E., Woody, C.O. and Pope, A.L. (1966) Inequality in function of the right and left ovaries and uterine horns of the ewe. J. Anim. Sci., 25: 1169.

Ch'ang, T.S. and Rae, A.L. (1961) Sources of variation in the weaning weight of Romney Marsh lambs. N.Z. J. Agric. Res., 4: 578.

Ch'ang, T.S. and Rae, A.L. (1970) The genetic basis of growth, reproduction and maternal environment in Romney ewes. I. Genetic variation in hogget characters and fertility of the ewe. Aust. J. Agric. Res., 21: 115.

Chapman, A.B. and Lush, J.L. (1932) Twinning, sex ratios and genetic variability in birthweight in sheep. J. Hered., 23: 473.

Clarke, E.A. (1962) Crossbreeding in sheep. Proc. Ruakura Fmrs. Conf. p.42.

Clarke, I.J. (1973) A study of the ovarian response of New Zealand Romney ewes sequentially superovulated with Pregnant Mare's Serum Gonadotrophin. M. Agric. Sci. Thesis, Massey University.

Clarke, J.N., Roberts, E.M., Carter, A.H. and Kirton, A.H. (1966) Hormonal synchronisation of oestrus in Romney ewes during the breeding season. Proc. N.Z. Soc. Anim. Prod., 26: 107.

Cockrem, F. (1965) The analysis and interpretation of data on the bodyweight of the two-tooth ewe. Proc. N.Z. Soc. Anim. Prod., 25: 164.

Cole, H.H. and Millar, R.F. (1933) Artificial induction of ovulation and oestrus in the ewe during anoestrum. Amer. J. Physiol., 104: 165.

Coombe, J.B., Wardrop, I.D. and Tribe, D.E. (1960) A study of milk production in the grazing ewe, with emphasis on the experimental technique employed. J. Agric. Sci., 54: 353.

Coop. I.E. (1950) The effect of level of nutrition during pregnancy and during lactation on lamb and wool production of grazing sheep. J. Agric. Sci., 40: 311.

Coop, I.E. (1957) Border Leicester cross ewes for fat-lamb production. N.Z. J. Sci. Tech., A38: 966.

Coop, I.E. (1966) The response of ewes to flushing. World Rev. Anim. Prod., 4: 69.

Coop, I.E. (1967) Recent developments in crossbreeding of sheep. N.Z. J. Agric., 115: 66.

Coop, I.E. (1972) Nutrition of grazing sheep with particular reference to reproduction. Proc. N.Z. Vet. Assn. Sheep Soc., 2: 8.

Coop, I.E. (1973) Age and liveweight in sheep. N.Z. J. Exptl. Agric., 1: 65.

Coop, I.E. and Clark V.R. (1965) A comparison of Romney and first cross Border Leicester-Romney ewes for export lamb production. N.Z. J. Agric. Res., 8: 188.

Coop. I.E., Clark, V.R. and Claro, D. (1972a) Nutrition of the ewe in early lactation. I. Lamb growth rate. N.Z. J. Agric. Res., 15: 203.

Coop, I.E., Clark, V.R. and Claro, D. (1972b) Nutrition of the ewe in early lactation. II. Milk yield. N.Z. J. Agric. Res., 15: 209.

Coop, I.E. and Drew, K.R. (1963) Maintenance and lactation requirements of grazing sheep. Proc. N.Z. Soc. Anim. Prod., 23: 52.

Corbett, J.L., Furnival, E.P. and Southcott, W.H. (1973) Induced cryptorchidism in lambs. Anim. Prod., 16: 157.

Culpin, S. (1962) In-wintering of in-lamb ewes. Agriculture, Lond., 68: 579.

Cumming, I.A. (1965) A study of ovulation and early prenatal mortality in the New Zealand Romney ewe. M. Agric. Sci. Thesis, Massey University.

Cumming, I.A. (1972) Studies of the physiology of the oestrous cycle and early pregnancy in the sheep. Ph.D. Thesis, University of Melbourne.

Cumming, I.A., Baxter, R. and Lawson, R.A.S. (1974) Steroid hormone requirements for the maintenance of early pregnancy in the sheep: a study using ovariectomised, adrenalectomised ewes. J. Reprod. Fert., 40: 443.

Cumming, I.A. and McDonald, M.F. (1967) The production of ova by New Zealand Romney ewes following hormonal stimulation. N.Z. J. Agric. Res., 10: 226.

Cumming, I.A., Mole, B.J., Obst, J., de B. Blockey, M.A., Winfield, C.G. and Goding, J.R. (1971) Increase in plasma progesterone caused by undernutrition during early pregnancy in the ewe. J. Reprod. Fert., 24: 146.

Cutten, I.N. (1970) Immediate and long term effects of post-mating laparotomy on the lambing performance of Merino ewes. Proc. Aust. Soc. Anim. Prod., 8: 388.

Davies, H.L. (1963) The milk production of Merino ewes at pasture. Aust. J. Agric. Res., 14: 824.

Davies, P.J., Johnston, R.G. and Ross, D.B. (1971) The influence of energy intake on plasma levels of glucose non-esterified fatty acids and acetone in the pregnant ewe. J. Agric. Sci., 77: 261.

Denamur, R. and Martinet, J. (1955) Effects of l'ovariectomie chez la brebis pendant la gestation. Comptes Rendus des seances de la soc. de Biol., Paris, 149: 2105.

Denamur, R. and Martinet, J. (1973) Pituitary control of the corpus luteum. J. Reprod. Fert., 32: 207.

Dermody, W.C., Foote, W.C. and Hulet, C.V. (1970) Effects of season and progesterone synchronisation on ovulation rate in mature western range ewes. J. Anim. Sci., 30: 214.

Dickinson, A.G. (1960) Some genetic implications of maternal effects - an hypothesis of mammalian growth. J. Agric. Sci. 54: 378.

Dickinson, A.G., Hancock, J.L., Hovell, G.J.R., Taylor, S. and Wiener, G. (1962) The size of lamb at birth - a study involving egg transfer. Anim. Prod., 4: 64.

Dolling, C.H.S. and Nicolson, A.D. (1967) Vital statistics for an experimental flock of Merino sheep. 4. Failure in conception and embryonic loss as causes of failure to lamb. Aust. J. Agric. Res., 18: 767.

Donald, H.P. and McLean, J.W. (1935) The growth rate of lambs in Canterbury. N.Z. J. Sci. Tech., 17: 497.

Donald, H.P. and Purser, A.F. (1956) Competition *in utero* between twin lambs. J. Agric. Sci., 48: 245.

Donald, H.P., Read, J.L. and Russell, W.S. (1968) A comparative trial of crossbred ewes by Finnish Landrace and other sires. Anim. Prod., 10: 413.

Donald, H.P., Read, J.L. and Russell, W.S. (1970) Influence of litter size and breed of sire on carcass weight and quality of lambs. Anim. Prod., 12: 281.

Donald, H.P. and Russell, W.S. (1970) The relationship between liveweight of ewe at mating and weight of newborn lamb. Anim. Prod., 12: 273.

Doney, J.M., Gunn, R.G. and Smith, W.F. (1973) Transuterine migration and embryo survival in sheep. J. Reprod. Fert., 34: 363.

Dooley, M., Wodzicka-Tomaszewska, M. and Edey, T.N. (1974) Luteal function following embryonic mortality in ewes. J. Reprod. Fert., 36: 462.

Dunn, R.G., Rich, T.D., Alliston, C.W. and Kaltenbach, C.C. (1972) Progesterone levels in ewes during induced oestrus and in a hot environment. J. Anim. Sci., 34: 902.

Dutt, R.H. and Casida, L.E. (1948) Alteration of the estrual cycle in sheep by the use of progesterone and its effect upon subsequent ovulation and fertility. Endocrinology, 43: 208.

Edey, T.N. (1966) Nutritional stress and pre-implantation embryonic mortality in Merino sheep. J. Agric. Sci., 67: 287.

Edey, T.N. (1967) Early embryonic death and subsequent cycle length in the ewe. J. Reprod. Fert., 13: 437.

Edey, T.N. (1969) Prenatal mortality in sheep: A review. Anim. Breed. Abstr., 37: 173.

Edey, T.N. (1970) Nutritional stress and pre-implantation mortality in Merino sheep, (1964-7). General discussion and conclusions. J. Agric. Sci., 74: 199.

Edey, T.N. (1972) Fertility at the first oestrus following embryonic death. J. Reprod. Fert., 28: 147.

Edey, T.N. and Thwaites, C.J. (1966) Synchronisation of ewes at the second oestrus after progestagen treatment. Proc. Aust. Soc. Anim. Prod., 6: 38.

Edgar, D.G. and Ronaldson, J.W. (1958) Blood levels of progesterone in the ewe. J. Endocr., 16: 378.

Evans, W.M.R. and Wilcox, J.C. (1969) Effect of feeding during late pregnancy on growth of lambs before and after birth. Exptal. Husb., 17: 47.

Everitt, G.C. (1967a) Prenatal development of uniparous animals with particular reference to the influence of maternal nutrition in sheep. In "Growth and development of mammals" Eds. Lodge, G.A. and Lamming, G.E., Butterworths, Lond.

Everitt, G.C. (1967b) Residual effects of pre-natal nutrition on the post-natal performance of Merino sheep. Proc. N.Z. Soc. Anim. Prod., 27: 52.

Foord, H.E. (1966) Observations on the use of progestagen impregnated tampons in a herd of Dorset Hill sheep. Vet. Rec., 78: 461.

Forbes, J.M. (1967) Factors affecting the gestation length in sheep. J. Agric. Sci., 68: 191.

Forbes, J.M. (1969) A note on the voluntary feed intake of lactating ewes, their milk yield and the growth rate of their lambs. Anim. Prod., 11: 263.

Forbes, T.J. and Robinson, J.J. (1967) The effect of source and level of dietary protein on the performance of in-lamb ewes. Anim. Prod., 9: 521.

Fraser, A.F., Nagaratham, V. and Callicott, R.B. (1971) The comprehensive use of Doppler ultra-sound in farm animal reproduction. Vet. Rec., 88: 202.

Fylling, P. (1970) The effect of pregnancy, ovariectomy and parturition on plasma progesterone level in sheep. Acta. Endocr., 65: 273.

Gadsby, J.E., Heap, R.B., Powell, D.G. and Walters, D.E. (1972) Diagnosis of pregnancy and of the number of foetuses in sheep from plasma progesterone concentrations. Vet. Rec., 90: 339.

Geenty, K.G. and Jagusch, K.T. (1974) A comparison of the performance of Romney, Corriedale and Dorset sheep during lactation. Proc. N.Z. Soc. Anim. Prod., 34: 14.

Ginther, O.J. (1971) Influence of progesterone and number of corpora lutea on ovaries in sheep. Amer. J. Vet. Res., 32: 198.

Glover, A.F. (1972) Milk production in the ewe - a review. N.Z. Vet. Assn. Sheep Soc., 2: 22.

Gordon, I. (1958) The use of serum gonadotrophin (P.M.S.) in the control of fertility of sheep. 1. The hormonal augmentation of fertility in the ewe during the breeding season. J. Agric. Sci., 50: 123.

Gordon, I. (1963) The induction of pregnancy in the anoestrous ewe by hormonal therapy. I. Progesterone - Pregnant Mare's Serum therapy during the breeding season. J. Agric. Sci. 60: 31.

Gordon, I. (1971) Induction of early breeding in sheep by standard and modified progestagen - PMS treatments. J. Agric. Sci., 76: 337.

Gordon, I. (1972) Control of reproduction in sheep: Towards programmed lamb production. Ir. Dept. Agric. J., 68: 3.

Guerra, J.C., Thwaites, C.J. and Edey, T.N. (1971) The effects of live weight on the ovarian response to pregnant mare serum gonadotrophin and on embryonic mortality in the ewe. J. Agric. Sci., 76: 177.

Guerra, J.C., Thwaites, C.J. and Edey, T.N. (1972) The effects of components of body weight on reproductive efficiency in the Merino ewe. J. Agric. Sci., 78: 245.

Gunn, R.G. and Doney, J.M. (1973) A note on the influence of the pattern of live-weight and body condition recovery between weaning and mating on food consumption and reproductive performance of Scottish Blackface ewes. J. Agric. Sci. 81: 189.

Gunn, R.G., Doney, J.M. and Russel, A.J.F. (1969) Fertility in Scottish Blackface ewes as influenced by nutrition and body condition at mating. J. Agric. Sci., 73: 289.

Gunn, R.G., Doney, J.M. and Russel, A.J.F. (1972) Embryo mortality in Scottish Blackface ewes as influenced by body condition at mating and by post mating nutrition. J. Agric. Sci., 79: 19.

Hafez, E.S.E. (1963) Symposium on Growth: physio-genetics of prenatal and postnatal growth. J. Anim. Sci., 22: 779.

Hammond, J. (1932) In "Growth and development of mutton qualities in the sheep". Oliver and Boyd, Edinburgh.

Hammond, J. (1944) Physiological factors affecting birthweight. Proc. Nutr. Soc., 2: 8.

Hazel, L.N. and Terrill, C.E. (1945) Effects of some environmental factors on weanling traits of range Rambouillet lambs. J. Anim. Sci., 4: 331.

Hedges, D.A. and Reardon, R.F. (1973) Effects of liveweight and PMS administration on reproduction rate in Merino ewes. Third World Conference on Animal Production, Melbourne, Aust., 1: 5(e) 13.

Hight, G.K. and Jury, K.E. (1973) Ewe liveweights and the relationship of liveweight and fertility in Romney and Border Leicester x Romney ewes. N.Z. J. Agric. Res., 16: 447.

Hight, G.K., Lang, D.R. and Jury, K.E. (1973) Hill country sheep production. V. Occurrence of oestrus and ovulation rate of Romney and Border Leicester x Romney ewe hoggets. N.Z. J. Agric. Res., 16: 509.

Hodge, R.W. (1966) The effect of nutritional restriction during and at mid pregnancy on the reproductive performance of crossbred ewes. Aust. J. Exptal. Anim. Husb., 6: 311.

Holst, P.J. (196) The ovarian response to Pregnant Mare's Serum (PMS) administration after intravaginal progestagen treatment of cyclic and anoestrous ewes. Aust. J. Agric. Sci., 20: 1143.

Holst, P.J., Mattner, P.E., and Braden, A.W.H. (1973) The effect of handling the reproductive tract on tubal transport in the ewe. J. Reprod. Fert., 32: 313.

Huggett, A. St G. (1959) Aspects of placental function. Ann. N.Y. Acad. Sci., 75: 873.

Hughes, K.L. (1972) Experimental Brucella ovis infection in ewes. Aust. Vet. J., 48: 12.

Hulet, C.V. (1972) A rectal-abdominal palpation technique for diagnosing pregnancy in the ewe. J. Anim. Sci., 35: 814.

Hulet, C.V. and Foote, W.C. (1967) Physiological factors affecting frequency and rate of lambing. J. Anim. Sci., 26: 553.

Hulet, C.V. and Foote, W.C. (1969) Ovulatory response of the ewe to repeated injections of PMS. J. Anim. Sci., 29: 457.

Hulet, C.V. and Shupe, W.L. (1973) Predicting multiple births in sheep by rectal-abdominal palpation. Proc. (West Sec.) Amer. Soc. Anim. Sci., 24: 237.

Hulet, C.V. and Stormshak, F. (1972) Some factors affecting response of anoestrous ewes to hormone treatment. J. Anim. Sci., 34: 1011.

Hunt, W.L., Addleman, D. and Bogart, R. (1971) Induction of multiovulation in the ewe following synchronisation of ostrus. J. Anim. Sci., 32: 491.

Hunter, G.L. (1956) The maternal influence on size in sheep. J. Agric. Sci., 48: 36.

Hunter, G.L. (1968) Increasing the frequency of pregnancy in sheep. II. Artificial control of rebreeding and problems of conception and maintenance of pregnancy during the post-partum period. Anim. Breed. Abstr., 36: 533.

Hunter, G.L., Adams, C.E. and Rowson, L.E.A. (1955) Inter-breed ovum transfer in sheep. J. Agric. Sci., 46: 143.

Jeffries, B.C. (1961) Body condition scoring and its uses in management. Tasm. J. Agric., 32: 19.

Jeffries. B.C. and Fearn, J.T. (1956) Overfat ewes have light lambs. J. Dept. Agric., S. Aust., 60: 133.

Kammalade, W.G., Welch, J.A., Nalbandov, A.V. and Norton, H.W. (1952) Pituitary activity of sheep in relation to the breeding season. J. Anim. Sci., 11: 646.

Karihaloo, A.K. and Combs, W. (1971a) Some maternal effects on growth in lambs produced by reciprocal crossbreeding between Lincoln and Southdown sheep. Can. J. Anim. Sci., 51: 511.

Karihaloo, A.K. and Combs, W. (1971b) Some prenatal effects on birth size in Lincoln and Southdown lambs produced by reciprocal ovum transfers. Can. J. Anim. Sci., 51: 729.

Keane, M.G. (1973) Effects of body condition and level of nutrition on the response of ewes to hormone treatment in the non-breeding season. Irish J. Agric. Res., 12: 229.

Keane, M.G. (1974) Effect of progestagen-PMS hormone treatment on reproduction in ewe lambs. Irish J. Agric. Res., 13: 39.

Kempthorne, O. (1952) "The design and analysis of experiments": J. Wiley and Sons, New York.

Kenny, P.A. and Davies, I.F. (1974) Effect of time of joining and rate of stocking on the production of Corriedale ewes in Southern Australia. 2. Survival and growth of lambs. Exptal. Agric. and Anim. Husb., 14: 434.

Keo gh, R. (1975) Pers Comm.

Killeen, I.D. (1967) The effects of body weight and level of nutrition before, during and after joining on ewe fertility. Aust. J. Exptal. Agric. Anim. Husb., 7: 126.

Killeen, I.D. (1972) The effect of liveweight on fertilisation in maiden andmature Border Leicester x Merino ewes. Proc. Aust. Soc. Anim. Prod., 9: 186.

Killeen, I.D. and Moore, N.W. (1970) The effect of PMS and HCG on ovulation and fertility in the ewe. Aust. J. Agric. Res., 21: 807.

Kirton, A.H. (1970) Lamb growth rates. N.Z. J. Agric., 121: 32.

Klosterman, W.E., Bolin, D.W., Buchanan, M.L. Bolin, F.M. and Dinusson, W.E. (1953) Protein requirements of ewes during breeding and pregnancy. J. Anim. Sci., 12: 188.

Knight, T.W., Oldham, C.M. and Lindsay, D.R. (1975) Studies in ovine fertility in agricultural regions in Western Australia: the influence of a supplement of Lupins (*Lupinus angustifolius* cv. Uniwhite) at joining on the reproductive performance of ewes. *Aust. J. Agric. Res.*, *26*: 567.

Laing, J.A. and Heap, R.B. (1971) The concentration of progesterone in the milk of cows during the reproductive cycle. *Br. Vet. J.*, *127*: xix.

Lamond, D.R. (1962) The effect of season on hormonally induced ovulation in Merino ewes. *J. Reprod. Fert.*, *4*: 111.

Lamond, D.R. (1963) The effect of nutritive status on oestrus, ovulation and Graaafian follicles of ewes. *Aust. J. Agric. Res.*, *14*: 483.

Lamond, D.R. (1964a) Synchronisation of ovarian cycles in sheep and cattle. *Anim. Breed. Abstr.*, *32*: 269.

Lamond, D.R. (1964b) Quantitative studies of the interaction between Pregnant Mare Serum and progesterone on ovarian function in the ewe. *J. Reprod. Fert.*, *7*: 171.

Lamond, D.R. (1973) The role of the bovine practitioner in synchronisation and twinning in cattle. *Bovine Practitioner*, *1*: 2.

Lamond, D.R. and Bindon, B.M. (1966a) The biological assay of follicle stimulating hormone in hypophysectomised immature mice. *J. Endocr.*, *34*: 365.

Lamond, D.R. and Bindon, B.M. (1966b) Effect of gonadotrophins on uterine growth of hypophysectomised mice. *Nature, Lond.*, *209*: 512.

Lamond, D.R. and Emmens, C.W. (1959) The effect of hypophysectomy on mouse uterine weight response to gonadotrophins. J. Endocr., 18: 251.

Lamond, D.R. and Gaddy, R.G. (1972) Plasma progesterone in cows with multiple ovulations. J. Reprod. Fert., 29: 307.

Lamond, D.R., Gaddy, R.G. and Kennedy, S.W. (1972) Influence of season and nutrition on luteal plasma progesterone in Rambouillet ewes. J. Anim. Sci., 34: 626.

Lamond, D.R., Henricks, D.M., Hill, J.R. and Dickey, J.R. (1971) Breed differences in plasma progesterone concentraticns in the bovine during proestrus. Biol. Reprod., 5: 258.

Land, R.B. (1971) The incidence of oestrus during lactation in Finnish Landrace, Dorset Horn and Finn-Dorset sheep. J. Reprod. Fert., 24: 345.

Land, R.B. (1973) Ovulation rate of Finn-Dorset sheep following unilateral ovariectomy or chlorpromazine treatment at different stages of the oestrous cycle. J. Reprod. Fert., 33: 99.

Land, R.B. (1974) Physiological studies and genetic selection for sheep fertility. Anim. Breed. Abstr., 42: 155.

Lang, D.R. and Hight, G.K. (1967) Age of puberty, length of breeding season and ovulation rate in Romney Marsh and Border Leicester x Romney Marsh hoggets. Proc. N.Z. Soc. Anim. Prod., 27: 48.

Langlands, J.P. (1972) Growth and herbage consumption of grazing Merino and Border Leicester lambs reared by their mothers or fostered by ewes of the other breed. Anim. Prod., 14: 317.

Langlands, J.P. (1973) Milk and herbage intakes by grazing lambs born to Merino ewes and sired by Merino, Border Leicester, Corriedale, Dorset Horn and Southdown rams. Anim. Prod., 16: 285.

Large, R.V. (1970) The biological efficiency of meat production in sheep. Anim. Prod., 12: 393.

Larsen, W.A. (1971) A study of some factors affecting reproductive performance in New Zealand Romney and Border-Leicester x Romney two-tooth ewes. M. Agric. Sci. Thesis, Massey University.

Laster, D.B. (1972) Follicular development in heifers infused with follicle-stimulating hormone. J. Reprod. Fert., 28: 285.

Laster, D.B. and Glimp, H.A. (1974) Influence of breed on response to exogenous hormones in estrous and anestrous ewes. J. Anim. Sci., 39: 1129.

Lawson, R.A.S. and Rowson, L.E.A. (1972) Influence of breed of ewe and offspring on litter size after egg transfer in sheep. J. Reprod. Fert., 28: 433.

Liggins, G.C. (1968) Premature parturition after infusion of corticotrophin or cortisol into foetal lambs. J. Endocr., 42: 323.

Liggins, G.C., Grieves, S.A., Kendall, J.Z. and Knox, B.S. (1972) The physiological roles of progesterone, oestradiol-17B and prostaglandin $F_{2\alpha}$ in the control of ovine parturition. J. Reprod. Fert. Suppl., 16: 85.

Lightfoot, R.J. and Marshall, T. (1974) The effects of pasture type and lupin grain supplementation on ovulation rate of Merino ewes. 1 - Rate of lupin grain supplementation. West. Aust. J. Agric., 15: 29.

Lightfoot, R.J. and Marshall, T. (1975) Effects of lupin grain supplementation on ovulation rate and fertility of Merino ewes. Proc. Aust. Soc. Reprod. Biol., 7: 36.

Louca, A., Mavrogenis, A. and Lawlor, M.J. (1974) Effects of plane of nutrition in late pregnancy on lamb birthweight and milk yield in early lactation of Chios and Awassi sheep. Anim. Prod., 19: 341.

Lynch, J.J., Brown, G.D., May, P.F. and Donnelly, J.B. (1972) The effect of witholding drinking water on wool growth and lamb production of grazing Merino sheep in a temperate climate. Aust. J. Agric. Res., 23: 659.

McClelland, T.H. and Forbes, T.J. (1973) The effect of level and pattern of energy intake during late pregnancy on the performance of housed Scottish Blackface ewes. Anim. Prod., 16: 165.

McConnell, G.R. and Jagusch, K.T. (1972) The production of prime lambs from Coopworth ewes. Proc. N.Z. Soc. Anim. Prod., 32: 50.

McDonald, M.F. (1969) Egg transplantation studies in Romney ewes. Proc. N.Z. Soc. Anim. Prod., 29: 95.

McDonald, M.F. and Ch'ang, T.S. (1966) Variation in ovarian activity of Romney Marsh ewes. Proc. N.Z. Soc. Anim. Prod., 26: 98.

Mackenzie, A.J. and Edey, T.N. (1975) Effects of pre-mating undernutrition on oestrus, ovulation and prenatal mortality in Merino ewes. J. Agric. Sci., 84: 119.

McLaren, A. (1962) The relation between natural fecundity and response to follicle stimulating hormone. J. Endocr., 25: 137.

McLaren, A. and Michie, D. (1969) Control of pre-natal growth in mammals. Nature, 187: 363.

McLaren, A. and Michie, D. (1963) Nature of the systemic effect of litter size on gestation period in mice. J. Reprod., Fert., 6: 139.

McNatty, K.P., Allison, A.J. and Thurley, D.C. (1972) Progesterone levels in peripheral plasma of Romney ewes during pregnancy. N.Z. J. Agric. Res., 15: 831.

McNatty, K.P., Revfeim, K.J.A. and Young, A. (1973) Peripheral plasma progesterone concentrations in sheep during the oestrous cycle. J. Endocr., 58: 219.

McNatty, K.P. and Thurley, D.C. (1974) Variation in peripheral progesterone levels during the day at different stages of gestation in sheep. N.Z. J. Agric. Res., 17: 309.

Marshall, T. and Lightfoot, R.J. (1974) The effects of pasture type and lupin grain supplementation on ovulation rate of Merino ewes. 2 - Duration of lupin grain supplementation. West. Aust. J. Agric., 15: 31.

Migalina, T.G. (1973) The effect of Vitamin A and PMS on oestrus, conception rate and prolificacy in Karakul ewes. Anim. Breed. Abstr., 42: 172.

Monteath, M.A. (1971) The effect of sub maintenance feeding of ewes during mid pregnancy on lamb and wool production. Proc. N.Z. Soc. Anim. Prod., 31: 105.

Moore, N.W. (1968) The survival and development of fertilised eggs transferred between Border Leicester and Merino ewes. Aust. J. Agric. Res., 19: 295.

Moore, N.W., Barrett, S., Brown, J.B., Schindler, I., Smith, M.A., and Smyth, B. (1969) Oestrogen and progesterone content of ovarian vein blood of the ewe during the oestrous cycle. J. Endocr., 44: 55.

Moore, N.W., Barrett, S. and Brown, J.B. (1972) Progesterone concentrations in maternal and foetal blood plasma of ewes. J. Endocr., 53: 187.

Moore, N.W., Rowson, L.E.A. and Short, R.V. (1960) Egg transfer in sheep. Factors affecting the survival and development of transferred eggs. J. Reprod. Fert., 1: 332.

Moore, R.W. (1966) Genetic factors affecting the milk intake of lambs. Aust. J. Agric. Res., 17: 191.

Moore, R.W. (1975) Pers. Comm.

Moore, R.W. and Hight, G.K. (1973) Pre-mating supplementation of ewes. M.A.F. Res. Div. Ann. Report - Whatawhata. p.13.

Murphy, B.E.P. (1964) Application of the property of protein-binding to the assay of minute quantities of hormones and other substances. Nature (Lond.) 201: 679.

Murphy, B.E.P. (1967) Some studies of the protein-binding of steroids and their application to the routine micro and ultramicro measurement of various steroids in body fluids by competitive protein-binding radioassay. J. Clin. Endocr. Metab., 27: 973.

Neville, W.E. (1966) Reproduction of ewes affected by level and time of PMS injection. J. Anim. Sci., 25: 927.

Newton, J.E. and Betts, J.E. (1968) Factors affecting litter size in the Scotch Halfbred ewe. II. Superovulation and the synchronisation of oestrus. J. Reprod. Fert., 17: 485.

Newton, J.E., Betts, J.E. and Large, R.V. (1970) Increasing litter size in three breeds of sheep by super ovulation. J. Agric. Sci., 75: 355.

Newton, J.E., Denehy, H.L. and Betts, J.E. (1972) The effect of Pregnant Mare Serum Gonadotrophin on ovulation rate in Scottish Halfbred and Scottish Blackface ewes. Br. Vet. J., 128: 35.

Niswender, G.D. and Midgley, A.R. (1970) In "Immunological methods in steroid determination". Eds. Peron, F. and Caldwell, B. Appleton-Century-Crofts, New York.

Obst, J.M. and Seamark, R.F. (1970) Plasma progesterone concentrations during the reproductive cycle of ewes grazing yarloop clover. J. Reprod. Fert., 21: 545.

Obst, J.M., Seamark, R.F. and McGowan, C.J. (1971) Plasma progesterone concentrations during pregnancy and parturition of ewes grazing yarloop clover. J. Reprod. Fert., 26: 259.

Obst, J.M., Seamark, R.F. and McGowan, C.J. (1972) Plasma hormone levels during pregnancy in ewes grazing oestrogenic clover. Proc. Aust. Soc. Anim. Prod., 9: 204.

O'Shea, T., Piggott, F.A., Thwaites, C.J. and Edey, T.N. (1974) Sperm transport in ewes following embryonic death. Proc. 6th Ann. Conf. Aust. Soc. Reprod. Biol. Paper No.23.

Packham, A. and Triffit, L.K. (1966) Association of ovulation rate and twinning in Merino sheep. Aust. J. Agric. Res., 17: 515.

Palsson, H. (1956) Augmentation of fertility in Iceland ewes with pregnant-mare-serum in successive years. Proc. III Int. Congr. Reprod., Camb., 3: 112.

Palsson, H. (1962) Augmentation of fertility of Icelandic ewes with PMSG in successive years. J. Reprod. Fert., 3: 55.

Palsson, H. and Verges, J.B. (1952) Effects of the plane of nutrition on growth and the development of carcass quality in lambs. Pt 1. The effects of high and low planes of nutrition at different ages. J. Agric. Sci., 42: 1.

Pant, H.C., Hopkinson, C. and Fitzpatrick, R.J. (1972) Plasma oestradiol, progesterone and LH concentrations during the ovine oestrous cycle. J. Reprod. Fert. 31: 501.

Papadopoulos, J.C. and Robinson, T.J. (1957) Fat lamb studies in Victoria. II. The interaction between pre- and post-natal planes of nutrition on the production of wool and lambs by crossbred sheep. Aust. J. Agric. Res., 8: 471.

Parkins, J.J., Fraser, J., Ritchie, N.S. and Hemingway, R.G. (1974) Urea as a protein source for ewes with twin lambs in late pregnancy and early lactation. Anim. Prod., 19: 321.

Pascoe, W.B. (1973) Effects of grazing on the growth and development of white clover. M. Agr. Sci. Thesis, Massey University.

Peters, H., Byskov, A.G., Lyntern-Moore, S. and Faber, M. (1973) Follicle growth initiation in the immature mouse ovary: extraovarian or intraovarian control? J. Reprod. Fert., 35: 619.

Polge, C. and Rowson, L.E.A. (1973) Recent progress in techniques for increasing reproductive potential in farm animals. Proc. World Conf. Anim. Prod. (1973), 6: 1.

Quinlivan, T.D., Martin, C.A., Taylor, W.B. and Cairney, I.M. (1966) Estimates of pre- and perinatal mortality in the New Zealand Romney Marsh ewe. 1. Pre- and perinatal mortality in those ewes that conceived to one service. J. Reprod. Fert., 11: 379.

Radford, H.M. (1959) Variation in the incidence of twin ovulations in Merino ewes on a constant plane of nutrition. Aust. J. Agric. Res., 10: 337.

Reeve, J.L., Kenney, P.A., Baxter, R. and Cumming I.A. (1975) Effect of lupin grain, wheat and lucerne supplements on ovulation rate in maiden Border Leicester x Merino ewes. Proc. Aust. Soc. Reprod. Biol., 7: 38.

Reid, R.L. (1958) The nutritional physiology of the ewe in late pregnancy. J. Aust. Inst. Agric. Sci., 24: 291.

Reid, R.L. (1963) The nutritional physiology of the pregnant ewe. J. Aust. Inst. Agric. Sci., 29: 215.

Richardson, C. (1972) Pregnancy diagnosis in the ewe: A review. Vet. Rec., 90: 264.

Rizzoli, D.J., Baxter, R., Reeve, J. and Cumming, I.A. The effect of lupin grain supplementation on ovulation rate in Border Leicester x Merino ewes. Proc. Aust. Soc. Reprod. Biol., 7: 37.

Roberts, E.M. and Edgar, D.G. (1966) Timing of injection of PMS for the anoestrous breeding of ewes. Nature (Lond.) 212: 1048.

Robertson, H.A. and Sarda, I.R. (1971) A very early pregnancy test for mammals: its application to the cow, ewe and sow. J. Endocr., 49: 407.

Robinson, J.J. (1973) Some aspects of ewe nutrition. Vet. Rec., 92: 602.

Robinson, J.J. and Forbes, T.J. (1968) The effect of protein intake during gestation on ewe and lamb performance. Anim. Prod., 10: 297.

Robinson, T.J. (1951) The control of fertility in sheep. The augmentation of fertility by gonadotrophin treatment of the ewe in the normal breeding season. J. Agric. Sci., 41: 6.

Robinson, T.J. (1955) Endocrine relationships and the induction of oestrus and ovulation in the anoestrous ewe. J. Agric. Sci., 46: 37.

Robinson, T.J. (1961) The time of ovulation and efficiency of fertilisation following proge terone and Pregnant Mare Serum treatment in the cyclic ewe. J. Agric. Sci., 57: 129.

Robinson, T.J. (1967) Conclusions. In "The control of the ovarian cycle in sheep". Ed. T.J. Robinson, Sydney University Press.

Robinson, T.J., Salamon, S., Moore, N.W., and Smith, J.F. (1967) The evaluation of SC-9880-impregnated intravaginal sponges for the synchronisation of oestrus for large scale artificial insemination of Merino ewes in summer and autumn. In "The control of the ovarian cycle in the sheep". Ed. T.J. Robinson, Sydney University Press.

Robinson, T.J. and Smith, J.F. (1967) The evaluation of SC-9880-impregnated intravaginal sponges used with or without PMS for the advancement of the breeding season of British breed ewes. In "The control of the ovarian cycle in sheep". Ed. T.J. Robinson, Sydney University Press.

Roche, J.F. (1968) Effect of the interval between withdrawal of progestagen pessaries and time of PMS administration on oestrus and ovulation in cyclic ewes. Irish J. Agric. Res. 7: 1.

Rowson, L.E.A., Lawson, R.A.S. and Moor, R.M. (1971) Production of twins in cattle by egg transfer. J. Reprod. Fert., 25: 261.

Russel, A.J.F., Doney, J.M. and Gunn, R.G. (1969) Subjective assessment of body fat in live sheep. J. Agric. Sci., 72: 451.

Russel, A.J.F., Doney, J.M. and Reid, R.L. (1967a) The use of biochemical parameters in controlling nutritional state in pregnant ewes, and the effect of undernourishment during pregnancy on lamb birth-weight. J. Agric. Sci., 68: 351.

Russel, A.J.F., Doney, J.M. and Reid, R.L. (1967b) Energy requirements of the pregnant ewe. J. Agric. Sci., 68: 359.

Russel, A.J.F. and Foot, J.Z. (1971) The use of circulating progesterone concentrations in the identification of twin-bearing ewes. Anim. Prod., 13: 377.

Russel, A.J.F. and Foot, J.Z. (1973) The effect of level of nutrition at two stages of pregnancy on the performance of primiparous ewes. Proc. Nutr. Soc., 32: 27A.

Sarda, I.R., Robertson, H.A. and Smeaton, T.C. (1973) Sequential changes in plasma progesterone levels in the ewe during the estrous cycle, and during pregnancy in intact and ovariectomised sheep. Can. J. Anim. Sci., 53: 25.

Saumande, J. and Thimonier, J. (1972) Early pregnancy diagnosis in the ewe by measuring the progesterone in the peripheral blood. Anim. Breed. Abstr., 41: 392.

Scales, G.H. (1968) Lactation performances of Romney, Corriedale, and Merino ewes in a tussock grassland environment. N.Z. J. Agric. Res., 11: 155.

Scanlon, P.F. (1972) Frequency of transuterine migration of embryos in ewes and cows. J. Anim. Sci., 34: 791.

Schmidt-Elmendorff, H., Loraine, J.A. and Bell, E.T. (1962) Studies on the biological activity of various gonadotrophin preparations. J. Endocr., 24: 349.

Sheehan, W. and Lawlor, M.J. (1972) Optimum levels of energy supplementation of silage for ewes in late pregnancy. Anim. Prod., 15: 29.

Shemesh, M., Ayalon, N. and Linder, H.R. (1973) Early pregnancy diagnosis based upon plasma progesterone levels in the cow and the ewe. J. Anim. Sci., 36: 726.

Short, R.V. (1957) Progesterone and related steroids in the blood of domestic animals. CIBA. Foundation Colloquia on Endocrinology, 11: 362.

Short, R.V. (1960) Appendix to "Egg transfer in sheep. Factors affecting the survival and development of transferred eggs". J. Reprod. Fert., 1: 347.

Short, R.V. (1961) 'Progesterone', in "Hormones in blood". Eds. C.H. Gray and A.L. Bacharach. New York: Academic Press.

Short, R.V., McDonald, M.F. and Rowson, L.E.A. (1963) Steroids in the ovarian venous blood of ewes before and after gonadotrophic stimulation. J. Endocr., 26: 155.

Sittman, K. (1972) Intrauterine migration and mortality of sheep embryos. Can. J. Anim. Sci., 52: 195.

Slen, S.B. and Whiting, F. (1952) Lamb production as affected by level of protein in the ration of the mature ewe. J. Anim. Sci., 11: 166.

Slotin, C.A., Harrison, F.A. and Heap, R.B. (1971) Kinetics of progesterone metabolism in the pregnant sheep. J. Endocr., 49: xxx.

Smith, J.F. (1975) Pers. Comm.

Smith, J.F., Fairclough, R.J., Payne, E. and Peterson, A.J. (1975) Plasma hormone levels in the cow. 1. Changes in progesterone and oestrogen during the normal oestrous cycle. N.Z. J. Agric. Res., 18: 123.

Sokal, R.R. and Rohlf, F.J. (1969) "Biometry": Freeman, San Francisco.

Spedding, C.R.W., Large, R.V. and Walsingham, J.M. (1974) The importance of the size of the female in sheep. Wld. Rev. Anim. Prod., 8: 90.

Stabenfeldt, G.H., Drost, M. and Franti, C.E. (1972) Peripheral plasma progesterone levels in the ewe during pregnancy and parturition. Endocrinology, 90: 144.

Stabenfeldt, G.H., Holt, J.A. and Ewing, L.L. (1969) Peripheral plasma progesterone levels during the ovine oestrus cycle. Endocrinology, 85: 11.

Tait, R.M. (1971) Influence of nutritional status on hormone-induced superovulation in normally cycling ewes. Can. J. Anim. Sci., 51: 771.

Terrill, C.E. (1944) The gestation period of range sheep. J. Anim. Sci., 3: 434.

Terrill, C.E. (1972) In "Reproduction in Farm Animals". Lea and Febigen, Philadelphia.

Terrill, C.E. and Hazel, L.N. (1947) Length of gestation in range sheep. Amer. J. Vet. Res., 8: 66.

Tervit, H.R. (1967) Studies in the in vivo cleavage and in vitro culture of New Zealand Romney sheep ova. M. Agr. Sci. Thesis, Massey University.

Thimonier, J., Pelletier, J. and Land, R.B. (1972) The concentration of plasma LH in male and female lambs of high and low prolificacy breed types. J. Reprod. Fert., 31: 498.

Thompson, A.M. and Thompson, W. (1949) Lambing in relation to the diet of the ewe. Brit. J. Nutr., 2: 290.

Thompson, F.N. and Wagner, W.C. (1974) Plasma progesterone and oestrogens in sheep during late pregnancy: contribution of the maternal adrenal and ovary. J. Reprod. Fert., 41: 57.

Thompson, W. and Aitken, F.C. (1959) Diet in relation to reproduction and the viability of the young. II. Sheep: World survey of reproduction and review of feeding experiments. Tech. Comm. Commonw. Bur. Anim. Nutr. No.20.

Thompson, W. and Fraser, A.H.H. (1939) Feeding concentrates to the in-lamb ewe. The effects on lambing results. Scot. J. Agric., 22: 71.

Thorburn, G.D., Bassett, J.M. and Smith, I.D. (1969) Progesterone concentration in the peripheral plasma of sheep during the oestrous cycle. J. Endocr., 45: 459.

Thorburn, G.D., Cox., R.I., Currie, W.B., Restall, B.J. and Schneider, W. (1973) Prostaglandin F and progesterone concentrations in the utero-ovarian venous plasma of the ewe during the oestrous cycle and early pregnancy. J. Reprod. Fert. Suppl., 18: 151.

Thorburn, G.D., Nicol, D.H., Bassett, J.M., Shutt, D.A. and Cox, R.I. (1972) Parturition in the goat and sheep: changes in corticosteroids, progesterone, oestrogens, and prostaglandin F. J. Reprod. Fert. Suppl., 16: 61.

Treacher, T.T. (1970a) Effects of nutrition in late pregnancy on subsequent milk production in ewes. Anim. Prod., 12 23.

Treacher, T.T. (1970b) Apparatus and milking techniques used in lactation studies with sheep. J. Dairy Res., 37: 289.

Trounson, A.O. and Moore, N.W. (1972) Ovulation rate and survival of fertilized ova in Merino ewes selected for and against multiple births. Aust. J. Agric. Res., 23: 851.

Trounson, A.O. and Moore, N.W. (1973) The effect of progesterone and oestrogen on the survival of fertilised ova in ovariectomised ewes. Proc. Aust. Soc. Endocr., 16: 32.

Trounson, A.O. and Moore, N.W. (1974) Effect of progesterone and oestrogen on the survivaland development of fertilised ova in the ovariectomised ewe. Aust. J. Biol. Sci., 27: 511.

Turner, C.B. and Hindson, J.C. (1975) An assessment of a method of manual pregnancy diagnosis on the ewe. Vet. Rec., 96: 56.

Underwood, E.J. and Shier, F.L. (1942) Studies in sheep husbandry in W.A. ii - The influence of feeding during late pregnancy on the birth-weight, growth rate, and quality of the lamb. J. Agric. W. Aust., 19: 37.

Underwood, E.J., Shier, F.L. and Cariss, H.G. (1943) Studies in sheep husbandry in W.A. iv. - The influence of a high level of prenatal feeding in lamb production. J. Agric. W. Aust., 20: 288.

Wallace, L.R. (1948) The growth of lambs before and after birth in relation to the level of nutrition. J. Agric. Sci., 38: 93.

Wallace, L.R. (1954) Studies in the augmentation of fertility of Romney ewes with Pregnant-Mare Serum. J. Agric. Sci., 45: 60.

Warwick, E.J. and Casida, L.E. (1943) Effects of pituitary gonadotrophins on estrual phenomena in ewes. Endocrinology, 33: 169.

Wilcox, J.C. (1968) Effect of time and method of castration on performance of fat lambs. Exptal. Husb., 17: 52.

Williams, P.C. (1945) Studies on the biological action of serum gonadotrophin. 1. Decline in response after hypophysectomy. J. Endocrin., 4: 127.

Yeates, N.T.M. (1953) The effect of high air temperature on reproduction in the ewe. J. Agric. Sci., 43: 199.

Young, S.S.Y., Grown, G.H., Turner, H.N. and Dolling, C.H.S. (1965) Genetic and phenotypic parameters for body weight and greasy fleece weight at weaning in Australian Merino sheep. Aust. J. Agric. Res., 16: 997.

Yuzlikaev, R.D. (1973) The biological and economic effectiveness of PMS. Anim. Breed. Abstr., 42: 129.

A P P E N D I C E S

APPENDIX 1: BARTLETT'S TEST FOR HOMOGENEITY OF VARIANCE FOR OVULATION RATE DATA (BORDER-ROMNEY, LOW PLANE OF NUTRITION GROUP).

a. Raw Data

Dose of PMSG (i.u.)	d.f. (n-1)	Variance S^2	Coded S^2	Log Coded S^2
0	17	0.2516	2.516	0.4007
600	19	0.5763	5.763	0.7606
1200	18	3.6198	36.198	1.5586

$Chi^2 = 89.57$ **

The variance is heterogeneous

b. Square Root Transformed Data

Dose of PMSG (i.u.)	d.f. (n-1)	Variance S^2	Coded S^2	Log Coded S^2
0	17	0.0424	4.24	0.6274
600	19	0.0781	7.81	0.8927
1200	18	0.2538	25.38	1.4045

$Chi^2 = 14.74$ **

The variance approaches homogeneity

APPENDIX II: REPARAMETRISATION OF NON FULL RANK (EXPERIMENTAL DESIGN) MODELS

Given that all treatment classes exist, the reparametrisation such as that summarised in Appendix III can be used to estimate directly the treatment comparisons of interest.

For example, in the analysis of weight of lamb born (see Chapter II) the treatment comparison that estimates the difference between breeds if given by:

$$\tfrac{1}{9}\ (t_1 + t_2 + t_3 - t_4 - t_5 - t_6 \ldots\ldots\ldots - t_{16} - t_{17} - t_{18})$$

The reparametrised model estimated $u + t_1$, for example, by:

$$\widehat{u + t_1} = \hat{u} + \widehat{BRD} - \hat{P}_l + \hat{P}_q - \hat{L}_l + \hat{L}_q - \widehat{BP}_l + \widehat{BP}_q - \widehat{BL}_l$$
$$+ \widehat{BL}_q + \widehat{P_lL_l} - \widehat{P_lL_q} - \widehat{P_qL_l} + \widehat{BP_lL_l} - \widehat{BP_lL_q} - \widehat{BP_qL_l}$$

as given by the first row of the Tableau in Appendix III. Similarly, $\widehat{u + t_j}$ is given by the j^{th} row of the Tableau. Thus the estimated difference between breeds, for example, is given by:

$$\tfrac{1}{9}\Big[(\widehat{u + t_1}) + (\widehat{u + t_2}) + (\widehat{u + t_3}) - (\widehat{u + t_4}) \ldots\ldots - (\widehat{u + t_{17}})$$
$$- (\widehat{u + t_{18}})\Big]$$

$$= \tfrac{1}{9}\Big[\hat{u} + \widehat{BRD} - \hat{P}_l + \ldots\ldots\ldots - \widehat{BP_qL_l}$$
$$+ \hat{u} + \widehat{BRD} - \hat{P}_l + \ldots\ldots\ldots + 2\widehat{BP_lL_q} + 0$$
$$\vdots$$
$$- \hat{u} + \widehat{BRD} - \hat{P}_l - \ldots\ldots\ldots + \widehat{BP_qL_l}$$

$$= \tfrac{1}{9}\ (18\ \widehat{BRD}) = 2\ \widehat{BRD}$$

Thus the estimated partial regression coefficient $\widehat{BRD}$ must be multiplied by two to obtain the estimated difference between breeds (Border Leicester x Romney - Romney). Thus the reparametrised regression coefficients will estimate multiples of the required treatment comparisons. The actual multiple in any case may be derived from the Tableau. For example, the linear PMSG effect is given by the treatment comparison:

$$\tfrac{1}{6}\,(-\,t_1 - t_2 - t_3 \,\ldots\ldots\ldots + t_{16} + t_{17} + t_{18})$$

which is estimated by $2\hat{P}_1$.

Since the reparametrised Tableau is orthogonal, $\hat{P}1$, for example, estimates:

$$\Sigma_j c_j t_j / \Sigma c_j^2$$

$$= \tfrac{1}{12}\,(\,-\,t_1 - t_2 - t_3 \,\ldots\ldots\ldots + t_{16} + t_{17} + t_{18})$$

which is one-half the linear PMSG effect.

However, the t values obtained for the estimated regression coefficients are unaffected by scalar multiplication of the estimates.

If the estimated variance of $\widehat{BRD}$ equals $\hat{\sigma}_B^2$, for example, then the value of the t-statistic corresponding to the null hypothesis $\widehat{BRD} = 0$, is given by:

$$\widehat{BRD}/\hat{\sigma}_B = t$$

This is the same as the value of the t-statistic corresponding to the null hypothesis: $2\widehat{BRD} = 0$ since the estimated variance of $2\widehat{BRD}$ is given by $4\,\hat{\sigma}_B^2$ and:

$$t = \frac{2\ \widehat{BRD}}{2\ \hat{\sigma}_B} = \frac{\widehat{BRD}}{\hat{\sigma}_B} \quad \text{as before}$$

However, given now that all treatment classes do <u>not</u> exist, the estimated regression coefficients from the reparametrised Tableau must be interpreted with care. For example, if treatments 3 and 6 (in Appendix III) of the Tableau were omitted, then, proceeding as before, the result of the difference between breeds, for example:

$$\frac{1}{8}(t_1 + t_2 - t_4 - t_5 + t_7 \ldots\ldots\ldots - t_{17} - t_{18})$$

is estimated by

$$\frac{1}{8}(16\ \widehat{BRD} + 2\widehat{BP}_l - 2\widehat{BP}_q - 2\widehat{BL}_l - 2\widehat{BL}_q + 2\widehat{BP_l L_l} + 2\widehat{BP_l L_q} - 2\widehat{BP_q L_l})$$

which is not a simple multiple of the estimated regression coefficient $\widehat{BRD}$.

Thus in the unbalanced case an alternative reparametrisation is needed to estimate the treatment comparisons of interest directly.

In the present example, however, the required estimates were obtained by taking the appropriate comparison among treatment means as described in Chapter II.

APPENDIX III: REPARAMETRISED TABLEAU FOR MODEL TO INVESTIGATE WEIGHT OF LAMB BORN

						PMSG		Litter Size		Interactions									
t_j	Breed of ewe	Litter Size	Dose of PMSG	Mean u	Breed BRD	Linear P_l	Quad-ratic P_q	Linear L_l	Quad-ratic L_q	BP_l	BP_q	BL_l	BL_q	P_lL_l	P_lL_q	P_qL_l	BP_lL_l	BP_lL_q	BP_qL_q
1	B	S[A]	0	1	1	-1	1	-1	1	-1	1	-1	1	1	-1	-1	1	-1	-1
2	B	Tw	0	1	1	-1	1	0	-2	-1	1	0	-2	0	2	0	0	2	0
3	B	Tr	0	1	1	-1	1	1	1	-1	1	1	1	-1	-1	1	-1	-1	1
4	R	S	0	1	-1	-1	1	-1	1	1	-1	1	-1	1	-1	-1	-1	1	1
5	R	Tw	0	1	-1	-1	1	0	-2	1	-1	0	2	0	2	0	0	-2	0
6	R	Tr	0	1	-1	-1	1	1	1	1	-1	-1	-1	-1	-1	1	1	1	-1
7	B	S	1	1	1	0	-2	-1	1	0	-2	-1	1	0	0	2	0	0	2
8	B	Tw	1	1	1	0	-2	0	-2	0	-2	0	-2	0	0	0	0	0	0
9	B	Tr	1	1	1	0	-2	1	1	0	-2	1	1	0	0	-2	0	0	-2
10	R	S	1	1	-1	0	-2	-1	1	0	2	1	-1	0	0	2	0	0	-2
11	R	Tw	1	1	-1	0	-2	0	-2	0	2	0	2	0	0	0	0	0	0
12	R	Tr	1	1	-1	0	-2	1	1	0	2	-1	-1	0	0	-2	0	0	2
13	B	S	2	1	1	1	1	-1	1	1	1	-1	1	-1	1	-1	-1	1	-1
14	B	Tw	2	1	1	1	1	0	-2	1	1	0	-2	0	-2	0	0	-2	0
15	B	Tr	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	R	S	2	1	-1	1	1	-1	1	-1	-1	1	-1	-1	1	-1	1	-1	1
17	R	Tw	2	1	-1	1	1	0	-2	-1	-1	0	2	0	-2	0	0	2	0
18	R	Tr	2	1	-1	1	1	1	1	-1	-1	1	-1	1	1	1	-1	-1	-1

[A] S - Single Tw - Twin Tr - Triplet

APPENDIX IV: RAINFALL OVER THE FOUR MONTHS AFFECTING THE EARLY PART OF THE TRIAL - A COMPARISON WITH THE 30-YEAR AVERAGE

	Rainfall in mm[A]			
	Jan	Feb	Mar	Apr
1973[B]	50.4	15.6	102.3	58.6
30-year Average	83.8	63.6	73.3	74.4

A - Source D.S.I.R. Grasslands Division, Palmerston North.

B - Year of trial.

APPENDIX V: STUDENT-NEWMANS-KEULS TEST TO COMPARE MEANS: CYCLE LENGTHS FOLLOWING PMSG TREATMENT

1. Differences between means when these are ranked from largest to smallest

	1	2	3
Rank	1	2	3
Mean	16.158	15.768	15.674
No./group	52	57	53
Group	0 i.u.	1200 i.u.	600 i.u.

Rank	Mean	No./group	Group			
1	16.158	52	0 i.u.		-	-
2	15.768	57	1200 i.u.	0.390[A] *	-	-
3	15.674	53	600 i.u.	0.484. *	0.094 N.S.	-

$M.S._{within} = 0.812$ $\sqrt{M.S._{within}} = 0.901$

Degrees of freedom 150 Use d.f. = 120

2.

		K^{B} =	2	3
$\sqrt{M.S._{within}}$	x	$Q^{C}_{0.05(K,120)}$	2.800	3.356
		$Q_{0.05(K,120)}$	2.523	3.024
$\sqrt{M.S._{within}}$	x	$Q_{0.01(K,120)}$	3.702	4.200
		$Q_{0.01(K,120)}$	3.336	3.784

3. For a difference between means to be significant at the level of significance it must be equal to or greater than:-

$$LSR = Q_{\alpha(K,120)} \sqrt{M.S._{within} \quad \frac{n_1 + n_2}{2n_1 n_2}}^{D}$$

A Difference between means.

B K = 1 + difference in ranks of two means.

C $Q_{0.05(K,120)}$ = value from studentized range for different values of K when the error variance has 120 degrees of freedom. The test is carried out at the 5% (0.05) or 1% (0.01) level of significance.

D n_1 and n_2 are the sample sizes associated with the two means.

4. Using the calues calculated in 2. the following ranges may be calculated using the formula of 3.

(a) 5% level of significance

$LSR^{A}_{1 \rightarrow 3} = 3.024 \sqrt{0.019} = 0.417^{*}$ B

$LSR_{1 \rightarrow 2} = 2.523 \sqrt{0.018} = 0.342^{*}$

$LSR_{2 \rightarrow 3} = 2.523 \sqrt{0.018} = 0.243$ N.S. C

(b) 1% level of significance (testing only those ranges which were significant at the 5% level)

$LSR_{1 \rightarrow 3} = 3.784 \sqrt{0.019} = 0.522$ N.S.

$LSR_{1 \rightarrow 2} = 3.336 \sqrt{0.018} = 0.448$ N.S.

A $LSR_{1 \rightarrow 3}$ = least significant range to compare means with ranks of 1 and 3.

B The difference between the means is greater than the LSR. Hence the two means are significantly different at the level of significance tested for.

C The difference between the means is less than the LSR.

5. From this test it is clear that:

i) Both groups of ewes receiving PMSG had shorter cycle lengths ($0.01 < P < 0.05$) than ewes not receiving the drug.

ii) There was no significant difference in cycle length ($P < 0.05$) between groups of ewes receiving either 600 i.u. or 1200 i.u. PMSG.

APPENDIX VI: DISCRIMINATION POINTS AND ACCURACY OF PREDICTION OF NUMBERS OF CORPORA LUTEA USING PLASMA PROGESTERONE CONCENTRATIONS (Estimated using AOV model[A])

	Border-Romney			Romney		
	Discrimination Points	Diagnoses: Total	Correct	Discrimination Points	Diagnoses: Total	Correct
Day 20						
1 CL	0.092	10	4	1.221	8	6
2	0.903-1.110	12	2	1.222-1.362	9	0
3	1.111-1.416	10	3	1.363-1.479	4	0
4	1.417-1.709	3	2	1.480-1.728	3	0
5	1.710-1.724	2	0	1.729-2.064	2	1
6	1.725	4	1	2.065	1	1
		41	12(29.3%)		27	8(29.6%)
Day 40						
1 CL	1.115	10	6	1.274	8	8
2	1.116-1.362	12	3	1.275-1.586	9	2
3	1.363-1.661	10	3	1.587-1.835	4	2
4	1.662-1.876	3	0	1.836-1.964	3	0
5	1.877-1.983	2	0	1.965-2.148	2	0
6	1.984	4	3	1.149	1	1
		41	15(36.6%)		27	13(48.1%)
Day 60						
1 CL	1.692	10	7	1.718	8	5
2	1.693-1.934	12	4	1.719-2.011	9	3
3	1.935-2.009	10	1	2.012-2.216	4	1
4	2.010-2.028	3	0	2.217-2.298	3	1
5	2.029-2.276	2	0	2.299-2.524	2	0
6	2.277	4	2	2.524	1	1
		41	14(34.2%)		27	11(40.7%)

[A] See Table 5-1