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Breeding ewe lambs successfully to improve lifetime performance☆

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ABSTRACT

Ewe lambs have the ability to be successfully bred at 7–9 months of age. Breeding ewe lambs has a number of advantages including increased profitability and lifetime reproductive performance. However due to low and variable reproductive performance and the potential for negative effects on future performance, most ewe lambs are not bred. This review compares the differences in reproductive performance between ewe lambs and mature ewes. In addition, it summarises the known effects of ewe lamb breeding on lifetime performance. It also focuses on factors affecting the success of ewe lamb breeding. Lastly, it outlines the optimal management of the ewe lamb to the weaning of her first lamb and to maximise her lifetime performance.

1. Introduction

Ewe lambs at 7–9 months of age have the potential to be successfully bred. However in many production systems such, as those in New Zealand, less than 40% of ewe lambs are bred to lamb at 12–14 months of age (Anonymous, 2013). While in Australia, less than 20% of non-Merino and less than 5% of Merino ewe lambs are bred (Curtis and Croker, 1985). If a ewe lamb can be successfully bred to lamb at one year of age, and rear lamb(s) successfully to weaning, there is the potential to increase profitability (Young et al., 2010) and lifetime reproductive performance (Kenyon et al., 2011). Additional advantages from breeding ewe lambs can also include: (1) increased feed demand in lactation, hence improving utilisation of additional herbage grown in the spring period, (2) an increase in total number of lambs born per farm per year and therefore greater income through the sale of additional lambs, (3) an early selection tool for ewe replacements, (4) more progeny born on farm, thereby increasing selection pressure for replacements, (5) a reduction in the generation interval through the selection of progeny born to ewe lambs, and (6) a reduction in greenhouse gas emissions per unit of product produced (Dyrmundsson, 1973; Tyrell, 1976; Baker et al., 1978; McCall and Hight, 1981; Hight, 1982; Gavigan and Rattray, 2002; Kenyon et al., 2004a; Hegarty et al., 2010; Kenyon, 2012).

However, given that the majority of ewes are not bred as lambs, there must be some limitations or disadvantages of this management technique that impede the use of ewe lamb breeding by farmers. Potential disadvantages include: (1) poor and variable reproductive performance, (2) an increase in feed demand, (3) greater live weight targets at a young age, (4) if not well managed, future live weight and productivity can be negatively affected, (5) progeny born to ewe lambs can display poorer survival and tend to be lighter at birth and weaning, (6) breeding at a young age can increase on farm costs, (7) breeding at a young age reduces management flexibility and can increase farmer workload, (8) mortality rates of pregnant/lactating ewe lambs can be

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higher than non-pregnant ewe lambs and (9) wool production can be reduced (Tyrell, 1976; McMillan and McDonald, 1983; Johnston et al., 1996; Gavigan and Rattray, 2002; Kenyon et al., 2004a; Kenyon, 2012).

The following review is in five parts. Firstly, it compares the reported differences in reproductive performance between ewe lambs and mature ewes. Secondly, it outlines the known effects of ewe lamb breeding on lifetime performance. Thirdly, it discusses factors affecting the success of breeding ewe lambs on the weaning of their lambs. Fourthly, it identifies management practices that maximise the performance of the ewe lamb and her progeny. Lastly, it briefly summarises the known long term effects of being born to a ewe lamb on lifetime productivity.

2. Comparison of reproductive performance of mature ewes and ewe lambs

Ewe lambs can display shorter less intense oestrus periods (Dyrmundsson, 1973; Edey et al., 1978; McMillan and Parker, 1981; Schick, 2001) and are less likely to seek and stand for the ram in comparison to mature ewes (Dyrmundsson, 1981; Smith and Knight, 1998) which has resulted in them being termed 'shy' breeders. This 'shy' breeding is illustrated by the results of Allison et al. (1975), who reported that ewe lambs need to be served by the ram on at least three occasions before 100% of ewe lambs actually have semen inside their reproductive tract. Keane (1976) reported that rams had more difficulty breeding with ewe lambs than mature ewes. Similarly, Davies and Beck (1993) suggested rams have a preference for mature ewes rather than ewe lambs, indicating ewe lambs and mature ewes should be separated for breeding. In support of this, Keane (1976) reported higher breeding performance in ewe lambs kept separate from mature ewes. A further issue with ewe lambs is the occurrence of oestrus without ovulation and ovulation without oestrus which can occur post puberty (Edey et al., 1977; Chu and Edey, 1978; Quirke, 1981). Ovulation (Quirke and Hanrahan, 1977; Davies and Beck, 1993; Beck et al., 1996; Mulvaney, 2011, Table 1) and conception/fertility rates (Keane, 1976; Smith and Knight, 1998; Annett and Carson, 2006) have also been reported to be lower in ewe lambs than mature ewes.

Post conception losses are usually greater in ewe lambs than mature ewes. Beck et al. (1996) reported higher rates of embryonic loss in ewes lambs between days 3 and 30 of pregnancy and Quirke and Hanrahan (1977) reported 33% and 73% of transferred embryos resulted in lambs born to ewe lambs and mature ewes respectively. Mulvaney (2011) reported more than twice the rates of reproductive loss, defined as the difference between ovulation rate and the number of fetuses in mid-pregnancy, in Romney ewe lambs compared to mature ewes. Quirke (1981) also stated that embryonic mortality in ewe lambs can be high and suggested that this loss was not due to a poorer uterine environment per se, but instead being due to poor quality of fertilised eggs. In support of this, Quirke and Hanrahan (1977) reported cleaved ova from ewe lambs had less than half the survival rate than those from mature ewes. McMillan and McDonald (1985) also reported fertilised ova from ewe lambs were less likely to survive than those from mature ewes which they believed was an important factor for the lower fertility observed in this age group. Lower progesterone concentrations in ewe lambs compared to mature ewes between days 14 and 30 of pregnancy (Davies and Beck, 1993) might contribute to reduced embryo survival observed in these other studies. The combined effects of lower ovulation rates, poorer breeding behaviour and increased rates of ova and embryo loss result in lower reproductive rates in ewe lambs compared to mature ewes (Donald et al., 1968; Forrest and Bichard, 1974; Mulvaney, 2011).

There are few data available on the comparative loss of fetuses in the latter half of pregnancy in ewe lambs and mature ewes. Mulvaney (2011) reported no difference in fetal loss rates between ewe lambs and mature ewes, whereas in an embryo transfer study, fetuses derived from embryos collected from ewe lambs were less likely to survive to term than those from mature ewes (Ptak et al., 2003). However, there is increased farmer and veterinary evidence in New Zealand suggesting that ewe lambs are more likely to lose fetuses in late pregnancy than mature ewes. Some potential reasons for this are discussed later in the review.

Litter size at birth is not only smaller in ewe lambs compared to mature ewes, but their lambs are also lighter and display lower survival rates (Donald et al., 1968; Dyrmundsson, 1973; Atta and El Khidir, 2005; Annett and Carson, 2006; Morel et al., 2010; Mulvaney, 2011). It has been reported that ewe lambs can display poorer maternal behaviour (Atta and El Khidir, 2005; Mulvaney, 2011), which could negatively impact on their lambs survival, although some refute this and indicate ewe lambs can be very good mothers (Dyrmundsson, 1973). Annett and Carson (2006) reported that lambs born to ewe lambs had lower IgG concentrations 24–36 h post birth than those born to mature ewes, which are also likely to impact on lamb survival. Snowder et al. (2001) using milk scores as a proxy measure for milk production showed that ewe lambs had lower milk production than older ewes and their lambs were lighter at weaning. The combined effects of lower litter sizes at birth and poorer lamb survival is that fewer lambs are weaned per ewe presented for breeding in ewe lambs compared to mature ewes (Donald et al., 1968; Dyrmundsson, 1973; Mulvaney, 2011).

3. Potential long term consequences for the young dam of breeding to lamb at 12 months of age

There are conflicting reports in the literature on the long term impacts of ewe lamb breeding. It has been reported that ewe lamb breeding can have a negative impact on live weight at the subsequent breeding, although this effect is often relatively small (Keane, 1974; Tyrell, 1976; Baker et al., 1981; McMillan and McDonald, 1983; Kenyon et al., 2008c). The potential for ewe lamb breeding to negatively affect rebreeding performance is greater if a large negative impact on rebreeding live weight occurs; however, any negative impact on live weight from breeding as a ewe lamb does not persist past the weaning of the second litter of lambs (Dyrmundsson, 1973; Kenyon et al., 2011). Similarly, while ewe lamb fleece weight can be reduced by pregnancy

Table 1
Comparison of ewe and mature ewe performance.

Experiment	Ovulation rate	Pregnancy rate[2] (%)	Litter size born per ewe	Lamb Survival (%)	Lambs weaned per ewe mated	Ewe age groups in comparison
Donald et al. (1968)		77 vs. 95 vs. 96		78 vs. 88 vs. 98	0.69 vs. 1.28 vs. 1.60	Ewe lambs, 2 and 3 year olds
Forrest and Bichard (1974)		56 vs. 93 vs. 95	1.15 vs. 1.55 vs. 1.73			Ewe lambs, 2 or 3 yr old ewes
Quirke and Hanrahan (1977)[1]	1.51 vs. 3.07					Ewe lambs, multiparous ewes 3–5 yea rs old
Davies and Beck (1993)	1.1 vs. 1.5					Ewe lambs, mature multiparous ewes
Beck et al. (1996)	1.07 vs.1.25					Ewe lambs, multiparous ewes 2–5 years old
Annett and Carson (2006)		0.67 vs. 0.85			0.59 vs. 1.50	Ewe lambs, multiparous
Munoz et al. (2009)			1.30–1.54 vs. 1.86–2.20	57–78 vs. 68–84	0.25–0.36 vs. 1.18–1.44	Ewe lambs and 2 year old ewes
Morel et al. (2010)				81 vs. 90		Ewe lambs, mixed aged ewes
Mulvaney (2011)	1.14 vs. 1.82	47 vs. 97	0.66 vs. 1.59	79 vs. 89	0.52 vs. 1.42	Ewe lambs, multiparous ewes 2–5 years old

Within studies parameters with differing superscripts are significantly different.
[1] Treated with PMSG.
[2] In some studies referred to as conception rate ($P < 0.05$).

and lactation, there appears to be no flow on effects in subsequent years (Tyrell, 1976; Baker et al., 1981; McCall and Hight, 1981). Therefore nutritional strategies need to limit any negative impact of ewe lamb breeding on future live weight and performance and this will be discussed later in this review.

Most studies indicate either no effect (Suiter and Croker, 1970; Moore et al., 1983; Akcapinar et al., 2005) or even a positive effect (McCall and Hight, 1981; Craig, 1982; McMillan and McDonald, 1983; Fogarty et al., 2007) of ewe lamb breeding on rebreeding reproductive performance and subsequent lamb survival. Ewe pregnancy rates and number of lambs born per ewe, as the ewe aged from two to six years have been reported not to differ between those either bred as a ewe lamb or not (Cannon and Bath, 1969; Baker et al., 1978; Ponzoni et al., 1979; Morel et al., 2010). Similarly, Kenyon et al. (2011) reported no difference in breeding performance and number of fetuses per ewe during the period from breeding at 18 months of age through to five years, between ewes that were either bred or not as a ewe lamb. This is not a new concept, in the review by Dyrmundsson (1973), he stated that “it is now widely accepted that early breeding of well managed and adequately nourished ewes has no detrimental effects on the ewes concerned in terms of subsequent reproductive efficiency”. When the data of ewes which had lambed as a ewe lamb was combined with the additional performance they achieved in later years, lifetime reproductive performance was greater than those which did not lamb in their first year of life (Kenyon et al., 2011). This result suggests that any additional benefit in lifetime reproductive performance by breeding a ewe lamb is very much dependant on the performance achieved as a ewe lamb (Young et al., 2010) and indicates the importance of ensuring appropriate management strategies during that period. Contrary to the believe of many farmers, ewe lamb breeding has not been reported to decrease ewe longevity through increased mature ewe losses (Ponzoni et al., 1979; Baker et al., 1981; Kenyon et al., 2011).

4. Factors affecting reproductive success in the ewe lamb

4.1. Timing of onset of puberty

Most sheep breeds display a seasonal pattern of reproduction, controlled by the photoperiod, which is an additional constraint to the timing of puberty in ewe lambs (Fitzgerald and Butler, 1982; Foster et al., 1985). Not only do ewe lambs need to be sufficiently mature to begin reproduction, they also need to breed within a defined period, so that their offspring are born at an optimal time for nourishment and survival (Foster et al., 1985). The younger (and therefore earlier) they can be bred, allows their next mating to be better integrated with the mating of the adult ewe flock, which can simplify management. The timing of puberty in ewe lambs occurs later in the breeding season than the onset of seasonal breeding activity in mature ewes, resulting in the breeding season of ewe lambing tending to be shorter than that of mature ewes (Dyrmundsson, 1973; Smith and Knight, 1998). Hulet et al. (1969) and Dyrmundsson (1973) reported that many ewe lambs display only one or two oestrus events within a season, and the timing between oestrus in those that display more than one event, can often be irregular. Further, the number of days between oestrus events can also be decreased in ewe lambs (Dyrmundsson, 1973). If a ewe lamb fails to achieve puberty in its first autumn, it will be delayed until the following breeding season (Foster et al., 1985). Those that fail to achieve puberty make up a significant proportion of ewe lambs diagnosed as barren for that breeding season, indicating that they are a major limiting factor in achieving high lambing percentage in ewe lambs (Bichard et al., 1974). Hulet et al. (1969) reported that ewe lambs which displayed oestrus in their first autumn displayed greater lifetime reproductive performance. Factors affecting the timing of puberty and the success of ewe lamb breeding include age, live weight, nutrition, genotype and breed and are discussed in later sections of this review.

The young ewe has the capability to reproduce after achieving puberty, but her reproductive capability increases during her first breeding season. For example, while ovulation rates do not to differ between the first, second and third oestrous cycles, Hare and Bryant (1985) reported fewer viable embryos in ewe lambs bred during their first cycle. Based on these findings they reported that fertility increased by approximately 20% when breeding occurred at the second rather than first oestrus period. Similarly, Beck and Davies (1994) reported improved fertility in the third versus first oestrus. Zain and Mousa (1999) also found that stage of the breeding season influenced ovarian activity, non-return rate and lambing rate.

Exogenous hormones can be used to manipulate puberty onset and ewe lamb reproductive performance. The techniques utilised include: (1) progestagen sponges or controlled internal drug releasers (CIDRs), (2) hormone therapy such as PMSG/eCG and, (3) the use of Regulin® (melatonin) implants (Quirke, 1979a,b, 1981; Smith and Knight, 1998; Gordon, 1999). However, many would question the wisdom of breeding from a young female that is not physiologically mature to achieve puberty spontaneously.

4.2. Genetic and breed effects

A number of genetic parameters affect reproductive performance of ewe lambs (Dyrmundsson, 1973). Selection for date of lambing is related to the date of ewe lamb first oestrus, and has been suggested as a screening aid in the selection process (Smith et al., 1995). Further, the fertility of two-year old is genetically correlated to ewe lamb oestrus (Chang and Rae, 1972), which itself is under genetic control (Chang and Rae, 1970). Baker et al. (1979) reported that the number of oestrous cycles during the first breeding season was a heritable trait (0.31 ± 0.08).

There is clear variation between breeds for the live weight at puberty, timing of puberty and the proportions displaying oestrus at differing time points within the season (Hulet et al., 1969; Laster et al., 1972; Dyrmundsson, 1973; Allison et al., 1975; Hight and Jury, 1976; Meyer and French, 1979; Craig, 1982; McMillan and Moore, 1983; Moore et al., 1983, 1989; Baker et al., 1985; Muir, 2001; Gaskin et al., 2005; Fogarty et al., 2007). There are also breed differences in pregnancy rates, reproductive rates and lambing percentages (McMillan and McDonald, 1983; Moore et al., 1983, 1984, 1989; Muir, 2001; Snowder et al., 2001; Stevens, 2001a,b; Kenyon et al., 2004b; Fogarty et al., 2007). For example, breeds such as Border Leicester, East Friesian, Finnish Landrace, Polypay and Rambouillet and composites derived from these breeds, and those with the Booroola gene, display higher rates of reproductive performance as a ewe lamb (Laster et al., 1972; Dyrmundsson, 1973; Kenyon et al., 2004b; Gaskin et al., 2005; Fogarty et al., 2007). An Irish study with four ewe lamb breeds reported that the lambing rate ranged from 23% to 92% depending on breed (Quirke, 1981). Breeds can also differ in the timing of when puberty occurs and the length of their first breeding season (Dyrmundsson, 1973; Muir, 2001). These results indicate that there is scope to change breed or to cross breed to improve the reproductive performance of ewe lambs. However, farmers will need to consider what other impacts these breeds, or composites based on these breeds, might have on their farming system before simply changing breed to improve ewe lamb breeding performance.

There are limited data on the heritability of traits associated with the reproductive performance of ewe lambs, regardless of breed, but they are likely to be low, given the low heritability of reproductive traits in adult sheep (Safari et al., 2005, 2007; Afolayan et al., 2008, 2009). Fogarty et al. (1994) reported heritability estimates for number of lambs born and weaned by ewe lambs of 0.17 ± 0.06 and 0.08 ± 0.05, respectively. Despite the low heritability estimates, it would seem likely that reproductive performance of ewe lambs could be improved by direct selection. A constraint to this approach is that sires need to be selected on the performance of their female relatives in traits that are not expressed until at least one year of age.

Scope exists for indirect selection and there appears to be significant variation within breed in age at puberty, the proportion of ewe lambs displaying oestrus at differing time points within the season, pregnancy rates and reproductive rates between animals with different genetic potential for growth, carcass and wool production traits. Rosales Nieto et al. (2013a,b) reported that Merino lambs within a flock with higher breeding values for growth to post-weaning age achieved puberty at a younger age and that a greater proportion of these ewe lambs achieved puberty by 8–10 months of age. The lambs with higher breeding values for post-weaning liveweight were also more fertile and achieved a higher reproductive rate than those with lower breeding values. This is consistent with Afolayan et al. (2008, 2009) who reported moderate genetic correlations between early growth and reproductive performance over the first three breeding seasons, but they did not compare the genetic correlations for ewes mated at 7 months of age compared to those mated at older ages.

4.3. Age of ewe lamb

The age of the ewe lamb has the potential to affect whether puberty occurs within her first autumn and how early in the breeding season puberty might occur. However, age and live weight (see later section) are often confounded and their effects can be difficult to separate. Hulet et al. (1969) reported that age had a small independent effect from live weight on puberty onset. Laster et al. (1972) found that age had a positive effect on the percentage of ewe lambs lambing and number of lambs born per ewe lamb. In contrast, age only influenced the probability of a ewe lamb becoming pregnant in one of four breeds in the study of Gaskin et al. (2005). Dyrmundsson (1973) reported that the mean age at which puberty occurred differed between breeds and that there was considerable range within breeds. This might explain the variation observed between studies on the impact of age. Regardless, Bichard et al. (1974) suggested selecting ewe lambs born early in the lambing season and then subsequently breeding them later in their first breeding season, as a means of maximising the percentage of ewe lambs pregnant.

4.4. The ram effect

The ram effect, commonly referred to as teasing, which commonly utilises vasectomised rams for 17 days just prior to the spontaneous onset of puberty can advance mean breeding date and overall pregnancy rates (Kenyon et al., 2005, 2006a,b,c; Kenyon, 2012; Cave et al., 2012) and on occasion has increased twin pregnancy rates (Kenyon et al., 2006b). It appears that the response to the teasing effect is greater closer to the expected onset of the ewe lamb breeding activity (Cave et al., 2012). The optimal vasectomised ram to ewe lamb ratio is in the range of 1:70–100 (Kenyon et al., 2007a). Alternatives to a full 17 day exposure to mature vasectomised rams include short-scrotum ram lambs or entire rams used for just a few days prior to breeding, but these are less successful (Kenyon et al., 2008a; Kenyon et al., 2006c).

4.5. Live weight and liveweight gain

Heavier ewe lambs are more likely to achieve puberty in their first autumn (Hulet et al., 1969; Dyrmundsson, 1973; Winn and Cumberland, 1974; Meyer and French, 1979; McMillan and Moore, 1983). Furthermore, there is a clear positive relationship between live weight and reproductive performance in ewe lambs (Dyrmundsson, 1973, 1981; Bichard et al., 1974; Allison et al., 1975; Hight and Jury, 1976; Keane, 1976; Moore et al., 1978; Meyer and French, 1979; Moore and Smeaton, 1980; Meyer, 1981; McMillan and Moore, 1983; Gaskin et al., 2005; Kenyon et al., 2005, 2006a, 2009, 2010). Therefore, any factor that affects the growth and thus live weight of the ewe lamb in its first 7–10 months of life can impact on its early reproductive performance. For example, age of dam, birth/rearing rank, date of birth, level of nutrition pre- and post-weaning and genetic potential for growth all have the potential to influence whether or not a ewe lamb reaches puberty in its first autumn (Dyrmundsson, 1973; McCall, 1978; Baker et al., 1979; Smith et al., 1995). It is universally accepted that puberty will occur within the range of 40–60% of mature ewe live weight. It has also been suggested that, rather than there being a critical live weight per-se that must be achieved for puberty to occur, there is in fact a threshold weight that an animal must at least achieve before they have the capability of achieving puberty (Fitzgerald and Butler, 1982). Foster et al. (1985), who showed that later in the breeding season, puberty was achieved at lighter live weights in comparison to earlier in the season.

In mature ewes, it is well established that higher live weights are associated with increases in fertility, ovulation rate and or reproductive rate (Smith, 1991; Scaramuzzi et al., 2006; Ferguson et al., 2011). McMillan and Moore (1983) stated that live weight at breeding accounted for 71% and 60% of the between-flock differences in ewe lambs successfully bred and lambs born per ewe joined respectively. The studies of McMillan and Moore (1983) and Stevens (2001a,b) found a 6.0%, 2.0%, and 3.5% increase in the percentage of ewe lambs displaying oestrus, conception rate and number of lambs born per ewe lamb presented for breeding respectively, per kg increase in live weight at breeding. Bichard et al. (1974) reported that the number of ewe lambs lambing increased by only 1% for each additional kg in live weight at the start of breeding. Reproductive rate in Merino ewe lambs increased linearly by around 4.5% for each additional kg of live weight at the start of breeding (Rosales Nieto et al., 2013a,b). These effects of live weight at breeding on fertility and reproductive rate are generally greater than those observed in mature ewes, suggesting that achieving heavier live weight at breeding is more critical for younger ewes. The results of Kenyon et al. (2004b) suggested each kg at breeding above 36 kg was worth an additional 2% of lambs weaned per ewe lamb.

Interestingly, Stevens and McIntyre (1999) reported that lambing percentage was not related to live weight over the range of 40–51 kg. This may suggest that there is a live weight range within some breeds and genotypes at least, where further gains in live weight do not always result in an additional increase reproductive performance. Similarly, in mature ewes, there is the plateauing of the static effect of live weight on ovulation rate at heaver live weights (Smith, 1991; Scaramuzzi et al., 2006).

In summary, across studies, poor performance occurs when live weight at breeding is below 35 kg; conversely higher performance occurs above 40–45 kg (Dyrmundsson, 1973, 1981; Bichard et al., 1974; Allison et al., 1975; Hight and Jury, 1976; Keane, 1976; Moore et al., 1978; Meyer and French, 1979; Moore and Smeaton, 1980; Meyer, 1981; McMillan and Moore, 1983; Gaskin et al., 2005; Kenyon et al., 2005, 2006a, 2009, 2010). Therefore there is some merit in using 40 kg as a minimum when deciding which ewe lambs to present for breeding. Further, as discussed later in the review, a ewe lamb that is heavier at breeding is more likely to wean a heavier lamb herself and she will be also be heavier at weaning.

Feeding regimen and/or the liveweight gain profile of the ewe lambs from when she was weaned until her first breeding can affect reproductive performance (McMillan and Wilson, 1983; Moore et al., 1978; Moore and Smeaton, 1980; Gaskin et al., 2005), although the effects are difficult to separate *per-se* from live weight itself at the start of breeding. In mature ewes, increased feeding prior to breeding, often termed the dynamic or "flushing" effect, can improve reproductive performance (Smith, 1991; Scaramuzzi et al., 2006). There is some evidence for a similar effect influencing ewe lamb breeding performance (Mulvaney et al., 2010a,b). McMillan and Moore (1983) reported that the greater the autumn liveweight gain, the higher the chance of a ewe lamb achieving oestrus for a given live weight, which they suggested was analogous to the 'dynamic' effect in flushing.

4.6. Body condition score

Body condition score (BCS) is a subjective measure of soft tissue, predominantly fat in the lumbar region (Jefferies, 1961; Russel et al., 1969). In mature ewes, there is a general positive relationship between reproductive performance and BCS. The use of the BCS technique in ewes lambs may be limited, if due to their stage of physiological development, ewe lambs are more likely to deposit protein (muscle) rather than body fat. However this potential limitation is in fact its advantage as a tool for identifying ewe lambs most suitable for breeding. A young animal that displays a greater level of fat may in fact be more physiologically mature and therefore more likely to have achieved puberty. Stephenson et al. (1980) found an association between the autumn rate of increase in the proportion of body fat and the percentage of ewe lambs bred. In Romney based ewe lambs the optimal body condition score is in the range of 2.5–3.5 at breeding (Kenyon et al., 2009, 2010; Cave et al., 2012). This suggests that early maturing ewes achieve higher reproductive performance when bred as ewe lambs.

4.7. Shearing pre-breeding, during breeding and immediately post breeding

The effects of shearing pre-breeding on ewe lamb breeding performance have been inconsistent. McMillan and Wilson (1982) reported no effect of shearing two or four weeks prior to breeding on the percentage mated. In a follow up study, they reported that the number of ewe lambs which lambed to their first mating was greatest in those shorn four weeks prior to breeding. However, McMillan and Knight (1982) reported that shearing either four or two weeks pre-mating reduced the numbers of ewes joined in the first two weeks of the breeding period and Sumner et al. (1982) reported shearing pre-breeding decreased non-pregnancy rates in one of four studies. Smith et al. (1980) reported that shearing 4–7 days before joining depressed ovulation rates. Similarly, McMillan and Knight (1982) reported that shearing either four or two weeks pre-mating reduced the numbers of ewes bearing multiple lambs. In contrast, Kenyon et al. (2004b) in a farmer survey found a positive effect of shearing ewe lambs pre-breeding on subsequent lambing percentage.

Given the potential of shearing pre-breeding to have negative consequences, farmers should be advised not to shear their ewe lambs closer than four weeks prior to breeding. Conversely, shearing can lead to increased heat loss and potentially a stimulation of appetite (Elvidge and Coop, 1974) and therefore increased liveweight gain. Thus, it might be expected that shearing in summer/early autumn well before breeding may have a positive influence on ewe lamb live weight and thus reproductive performance.

4.8. Rams

With mature ewe breeding, ram to ewe ratios are generally in the range of 1:100–1:200 (Allison, 1982). However, as previously stated, the breeding behaviour of ewe lambs is generally poorer than that of mature ewes indicating lower ratios are likely to be beneficial. In one of two studies, Allison et al. (1975) reported a ram to ewe ratio of 1:55 compared to 1:110 resulted in a greater percentage of ewe lambs mated and conceiving early in the breeding period. Similarly, Stevens and McIntyre (1999), using survey data, reported that as ram to ewe lamb ratios declined form 1:200 to 1:50 conception rates increased. While, Smith and Knight (1998) suggested a ram to ewe lamb ratio of 1:50 or lower. More recent studies suggest a ram to ewe lamb ratio of approximately 1:75 (Kenyon et al., 2004b, 2010). Combined the studies indicate the optimal range is likely to be between 1:50 and 1:75, which is approximately half of that recommended with mature rams.

Potentially, ram lambs could be bred with ewe lambs to further reduce the generation interval, if progeny born to ewe lambs are to be retained as replacement animals. If additional rams are required specifically to be bred with ewe lambs, ram lambs may be a relatively cheap source. However, the reproductive performance of ewe lambs is lower if bred with ram lambs (Bichard et al., 1974; Kenyon et al., 2007b) and therefore if ram lambs are to be utilised, they need to be used at lower ram:ewe ratios. In contrast, 18–19 month old rams can be just as effective as mature rams (Kenyon et al., 2007b). The reuse of mature rams after they have been used with the mature ewe flock, just prior to the ewe lamb breeding, is also a means of reducing the need and cost of additional specialised rams (Kenyon et al., 2009).

4.9. Nutrition

4.9.1. The influence of nutrition on conception rates, pregnancy rates and number of ewes lambing

In the following sections, the indoor and pasture based studies are discussed separately due to their many differences in design which are outlined in the following sections and the timing of nutritional manipulations are outlined in Tables 2 and 3.

4.9.1.1. Indoor studies. Wallace et al. (1996, Table 2) reported liveweight gains, greater than 230 g/day, resulted in lower conception rates than those gaining at 75 g/day. Annett and Carson (2006) over the liveweight change range of −124 to 87 g/day, reported that the nutritional treatment that lost the most live weight had the highest conception rates. In contrast, Munoz et al. (2009) with liveweights gains ranging from −88 to 115 g/day reported no effect of nutritional treatment on conception rates, although those with the highest liveweight gains tended to give birth to fewer lambs on a per ewe mated basis.

4.9.1.2. Pastoral based studies. Kenyon et al. (2008b) reported a greater proportion of ewe lambs gaining 223 g/day returned to service than those gaining at 134 g/day. However, the overall percentage of ewe lambs which lambed did not differ. Similarly, Mulvaney et al. (2010b) reported ewe lambs gaining 208 g/day compared to 153 g/day were more likely to return to breeding, although again overall pregnancy rates did not differ. Mulvaney et al. (2010a), in one of two studies, found high liveweight gains (170 g/day vs. −50 g/day) resulted in greater return to service rates, with no overall effects on pregnancy rates. Combined, these pastoral studies support the findings of Wallace et al. (1996) that high liveweight gains have the potential to negatively influence conception rates to first breeding, although overall pregnancy rates did not differ. In mature ewes, high liveweight gains around the

Table 2
Summary of the experiments comparing the reproductive performance of ewe lambs fed pelletized diets. Within columns and within experiments, data with different superscripts differ significantly ($P < 0.05$).

Study	Treatment group	Liveweight change (g/day)[1]	Conception rate (%)[3]	Pregnancy loss (%)	Gestation length (days)	Birth weight (kg)	Lamb survival (%)
Wallace et al. (1996)	Medium (post ET[2] to day 100)	75^{a}	85^{b}	8^{a}	143.1^{b}	4.34^{b}	91^{b}
	Ad libitum (post ET to day 100)	234^{b}	57^{a}	33^{b}	140.2^{a}	2.74^{a}	38^{a}
Wallace et al. (1997b)	Moderate (post ET to day 100)	84^{a}	59^{a}		145.4^{a}	4.82^{b}	
	High (post ET to day 100)	294^{b}	90^{b}		142.7^{b}	3.49^{a}	
Wallace et al. (1999)	Moderate/moderate (post ET-50-100)	52^{a}/62^{a}			144.7	4.94^{b}	
	Moderate/high (post ET-50-100)	51^{a}/342^{b}			140.8	3.11^{a}	
	High/high (post ET-50-100)	251^{b}/310^{b}			142.3	3.03^{a}	
	High/moderate (post ET-50-1040	250^{b}/49^{a}			144.0	4.45^{b}	
Wallace et al. (2003)	Moderate (post ET to day 100)	66^{a}				5.16^{b}	
	High (post ET to day 100)	323^{b}				2.89^{a}	
Annett and Carson (2006)	Low (day 1–31)	−124^{a}	82^{b}		145.7	6.01	
	Medium (day 1–31)	−38^{b}	61^{a}		145.4	6.01	
	High (day 1–31)	87^{c}	59^{a}		145.6	6.06	
Wallace et al. (2008)[1]	Moderate (post ET to term)	117^{a}				5.9^{b}	
	High (post ET to term)	266^{b}				4.02^{a}	
Munoz et al. (2009)	Low (day 1–39)	−88^{a}	61		146.2	4.49	57
	Medium (day 1–39)	16^{b}	51		147.0	4.64	75
	High (day 1–39)	115^{c}	38		147.0	5.25	78
	Medium (day 40–90)	96^{a}			146.6	4.87	71
	High (day 40–90)	140^{b}			146.9	4.71	67
Annett and Carson (2006)	0.6 Maintenance (day 1–35)	−124	82^{b}		145.7	6.0	
	Maintenance (day 1–35)	−38	61^{a}		145.4	6.0	
	2.0 Maintenance (day 1–35)	87	59^{a}		145.6	6.1	
Meyer et al. (2010)	Restricted (day 40 to early lactation)	12^{a}			149.2	4.3	
	Control (day 40 to early lactation)	111^{b}			148.1	4.7	
	High (day 40 to early lactation)	173^{c}			147.5	4.6	
Peel et al. (2012)[1]	Moderate (throughout pregnancy)	131			142	5.3	
	High (throughout pregnancy)	212			141	4.9	
	Moderate (throughout pregnancy)	99			149	5.1	
	High (throughout pregnancy)	252			144^{a}	5.7	

[1] Where live weight gains are not clearly stated they have been estimated based on start and end live weights.
[2] Embryo transfer.
[3] Conception rate/pregnancy rate.

Table 3
Summary of the experiments comparing the reproductive performance of ewe lambs grazed under pastoral conditions. Within columns and within experiments, data with different superscripts differ significantly ($P < 0.05$).

Study	Treatment group	Liveweight change (g/day)[1]	Conception rate (%)[2]	Pregnancy loss (%)	Gestation length (days)	Birth weight (kg)	Lamb Survival (%)
Morris et al. (2005)	Maintenance (day 13–term)	80[a]			147.9	3.91	72
	Medium (day 13–term)	145[b]			147.9	3.78	71
	Ad libitum (day 13–term)	210[c]			146.1	3.94	76
Mulvaney et al. (2008)	Maintenance (day 5–100–term)	70[a]	62[b]	28[b]		3.50[a]	36[a]
	Medium (day 5–term)	117[b]	66[b]	3[a]		4.00[b]	53[b]
	Ad libitum (day 5–term)	225[c]	46[a]	32[b]		4.00[b]	85[b]
Kenyon et al. (2008b)	Medium (day 5–term)	134[a]	78[b]		145.8[a]	4.02	74
	Medium/Ad libitum (day 5–36–term)	201[b]	83[b]		144.6[b]	3.74	69
	Ad libitum (day 5–term)	237[c]	54[a]		144.8[b]	4.21	71
Mulvaney et al. (2010a)Study one	Medium (4 days pre-breeding–day 64)	50[a]	48[b]				
	Ad libitum (4 days pre-breeding–day 64)	214[b]	37[a]				
Study two	Maintenance (17 days pre-breeding–day 5–day 124)		46	0			
	Medium (17 days pre-breeding–day 5–day 124)		40	2			
	Medium/Ad libitum (17 days pre-breeding–day 5–day 124)		46	2			
	Ad libitum (17 days pre-breeding–day 5–day 124)		49	2			
Mulvaney et al. (2010b)	Medium (day 1–day 140)	153[a]	65	18		4.46	86
	Ad libitum (day 1–day 140)	208[b]	72	10		4.66	88
Mulvaney et al. (2010c)	Medium (4 days pre-breeding–day 145)	125[a]	50[a]	7		4.1	84
	Ad libitum (4 days pre-breeding–day 145)	206[b]	63[b]	11		4.0	77
Mulvaney et al. (2012)	Medium (day 85–term)	293[a]				3.7[a]	80
	Ad libitum (day 85–term)	345[b]				4.0[b]	78

[1] Where live weight gains are not clearly stated they have been estimated based on start and end live weights.
[2] Conception rate/pregnancy rate.

breeding period can negatively effect progesterone concentrations resulting in lower embryonic survival (Parr, 1992). This might help explain the lower conception rates observed in ewe lambs with very high liveweight gains.

It is important to note that on a flock basis, higher liveweight gains during the breeding period may increase the percentage of ewe lambs achieving puberty by the end of that period. This would result in more individual ewe lambs actually being bred, which in turn may counter the negative influence of high liveweight gains on individual conception rates, resulting in no overall effect on flock pregnancy rates, which was observed in some of the above studies.

4.9.2. Influence of nutrition on fetal growth, lamb live weight and colostrum production

4.9.2.1. Indoor studies. Studies utilising concentrate feedstuffs have reported very high liveweight gains in pregnancy have negatively affected pregnancy maintenance, nutrient partitioning, placental weight, fetal growth, maternal and fetal metabolism, gestation length, birth weight, colostrum yield and subsequent lamb survival (Wallace et al., 1996, 1997a, 1997b, 1999, 2000, 2002a,b, 2003, 2006a,b, 2007, 2008, 2010; Palmer et al., 1998; Wallace, 2011; Thomas et al., 2001; Da Silva et al., 2003; Peel et al., 2012, also Table 2). However, these results may not be directly transferable to what might be observed under pastoral feeding conditions due to the differing diet, very high liveweight gains, the very young age of the ewe lambs, which were often peri-pubertal and around 6 to 7 months of age, and the use of embryo transfer. Indeed, Peel et al. (2012) stated that the lack of a negative effect of high liveweight gains on birth weight in their similar studies could be because they were naturally mated rather than via embryo transfer. Further, Wallace et al. (2006b) indicated that the high energy intakes may be somewhat responsible for the impaired placental development in rapidly growing adolescents. At lower liveweight gains with concentrate feeding, little impact of nutritional treatment on fetal size, gestation length, lamb live weight or apparent lamb colostrum uptake has been reported (Annett and Carson, 2006; Munoz et al., 2009; Meyer et al., 2010, 2011; Vonnahme et al., 2010; Peel et al., 2012).

At the other end of the nutritional spectrum and potentially less surprising, Swanson et al. (2008) from day 50 of pregnancy and Wallace et al. (2010) and Wallace (2011) through-out pregnancy have reported negative effects of prolonged under nutrition. In these studies, where ewe lambs would have likely lost a considerable amount of conceptus free live weight, under nutrition negatively affected lamb birth weight and colostrum production.

4.9.2.2. Pastoral studies. The effects of a higher level of nutrition and/or liveweight gains under New Zealand's pastoral conditions have not been negative although, the highest liveweight gain achieved in these studies was only 230 g/day (Table 3). Across a number of studies, liveweight gain has had no influence on pregnancy loss or lamb survival, but a positive effect on lamb live weight to weaning (Morris et al., 2005; Corner et al., 2006; Kenyon et al., 2008b; Mulvaney et al., 2008, 2010a,b,c, 2012).

The study of Mulvaney et al. (2008) contrasts with the pre-mentioned pastoral studies. They reported that ewe lambs which either maintained live weight to day 87 of pregnancy followed by a gain of 190 g/day, or that gained 230 g/day throughout the entire pregnancy period were more likely to lose pregnancies in the mid- to late-pregnancy period than those which gained at 130 g/day throughout pregnancy. In addition, lambs born to ewe lambs that gained 190 g/day in the late pregnancy period displayed lower survival and weaning live weight. However, this contrasting result might be explained by a *Neospora caninum* infection which was later found to be present (West et al., 2006; Howe et al., 2008) and therefore the results of Mulvaney et al. (2008) need to be interpreted with caution.

The consensus of the pre-mentioned indoor and pastoral studies would suggest that a suitable total liveweight gain throughout pregnancy is 100–150 g/day. The gravid uterine weight of a single bearing ewe lamb near term has been reported to be 8 kg (Loureiro et al., 2010). Therefore, if it is assumed that a ewe lamb gains 100–150 g/day (14.7–22.0 kg over pregnancy) in total live weight, her conceptus free liveweight gain will be 7–14 kg over the entire pregnancy. This level of conceptus-free liveweight gain will allow her to be better prepared for lactation and enable an easier transition towards rebreeding. Mulvaney et al. (2010c) concluded that ewe lambs fed ad libitum which gained 206 g/day in pregnancy were less efficient in terms of kg dry matter required per kg of lamb live weight than those fed to gain 125 g/day in pregnancy, further suggesting very high liveweight gains may be inappropriate within a production system. An alternative approach and potentially easier one for farmers to meet is to set live weight targets at breeding and throughout pregnancy. Schreurs et al. (2010) using a modelling approach, examined the impacts of live weight at breeding and at various stages during pregnancy on the ewe lamb and her progeny to weaning. They found that while live weight at each time point had a positive impact on the performance of the young ewe and her lamb to weaning, live weight at breeding had the biggest impact. Therefore, they suggested that more emphasis is required on pre-mating live weight targets than those in pregnancy.

4.10. Pregnancy losses in ewe lambs

Pregnancy losses in ewe lambs are greater than in mature ewes (Mulvaney, 2011). However, the causes of these losses are not well understood. As indicated earlier, under indoor concentrate fed conditions, the studies of Wallace and colleagues suggest very high liveweight gains in pregnancy can result in high pregnancy loss rates. However, under both indoor and pastoral based conditions with lower liveweight gains, losses still occur (Kenyon et al., 2008b; Munoz et al., 2009; Mulvaney et al., 2010a,b,c) suggesting other factors also contribute to losses.

Ewe lambs are very susceptible to pregnancy losses through abortive diseases. Kenyon et al. (2004b), in a survey, found that ewe lambs which had been vaccinated against toxoplasmosis and campylobacteriosis had higher lambing percentages than those which had not. There is also growing evidence, in New Zealand at least, to suggest *Neospora caninum* (West et al., 2006; Howe et al., 2008; Weston et al., 2009) could be a factor in pregnancy losses in ewe lambs. It is clear that further research is required to identify at which stages in pregnancy ewe lambs are most likely to lose pregnancies and the risk factors. Once these are known, management strategies can be put in place to reduce this loss of potential.

4.11. Shearing in mid pregnancy

Shearing mature ewes during pregnancy has the potential to enhance both lamb live weight and survival to weaning (Kenyon et al., 2003, 2006c; Corner et al., 2010). The response appears to be most consistent when shearing occurs in mid-pregnancy (Kenyon et al., 2003). With ewe lambs, pregnancy shearing has been found to increase the birth weight of singleton but not twins lambs, without influencing lamb weaning live weight or survival (Kenyon et al., 2006d; De Barbieri et al., 2012).

4.12. Mortality of lambs born to ewe lambs

Although it is often stated that the mortality of lambs born to ewe lambs is greater than those born to mature ewes, very few studies have directly compared this (Dyrmundsson, 1973; Corner et al., 2013, Table 1). Across numerous studies which do not have direct comparisons with mature ewes, mortality rates of lambs born to ewe lambs have been reported to be in the range of 12–60% (McCall and Hight, 1981; McMillan, 1983; Stevens and McIntyre, 1999; Stevens, 2001a,b; Morris et al., 2005; Fogarty et al., 2007; Kenyon et al., 2008b; Mulvaney et al., 2008, 2010b; Munoz et al., 2009; Schreurs et al., 2010; De Barbieri et al., 2012), which tend to be greater than that reported for singletons and twin lambs born to mature ewes (Hight and Jury, 1970; Dalton et al., 1980; Knight et al., 1988; Thompson et al., 2004; Everett-Hincks and Dodds, 2008; Morel et al., 2009). Recently, Corner et al. (2013) undertook two studies comparing mature ewe and ewe lamb performance when the two age classes were managed together in pregnancy and lactation. In the study with singleton bearing ewe lambs only, lamb survival was lower in lambs born to ewe lambs. In the second study, which included both singleton and twin bearing ewes, lamb survival was only lower in twins born to ewe lambs.

Afolayan et al. (2008) measured the reproductive performance of first cross ewes of different ages and from different maternal genotypes over three years in multiple environments in Australia. While lamb survival may have been expected to be lower in ewes that lamb at one year old, because they had fewer multiple births overall, lamb survival was similar.

McMillan (1983) found that dystocia was the single largest cause of death in the first three days post birth in lambs born to ewe lambs. Munoz et al. (2009) reported higher birthing assistance rates in ewe lambs compared to two-year-old ewes, and Kenyon et al. (2004b), in a farmer survey, indicated that 7% of ewe lambs needed assistance. Young et al. (2010) also reported dystocia was a major risk factor, as was starvation/exposure, especially in twin born lambs. These results suggest that ewe lambs may benefit from careful monitoring during the lambing period to reduce peri-natal loses.

The optimal birth weight range for lambs born to mature ewes from a survival perspective is in the range of 4.5–6.5 kg (Hight and Jury, 1970; Dalton et al., 1980; Knight et al., 1988; Thompson et al., 2004; Everett-Hincks and Dodds, 2008; Morel et al., 2009; Oldham et al., 2011), whereas in ewe lambs, McMillan (1983) stated the optimal lamb birth weight was in the range of 3.3–4.1 kg. More recently Schreurs et al. (2010) modelled a positive relationship between birth weight and lamb survival to at least 5.0 kg in ewe lambs.

4.13. Level of feeding in lactation

There is a general lack of information regarding nutritional management of the ewe lamb in lactation. Kenyon et al. (2004b), using survey information, reported that separating singleton- and twin-bearing ewe lambs prior to lambing and during lactation improved the lambing percentage, although pasture mass and/or height just prior to lambing had no effect. It is well established that lactation places a ewe under considerable nutritional strain (Nicol and Brookes, 2007). Therefore, it would be expected that higher levels of nutrition during lactation would be of benefit for both the young ewe and her progeny. Further, in many farming scenarios, the ewe lamb still needs to be gaining live weight in the later stages of lactation to help ensure she achieves a suitable rebreeding live weight, reiterating the importance of knowing the optimal feeding level in lactation. Additional studies are required to examine the impact of nutrition in lactation on the ewe lamb herself and her progeny.

4.14. Timing of weaning

With mature ewes, it has been shown that weaning at as early as 8 weeks post lambing does not negatively reduce lamb growth rates (Rattray et al., 1976; Smeaton et al., 1979; Earl et al., 1990), while it can have a positive influence on ewe live weight (Corbett and Furnival, 1976; Smeaton et al., 1979). Given that the ewe lamb is likely to need to gain live weight prior to re-breeding, early weaning might be an attractive management tool. However, Mulvaney et al. (2009, 2011) reported that weaning at 9, 10, 11 or 13 weeks of age had no effect on subsequent lamb growth and only a small positive effect on ewe lamb live weight from weaning at 10 weeks.

5. Is there a longer term impact of being born to a ewe lamb?

Loureiro et al. (2010) reported fetuses from ewe lambs in late pregnancy tended to be lighter than those from mature ewes, while Loureiro et al. (2011) reported that offspring born to ewe lambs were lighter at birth and to at least one year of age. Craig (1982) reported ewe lambs themselves born to ewe lambs had lower reproductive performance, when bred as a lamb, compared to those born to mature ewes. This indicates progeny born to ewe lambs may be less suitable to be bred at a young age. This could be caused by lighter live weights to one year of age.

Loureiro et al. (2012) compared singletons born to mature ewes or ewe lambs. When these two groups of ewes were bred at approximately 18 months of age, no difference in reproductive and lactational performance was observed (Loureiro et al., 2012). Longer term studies are required to determine if lifetime performance is affected and should include multiple-born progeny.

6. Conclusion

Breeding ewe lambs has the potential to lift both the total numbers of lambs weaned per farm per year each year and to lift lifetime performance of the individual ewe. However, the reproductive performance of ewe lambs is lower than that of mature ewes and can be a highly variable, limiting their potential. In this review, we have outlined the major causes of this lower productivity and have attempted to identify management practices than can result in greater level of productivity. Regardless of breed or the genotype used there are a number of practises a farmer can implement to maximise ewe lamb performance. Prior to breeding ewe lambs should be vaccinated against abortive diseases and exposed to teaser rams for 17 days. Ewe lambs should be at least 35–40 kg, depending on breed, and at a body condition score of 3.0 when bred with mature rams at a ratio of 1:50–1:75. Throughout pregnancy it is important that the ewe gains total live weight at a rate of 100–150 g/day. During lactation ewe lambs need to be fed at a level that ensures they lactate to their potential while still growing themselves.

Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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