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Effect of recipient breeds on birth and weaning weight, and wool and follicle characteristics of Merino lambs born by embryo transfer

T. WULIJI, R.N. ANDREWS, K.G. DODDS, J. ASPINALL[1], T. HARRISON[2] AND B.J. MOCKETT

AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel
[1] AgResearch, Woodlands Research Station, Woodlands, RD1, Invercargill
[2] AgResearch, Tara Hills High Country Research Station, Rural Bag 19, Omarama

ABSTRACT

One hundred and eighty three embryos were collected from 29 donor Merino ewes and transferred as either a single or twins to Merino (MR), Coopworth (CR) and Romney (RR) recipient dams. A total of 107 lambs were weaned from these implants. A control group (MN) of 24 naturally conceived single and twin lambs were included for comparison. Follicle fibre diameters at birth were 16.7, 17.2, 17.7 and 17.6 µm (SED 0.4) for MN, MR, CR and RR respectively; while the fibre diameter of wool samples at birth for all dam groups was 16.5 mm (SED 0.3). Follicle fibre diameters at weaning were 16.5µm, 15.9, 16.3 and 16.1 (SED 0.6) for MN, MR, CR and RR respectively while the corresponding wool FDs at weaning were 16.3 µm, 16.1, 16.0, and 16.0 (SED 0.4). Weaning weight was similar in CR and RR, while CR weaned significantly heavier lambs than Merinos (recipients or naturally bred). The results suggest that crossbred dams improve weaning weights of Merino lambs born to embryo transfer but do not affect their wool follicle characteristics.

Keywords: Embryo transfer, skin follicle, density, fibre diameter.

INTRODUCTION

Early life environmental effects, such as dam live weight, late pregnancy nutrition and dam lactation, have an important influence on survival and weaning performance of embryo transferred lambs. In a previous multiple ovulation and embryo transfer (MOET) programme (1991-1993) in ultrafine Merinos, it was noticed that the Merino recipients had low multiple lamb survival and poor juvenile liveweight from twin transferred embryos (Wuliji, unpublished data). The handicap in twins for birth, weaning weight and fleece weight has been extensively documented in sheep. The maternal environment has been shown to influence wool production performance of fine wool sheep as wool follicles are formed during early gestation and mature in the pre- and post-natal periods (Schinckel, 1955a,b). Follicle density and fibre diameter are important traits influencing quality and quantity of Merino wool. Schinckel (1955a,b) and Jackson *et al*., (1975) estimated a 5 to 10% reduction in fibre density and secondary to primary follicle ratios in twin born and reared Merino lambs compared to singles. On the other hand, crossbred sheep such as Coopworth and Romney are reputed to have better mothering, lambing and rearing ability than Merinos. Thus it is reasonable to assume that as recipient dams they would offer an advantage over Merinos for bearing multiple foetuses in embryo transfer programmes. The objective of this study was to investigate the potential benefit of crossbred recipients for ultrafine Merino embryo transfer programmes by examining live weights, and wool and follicle measurements in lambs up to weaning.

MATERIALS AND METHODS

Donors, recipients and embryo transfers

Fifteen ultrafine Merino ewes, which had a mean fibre diameter of at most 16.5 mm for the two previous performance recordings, were selected from the ultrafine Merino breeding flocks established at Tara Hills High Country Research Station (Wuliji *et al*., 1990) for a MOET programme in May 1995 and 1996. The procedure was as described by Wuliji *et al*., (1995), namely, oestrus in the donor ewes was synchronised by treatment with an intra-vaginal progesterone releasing device (CIDR-G®), and treated with a series of 6 reducing doses (total 24mg) of FSH-P injected i.m. at half-day intervals during the last 3 days of CIDR-GÒ treatment. Donor ewes were artificially inseminated with semen collected from three rams. Each year, 20 mature ewes from each of Merino (MR), Coopworth (CR) and Romney (RR) had oestrus cycles synchronised to serve as recipient dams. Embryos were recovered by a surgical technique (Tervit and Havik, 1976) or a modification of the laparoscopic procedure described by McKelvey *et al*., (1986) and examined under a light microscope to determine their suitability for transfer. The donors' embryos were transferred into randomly chosen recipient ewes by a minimal surgical procedure. Over the two years, 183 embryos were successfully collected from 29 donor Merino ewes, and transferred as either singles or twins into MR, CR and RR dams. A total of 107 lambs were weaned from these embryo implants. A control group (MN) of 12 naturally conceived single and twin lambs were included each year for comparison. Progeny were individually identified at birth and pedigree, birth date, birth weight (BW), birth/rearing ranks and weaning weight (WW) were recorded.

Measurements

A midside wool patch (8 x 8 cm) was clipped using a small animal clipper fitted with size No. 40 blade, at birth (October) and at weaning (January) on all lambs. Birth and weaning wool samples were measured for mean fibre diameter (FD1 and FD2 respectively) and coefficient of variation (FDCV1 and FDCV2 respectively) and fibre curvatures (CURV1 and CURV2 respectively) by an Optical Fibre Diameter Analyser (OFDA, SGS Pty Ltd) instrument. Duplicate skin biopsies of 50 mm^2 (8 μm in diameter) were taken within 7 days of birth and at weaning (ca. 90 days of age) from the cleared mid-side patch site after the administration of local anaesthetic. Skin biopsy samples were fixed in 10% buffered formalin solution for histological processing. Micro-histology measurements were performed on all lambs for birth and weaning samples by preparing 8 μm paraffin embedded transverse serial sections at sebaceous gland level (Maddocks and Jackson, 1988). Fibres in the skin section were differentiated with Long Ziehl-Neelsen carbol fuchsin stain. Microscope images of 4 fields per specimen were captured for computer image analyses to measure follicle fibre area (FFA1), follicle fibre diameter (FFD1), follicle density (DEN1) after birth, and at weaning (FFA2, FFD2 and DEN2 respectively) as described by Andrews *et al*., (1998).

Statistical analysis

Data were analysed by least squares analysis of variance, with year of birth, sex, birth rank, breed of dam group (breed of birth mother / mating method) and sire as fixed effects. Birth rank groups were not divided further into rearing rank groups for weaning measurement analysis, since only 3 of 44 twins were reared singly. Date of birth was not included in the models, since it was not significant and partially confounded with dam group. Correlations were calculated after adjustment for these fixed effects. Breed differences in embryo survivability were tested using contingency table analyses for each number of ova implanted.

TABLE 1: Birth weight, follicle and fibre characteristics of Merino lambs at birth

	N	BW (kg)	FFA1 (μm^2)	DEN1 (mm^{-2})	FD1 (μm)	FDCV1 (%)	CURV1	FFD1 (μm)
Dam group								
MN	24	4.2^{ab}	232	121	16.5	24.7	107^{b}	16.7
CR	42	4.4^{b}	243	122	16.5	25.3	95^{a}	17.2
MR	27	4.4^{b}	256	118	16.5	25.5	96^{a}	17.7
RR	38	4.0^{a}	253	114	16.5	26.0	96^{a}	17.6
SED		0.2	12	10^{ns}	0.3^{ns}	0.7^{ns}	3	0.4^{ns}
Sex								
Ewe	75	4.1	245	120	16.8	25.2	100	17.2
Ram	56	4.4	239	119	16.2	25.1	103	17.0
SED		0.1*	7^{ns}	6^{ns}	0.2**	0.4^{ns}	2^{ns}	0.3^{ns}
Birth rank								
S	56	4.7	246	113	16.7	25.0	99	17.3
T	75	3.8	237	125	16.3	25.4	104	16.9
SED		0.1***	7	6	0.2^{ns}	0.4^{ns}	2*	0.3^{ns}

*:P<0.05; **:P<0.01; ***:P<0.001; ns: non significant; ^{ab}: data bearing a different superscript were significant at P<0.05; FD: mean fibre diameter; FDCV: FD coefficient of variation; FFA1: follicle fibre area; FFD1: follicle fibre diameter; DEN1: follicle density.

TABLE 2: Live weight, follicle and fibrer characteristics of Merino lambs at weaning.

	N	WW (kg)	FFA2 (μm^2)	DEN2 (mm^{-2})	FD2 (μm)	FDCV2 (%)	CURV2 (μm)	FFD2	No. follicles (millions)^{e}
Dam group									
MN	23	25.6^{a}	218	108	16.3	19.9	92	16.5	84^{a}
CR	40	30.4^{c}	203	116	16.1	20.6	98	15.9	102^{b}
MR	25	27.6^{ab}	216	114	16.0	21.7	97	16.3	92^{ab}
RR	37	28.9^{bc}	207	109	16.0	20.9	97	16.1	92^{ab}
SED		1.1	16^{ns}	8^{ns}	0.4^{ns}	0.9^{ns}	3^{ns}	0.6^{ns}	7
Sex									
Ewe	71	26.1	221	105	16.2	20.8	96	16.6	83
Ram	54	28.5	206	116	16.1	20.2	94	16.0	97
SED		0.6***	10^{ns}	5*	0.2^{ns}	0.5^{ns}	1^{ns}	0.4^{ns}	4***
Birth rank									
S	51	29.6	217	110	16.3	20.3	94	16.5	95
T	74	24.9	210	111	16.0	20.7	95	16.1	85
SED		0.7***	10^{ns}	5^{ns}	0.2^{ns}	0.6^{ns}	2^{ns}	0.4^{ns}	4*

* P<0.05; ** P<0.01; *** P<0.001; ^{abc}: data bearing a different superscript were significant at P<0.05; FD: mean fibre diameter; FDCV2: FD coefficient of variation; FFA2: follicle fibre area; FFD2: follicle fibre diameter; DEN2: follicle density; ^{e}: estimated area of skin (m^2) $=0.0909WW^{0.67}$ (Lines and Pierce, 1931).

RESULTS

Birth weight, skin follicle and fibre characteristics of Merino lambs at birth are shown in Table 1. There were no differences in BW for lambs among MN, MR and CR, but those of RR were lighter (P<0.05) than those with other breeds of recipient dam. CURV1 was higher (P<0.01) for MN compared with the embryo transfers, but there was no difference among recipient dam groups. There were no differences among dam groups for FFA1, DEN1, FD1, FDCV1 or FFD1. Birth weight was significantly lower for ewe lambs than rams whilst FD1 was higher for ewes than rams but there were no differences in FFA1, DEN1, FDCV1, CURV1 or FFD1 between sexes. Single born lambs had significantly (P <0.01) heavier BW and lower CURV1 than twins.

Live weight, follicle and fibre characteristics of Merino lambs at weaning age are shown in Table 2. Overall, WW of lambs born from embryo transfer were significantly (P< 0.01) heavier than MN, with CR (P<0.01) heavier than MR lambs. None of the follicle or fibre measurements at weaning were different among dam groups. Although there was no apparent difference in DEN2 among recipient breeds there were indications of differences in total follicle number estimates at weaning among recipient breeds, with lambs born from CR having 10% more follicles than MR and RR (P<0.01). Rams had 17% more follicles at weaning than ewe lambs and singles had 11% more follicles at weaning than twins. Ram lambs had significantly (P<0.01) heavier WW and higher DEN2 (P<0.05) than ewes. There was no difference between sexes for any other follicle or fibre characteristic. Singles were significantly (P<0.01) heavier than twins at weaning.

Correlation coefficients between follicle and fibre characteristics of Merino lambs at birth and weaning age are shown in Table 3. There were significant (P<0.05) correlations among (but not between all pairs of) the characteristics of FD1, FDCV1, FD2 and FDCV2; and for FD2 with FFA1, FFD1 and DEN1 (negative). FFA1 was correlated significantly with FFD1 (P<0.001), and FFA2 (P<0.05) with FFD2, with significant correlations among all these traits (P<0.05). The correlation between BW and WW was

TABLE 3: Phenotypic correlation coefficients among follicle, fibre characteristics and coefficient of variation at birth and weaning age of lambs.

	FDCV1	FD2	FDCV2	FFA1	FFA2	FFD1	FFD2	DEN1	DEN2
FD1	0.23**	0.28*	0.02	0.21*	0.06	0.17	0.05	0.07	0.10
FDCV1		0.03	0.23*	0.16	0.04	0.17	0.05	-0.25**	-0.03
FD2			-0.09	0.39***	0.17	0.39***	0.18	-0.37***	-0.01
FDCV2				-0.02	0.07	-0.04	0.05	0.01	0.10
FFA1					0.19*	0.99***	0.21*	-0.56***	0.02
FFA2						0.19*	0.99***	-0.16	-0.18*
FFD1							0.20*	-0.56***	0.02
FFD2								-0.17	-0.02*
DEN1									0.08

* P<0.05; ** P<0.01; *** P<0.001; FD: mean fibre diameter; FDCV: FD coefficient of variation; FFA: follicle fibre area; FFD: follicle fibre diameter; DEN: follicle density.

0.43 (P<0.001). All other correlations were low.

The ultrasonic pregnancy scan indicated that there was no difference in embryo survival between recipient breeds (results not shown). The mean number of transferable embryos collected per donor was 6.3 and embryo survivability at foetal scanning was 95%. The number of lambs born per embryo scanned was 77% and number of lambs weaned per lamb born was 83%.

DISCUSSION

The ovulation rate and number of embryos recovered per donor were similar to data previously reported in sheep (Armstrong and Evans, 1983; Larsson *et al.*, 1991), and the number of embryos transferred, number of lambs born and number of lambs weaned per donor were comparable to those reported by Shackell and Isaacs (1991), Larsson *et al.,* (1991), Wuliji *et al*., (1995) and Cloete *et al*., (1998). Embryo transfer procedures have long been demonstrated to leverage increases in selection intensity (Rathie, 1982) and genetic gains (Smith, 1988). The uses of MOET for multiplying genetic resources for commercial sale (Lang *et al*., 1982), cryopreservation (Sakul *et al*., 1993), wool trait improvement (Wuliji *et al*., 1995) and improvement of multiple rearing ability (Cloete *et al*., 1998) have also been reported. However industry utilisation has remained low. Negative effects of reproductive technologies on productive traits such as increased birth weight, gestation length and incidence of dystocia in bovine embryos transferred by *in vitro* procedures have been documented (Behboodi *et al*., 1995; Farin and Farin, 1995; Wilson *et al*., 1995) and similar effects, but to a lesser extent, have been reported in ovine embryo studies (Thompson *et al*., 1995; Walker *et al*., 1992). These effects are primarily attributed to *in vitro* culture systems (Holm *et al*., 1994; Walker *et al*., 1992; Thompson *et al*., 1995) or embryo transfer procedures (Wilson *et al*., 1995), or hormonal treatments (Maxfield *et al*., 1996). However, in this limited observation of conventional (*in vivo*) embryo transfer procedures we have not found any negative effects in lambs on production traits such as birth weight, follicle density or FD. Thus a MOET programme is highly efficient in helping achieve specific breeding objectives. Earlier work of the authors has shown that the increase in FD with increasing age was significantly less in ewes born from MOET than in the ultrafine breeding and control flocks (Wuliji *et al*., 1995), so that FD variation within a flock could be reduced across ages, as well as between animals (due to the higher selection intensity with MOET).

Skin follicle studies showed that Merinos have low mean fibre diameters and tend to have high follicle density and secondary to primary follicle ratios (Hynd *et al*., 1996) compared with most other sheep breeds. Follicle density and diameter have moderate to high heritabilities of 0.4 to 0.6 in Merinos (Jackson *et al*., 1975; Purvis and Swan, 1997; Skerritt *et al*., 1997). The maternal handicap of twins for total follicle numbers was estimated as 11% in this trial, which was comparable to that reported for density in Merinos by Schinckel (1955b) and Jackson *et al*., (1975). There was no apparent difference in FD or follicle density between dam groups. Although there was no difference in follicle density per unit measured, small differences in follicle density combined with differences in WW may have masked differences in total follicle numbers. The follicle density may have underestimated in MOET lambs due to a synchronised birth (born 8 days earlier than MN on average) and an expanded body surface area with a higher live weight. This is shown by the estimates of the total follicle numbers (Table 2). Maternal nutrition affects the initiation and maturation of secondary follicles during the last third of the gestation period. A severe nutritional restriction during late pregnancy reduces wool production permanently, by an estimated 0.1 to 0.2 kg annually, due to reduced follicle numbers and skin area (Corbett, 1979). Post-natal nutritional restriction on follicle numbers is minor, but delays follicle maturation and fibre growth for up to 6-12 months (Reis, 1982). The follicle numbers in this trial were primarily affected by birth rank (single vs twins), dam breed (Coopworth vs others), and follicle maturation stages (birth vs weaning). However, we were unable to estimate the proportion of secondary follicles and thereby determine whether their maturation was delayed or permanently differed. Comparison of these animals as adults will provide more information. The difference in follicle numbers between Merinos and other sheep breeds appear to be mostly due to secondary follicle densities (Steinhagen *et al*., 1986). Therefore, enhancing later pregnancy and early post-natal conditions for MOET Merino lambs, by use of crossbred recipient dams, may improve adult fleece production.

The correlation values among follicle and fibre traits in this trial were consistent with reports of other workers (Jackson *et al*., 1975; Purvis and Swan, 1997; Skerritt *et al*., 1997; Andrews *et al*., 1998). However, both follicle and fibre diameter were much finer in MOET lambs of this study than in these previous reports.

The higher weaning weight in MOET lambs from crossbred recipients compared with those reared by Merinos suggests that the crossbreds have an advantage in growth rate and early live weight performance of their lambs. The benefits obtained from MOET programmes using crossbred ewes, especially Coopworth, as recipients will provide better mothering ability and lactation for multiple born MOET lambs, while still capturing the benefit of increased selection intensity from using MOET in the ultrafine Merino breeding nucleus flock.

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AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel
[1] AgResearch, Woodlands Research Station, Woodlands, RD1, Invercargill
[2] AgResearch, Tara Hills High Country Research Station, Rural Bag 19, Omarama

ABSTRACT

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MATERIALS AND METHODS

Donors, recipients and embryo transfers

Fifteen ultrafine Merino ewes, which had a mean fibre diameter of at most 16.5 mm for the two previous performance recordings, were selected from the ultrafine Merino breeding flocks established at Tara Hills High Country Research Station (Wuliji *et al*., 1990) for a MOET programme in May 1995 and 1996. The procedure was as described by Wuliji *et al*., (1995), namely, oestrus in the donor ewes was synchronised by treatment with an intra-vaginal progesterone releasing device (CIDR-G®), and treated with a series of 6 reducing doses (total 24mg) of FSH-P injected i.m. at half-day intervals during the last 3 days of CIDR-GÒ treatment. Donor ewes were artificially inseminated with semen collected from three rams. Each year, 20 mature ewes from each of Merino (MR), Coopworth (CR) and Romney (RR) had oestrus cycles synchronised to serve as recipient dams. Embryos were recovered by a surgical technique (Tervit and Havik, 1976) or a modification of the laparoscopic procedure described by McKelvey *et al*., (1986) and examined under a light microscope to determine their suitability for transfer. The donors' embryos were transferred into randomly chosen recipient ewes by a minimal surgical procedure. Over the two years, 183 embryos were successfully collected from 29 donor Merino ewes, and transferred as either singles or twins into MR, CR and RR dams. A total of 107 lambs were weaned from these embryo implants. A control group (MN) of 12 naturally conceived single and twin lambs were included each year for comparison. Progeny were individually identified at birth and pedigree, birth date, birth weight (BW), birth/rearing ranks and weaning weight (WW) were recorded.

Measurements

A midside wool patch (8 x 8 cm) was clipped using a small animal clipper fitted with size No. 40 blade, at birth (October) and at weaning (January) on all lambs. Birth and weaning wool samples were measured for mean fibre diameter (FD1 and FD2 respectively) and coefficient of variation (FDCV1 and FDCV2 respectively) and fibre curvatures (CURV1 and CURV2 respectively) by an Optical Fibre Diameter Analyser (OFDA, SGS Pty Ltd) instrument. Duplicate skin biopsies of 50 mm^2 (8 µm in diameter) were taken within 7 days of birth and at weaning (ca. 90 days of age) from the cleared mid-side patch site after the administration of local anaesthetic. Skin biopsy samples were fixed in 10% buffered formalin solution for histological processing. Micro-histology measurements were performed on all lambs for birth and weaning samples by preparing 8 µm paraffin embedded transverse serial sections at sebaceous gland level (Maddocks and Jackson, 1988). Fibres in the skin section were differentiated with Long Ziehl-Neelsen carbol fuchsin stain. Microscope images of 4 fields per specimen were captured for computer image analyses to measure follicle fibre area (FFA1), follicle fibre diameter (FFD1), follicle density (DEN1) after birth, and at weaning (FFA2, FFD2 and DEN2 respectively) as described by Andrews *et al*., (1998).

Statistical analysis

Data were analysed by least squares analysis of variance, with year of birth, sex, birth rank, breed of dam group (breed of birth mother / mating method) and sire as fixed effects. Birth rank groups were not divided further into rearing rank groups for weaning measurement analysis, since only 3 of 44 twins were reared singly. Date of birth was not included in the models, since it was not significant and partially confounded with dam group. Correlations were calculated after adjustment for these fixed effects. Breed differences in embryo survivability were tested using contingency table analyses for each number of ova implanted.

RESULTS

Birth weight, skin follicle and fibre characteristics of Merino lambs at birth are shown in Table 1. There were no differences in BW for lambs among MN, MR and CR, but those of RR were lighter (P<0.05) than those with other breeds of recipient dam. CURV1 was higher (P<0.01) for MN compared with the embryo transfers, but there was no difference among recipient dam groups. There were no differences among dam groups for FFA1, DEN1, FD1, FDCV1 or FFD1. Birth weight was significantly lower for ewe lambs than rams whilst FD1 was higher for ewes than rams but there were no differences in FFA1, DEN1, FDCV1, CURV1 or FFD1 between sexes. Single born lambs had significantly (P <0.01) heavier BW and lower CURV1 than twins.

Live weight, follicle and fibre characteristics of Merino lambs at weaning age are shown in Table 2. Overall, WW of lambs born from embryo transfer were significantly (P< 0.01) heavier than MN, with CR (P<0.01) heavier than MR lambs. None of the follicle or fibre measurements at weaning were different among dam groups. Although

TABLE 1: Birth weight, follicle and fibre characteristics of Merino lambs at birth

	N	BW (kg)	FFA1 (µm^2)	DEN1 (mm^{-2})	FD1 (µm)	FDCV1 (%)	CURV1	FFD1 (µm)
Dam group								
MN	24	4.2^{ab}	232	121	16.5	24.7	107^{b}	16.7
CR	42	4.4^{b}	243	122	16.5	25.3	95^{a}	17.2
MR	27	4.4^{b}	256	118	16.5	25.5	96^{a}	17.7
RR	38	4.0^{a}	253	114	16.5	26.0	96^{a}	17.6
SED		0.2	12	10^{ns}	0.3^{ns}	0.7^{ns}	3	0.4^{ns}
Sex								
Ewe	75	4.1	245	120	16.8	25.2	100	17.2
Ram	56	4.4	239	119	16.2	25.1	103	17.0
SED		0.1^{*}	7^{ns}	6^{ns}	0.2^{**}	0.4^{ns}	2^{ns}	0.3^{ns}
Birth rank								
S	56	4.7	246	113	16.7	25.0	99	17.3
T	75	3.8	237	125	16.3	25.4	104	16.9
SED		0.1^{***}	7	6	0.2^{ns}	0.4^{ns}	2^{*}	0.3^{ns}

*:P<0.05; **:P<0.01; ***:P<0.001; ns: non significant; ^{ab}: data bearing a different superscript were significant at P<0.05; FD: mean fibre diameter; FDCV: FD coefficient of variation; FFA1: follicle fibre area; FFD1: follicle fibre diameter; DEN1: follicle density.

TABLE 2: Live weight, follicle and fibrer characteristics of Merino lambs at weaning.

	N	WW (kg)	FFA2 (µm^2)	DEN2 (mm^{-2})	FD2 (µm)	FDCV2 (%)	CURV2 (µm)	FFD2	No. follicles (millions)^{e}
Dam group									
MN	23	25.6^{a}	218	108	16.3	19.9	92	16.5	84^{a}
CR	40	30.4^{c}	203	116	16.1	20.6	98	15.9	102^{b}
MR	25	27.6^{ab}	216	114	16.0	21.7	97	16.3	92^{ab}
RR	37	28.9^{bc}	207	109	16.0	20.9	97	16.1	92^{ab}
SED		1.1	16^{ns}	8^{ns}	0.4^{ns}	0.9^{ns}	3^{ns}	0.6^{ns}	7
Sex									
Ewe	71	26.1	221	105	16.2	20.8	96	16.6	83
Ram	54	28.5	206	116	16.1	20.2	94	16.0	97
SED		0.6^{***}	10^{ns}	5^{*}	0.2^{ns}	0.5^{ns}	1^{ns}	0.4^{ns}	4^{***}
Birth rank									
S	51	29.6	217	110	16.3	20.3	94	16.5	95
T	74	24.9	210	111	16.0	20.7	95	16.1	85
SED		0.7^{***}	10^{ns}	5^{ns}	0.2^{ns}	0.6^{ns}	2^{ns}	0.4^{ns}	4^{*}

* P<0.05; ** P<0.01; *** P<0.001; ^{abc}: data bearing a different superscript were significant at P<0.05; FD: mean fibre diameter; FDCV2: FD coefficient of variation; FFA2: follicle fibre area; FFD2: follicle fibre diameter; DEN2: follicle density; ^{e}: estimated area of skin (m^2) $=0.0909WW^{0.67}$ (Lines and Pierce, 1931).

there was no apparent difference in DEN2 among recipient breeds there were indications of differences in total follicle number estimates at weaning among recipient breeds, with lambs born from CR having 10% more follicles than MR and RR (P<0.01). Rams had 17% more follicles at weaning than ewe lambs and singles had 11% more follicles at weaning than twins. Ram lambs had significantly (P<0.01) heavier WW and higher DEN2 (P<0.05) than ewes. There was no difference between sexes for any other follicle or fibre characteristic. Singles were significantly (P<0.01) heavier than twins at weaning.

Correlation coefficients between follicle and fibre characteristics of Merino lambs at birth and weaning age are shown in Table 3. There were significant (P<0.05) correlations among (but not between all pairs of) the characteristics of FD1, FDCV1, FD2 and FDCV2; and for FD2 with FFA1, FFD1 and DEN1 (negative). FFA1 was correlated significantly with FFD1 (P<0.001), and FFA2 (P<0.05) with FFD2, with significant correlations among all these traits (P<0.05). The correlation between BW and WW was

TABLE 3: Phenotypic correlation coefficients among follicle, fibre characteristics and coefficient of variation at birth and weaning age of lambs.

	FDCV1	FD2	FDCV2	FFA1	FFA2	FFD1	FFD2	DEN1	DEN2
FD1	0.23**	0.28*	0.02	0.21*	0.06	0.17	0.05	0.07	0.10
FDCV1		0.03	0.23*	0.16	0.04	0.17	0.05	-0.25**	-0.03
FD2			-0.09	0.39***	0.17	0.39***	0.18	-0.37***	-0.01
FDCV2				-0.02	0.07	-0.04	0.05	0.01	0.10
FFA1					0.19*	0.99***	0.21*	-0.56***	0.02
FFA2						0.19*	0.99***	-0.16	-0.18*
FFD1							0.20*	-0.56***	0.02
FFD2								-0.17	-0.02*
DEN1									0.08

* $P<0.05$; ** $P<0.01$; *** $P<0.001$; FD: mean fibre diameter; FDCV: FD coefficient of variation; FFA: follicle fibre area; FFD: follicle fibre diameter; DEN: follicle density.

0.43 ($P<0.001$). All other correlations were low.

The ultrasonic pregnancy scan indicated that there was no difference in embryo survival between recipient breeds (results not shown). The mean number of transferable embryos collected per donor was 6.3 and embryo survivability at foetal scanning was 95%. The number of lambs born per embryo scanned was 77% and number of lambs weaned per lamb born was 83%.

DISCUSSION

The ovulation rate and number of embryos recovered per donor were similar to data previously reported in sheep (Armstrong and Evans, 1983; Larsson *et al.*, 1991), and the number of embryos transferred, number of lambs born and number of lambs weaned per donor were comparable to those reported by Shackell and Isaacs (1991), Larsson *et al.,* (1991), Wuliji *et al*., (1995) and Cloete *et al*., (1998). Embryo transfer procedures have long been demonstrated to leverage increases in selection intensity (Rathie, 1982) and genetic gains (Smith, 1988). The uses of MOET for multiplying genetic resources for commercial sale (Lang *et al*., 1982), cryopreservation (Sakul *et al*., 1993), wool trait improvement (Wuliji *et al*., 1995) and improvement of multiple rearing ability (Cloete *et al*., 1998) have also been reported. However industry utilisation has remained low. Negative effects of reproductive technologies on productive traits such as increased birth weight, gestation length and incidence of dystocia in bovine embryos transferred by *in vitro* procedures have been documented (Behboodi *et al*., 1995; Farin and Farin, 1995; Wilson *et al*., 1995) and similar effects, but to a lesser extent, have been reported in ovine embryo studies (Thompson *et al*., 1995; Walker *et al*., 1992). These effects are primarily attributed to *in vitro* culture systems (Holm *et al*., 1994; Walker *et al*., 1992; Thompson *et al*., 1995) or embryo transfer procedures (Wilson *et al*., 1995), or hormonal treatments (Maxfield *et al*., 1996). However, in this limited observation of conventional (*in vivo*) embryo transfer procedures we have not found any negative effects in lambs on production traits such as birth weight, follicle density or FD. Thus a MOET programme is highly efficient in helping achieve specific breeding objectives. Earlier work of the authors has shown that the increase in FD with increasing age was significantly less in ewes born from MOET than in the ultrafine breeding and control flocks (Wuliji *et al*., 1995), so that FD variation within a flock could be reduced across ages, as well as between animals (due to the higher selection intensity with MOET).

Skin follicle studies showed that Merinos have low mean fibre diameters and tend to have high follicle density and secondary to primary follicle ratios (Hynd *et al*., 1996) compared with most other sheep breeds. Follicle density and diameter have moderate to high heritabilities of 0.4 to 0.6 in Merinos (Jackson *et al*., 1975; Purvis and Swan, 1997; Skerritt *et al*., 1997). The maternal handicap of twins for total follicle numbers was estimated as 11% in this trial, which was comparable to that reported for density in Merinos by Schinckel (1955b) and Jackson *et al*., (1975). There was no apparent difference in FD or follicle density between dam groups. Although there was no difference in follicle density per unit measured, small differences in follicle density combined with differences in WW may have masked differences in total follicle numbers. The follicle density may have underestimated in MOET lambs due to a synchronised birth (born 8 days earlier than MN on average) and an expanded body surface area with a higher live weight. This is shown by the estimates of the total follicle numbers (Table 2). Maternal nutrition affects the initiation and maturation of secondary follicles during the last third of the gestation period. A severe nutritional restriction during late pregnancy reduces wool production permanently, by an estimated 0.1 to 0.2 kg annually, due to reduced follicle numbers and skin area (Corbett, 1979). Post-natal nutritional restriction on follicle numbers is minor, but delays follicle maturation and fibre growth for up to 6-12 months (Reis, 1982). The follicle numbers in this trial were primarily affected by birth rank (single vs twins), dam breed (Coopworth vs others), and follicle maturation stages (birth vs weaning). However, we were unable to estimate the proportion of secondary follicles and thereby determine whether their maturation was delayed or permanently differed. Comparison of these animals as adults will provide more information. The difference in follicle numbers between Merinos and other sheep breeds appear to be mostly due to secondary follicle densities (Steinhagen *et al*., 1986). Therefore, enhancing later pregnancy and early post-natal conditions for MOET Merino lambs, by use of crossbred recipient dams, may improve adult fleece production.

The correlation values among follicle and fibre traits in this trial were consistent with reports of other workers (Jackson *et al*., 1975; Purvis and Swan, 1997; Skerritt *et al*., 1997; Andrews *et al*., 1998). However, both follicle and fibre diameter were much finer in MOET lambs of this study than in these previous reports.

The higher weaning weight in MOET lambs from crossbred recipients compared with those reared by Merinos suggests that the crossbreds have an advantage in growth rate and early live weight performance of their lambs. The benefits obtained from MOET programmes using crossbred ewes, especially Coopworth, as recipients will provide better mothering ability and lactation for multiple born MOET lambs, while still capturing the benefit of increased selection intensity from using MOET in the ultrafine Merino breeding nucleus flock.

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