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SUMMARY

In a CSIRO Sheep Heterosis Experiment, 387 F_1 ewes were mated to either purebred, F_1 or F_2 rams for studying the effect of male heterosis on several lamb production traits and to investigate *pro rata* retention of male heterosis based on the dominance hypothesis. Evidence was found to demonstrate the occurrence of a moderate effect due to the F_1 rams (versus the purebreds) and the dominance hypothesis appeared adequate to account for the *pro rata* retention i.e. at 50%, of heterosis in the F_2 rams.

INTRODUCTION

The comparative performance of crossbred versus purebred males used as sires in animal breeding programmes has been studied in several species, including the sheep (Bradford *et al.*, 1963; Stritzke *et al.*, 1984). Recent results from a CSIRO experiment in Australia demonstrated statistically significant heterosis effect from maternal and paternal sources on "total weight of lambs weaned per ewe joined" (Table 3, Ch'ang and Evans, 1982). This economically important measurement of lamb production is determined by a number of component traits attributable to the ewe or the lamb. The purpose of this paper is to report the major findings from a study designed to estimate the effect on lamb production traits of the F_1 ewes, when they are joined (exposed) to either crossbred i.e F_1, or purebred (PB) rams at mating. The resulting difference due to this mating treatment is defined as the male heterosis effect; its *pro rata* retention, i.e. at 50%, in the F_2 rams is also described.

MATERIALS AND METHODS

The data used in the study were obtained from the terminal phase of the CSIRO Sheep Heterosis Experiment (1971-84) when 45 rams (18 PB, 15 F_1, 12 F_2) were joined with a total of 881 mixed-age ewes for a 5-week mating (May/June, 1983) using eight breeding policies (see Table 1 for mating design). The ewes were mated in single-ram groups standardized in age composition and number of ewes (18.5 to 22) per ram. During the ensuing lambing (October/November), 1119 lambs were born and of these, 892 survived to weaning at an average age of about 12 weeks. The PB and F_1 rams used in the matings were contemporaries (born October/November, 1981) sired by the same rams from a 3-breed (Dorset Horn, Merino, Corriedale) diallel mating design. The average genetic merit of these two ram populations is therefore expected to be equal except for the sampling errors involved. The F_2 rams used were born and reared together with the PB and F_1 rams but they were the progeny of *inter se* matings between the F_1 sheep.

The experimental unit in the statistical analysis was the ewe-record and the data for each trait were analysed by the least-squares method (Harvey, 1982) based on a linear model comprising the following effects: age of ewe (2 to 7 years), ewe population (PB, F_1, F_2), breed-genotype x breeding policy nested within ewe population (see Table 2), an overall mean and a residual error term. Appropriate subclass means were used to construct linear contrasts for evaluating the significance of the male heterosis effect ($h=\overline{F}_1-\overline{PB}$) and its *pro rata* retention, i.e. at 50%, by the F_2 rams based on the dominance hypothesis.

RESULTS

The mean body weights of ewes joined in the 1983 mating are presented in Table 1 below, as background data on the ewes studied in this paper.

Table 1. Least-squares means (±s.e.) for Breeding Policy in a 3-breed population.

Mating Design* Male x Female	Breeding Policy	No. Ewes Joined (EJ)	Ewe Weight (Kg)/EJ	Progeny Type
PB^{ii} x PB^{ii}	BP1	78	43.5±0.7	Purebred
PB^{ii} x PB^{jj}	BP2	116	43.8±0.6	2-way cross
$F_1^{ij(ji)}$ x PB^{kk}	BP3	71	43.2±0.7	3-way cross
PB EWES		265	43.5±0.4	
PB^{kk} x $F_1^{ij(ji)}$	BP4	157	46.7±0.5	3-way cross
$F_1^{ij(ji)}$ x $F_1^{ij(ji)}$	BP5	116	48.1±0.6	2-way cross(F_2)
$F_2^{ij(ji)}$ x $F_1^{ij(ji)}$	BP6	114	46.7±0.6	2-way cross
F_1 EWES		387	47.2±0.3	
$F_1^{ij(ji)}$ x $F_2^{ij(ji)}$	BP7	114	46.5±0.6	2-way cross
$F_2^{ij(ji)}$ x $F_2^{ij(ji)}$	BP8	115	45.0±0.6	2-way cross(F_3)
F_2 EWES		229	45.8±0.5	
ALL EWES		881	45.5±0.2	

* i,j,k can be any of the three parental breeds used, namely, Dorset Horn, Merino and Corriedale. $F_1^{ij(ji)}$ x PB^{kk} (for example) denotes the mating of F_1 rams of the ith (paternal) and jth (maternal) breeds to purebred ewes of the kth breed to produce 3-way cross lambs. The three possible permutations of this design comprises BP3. Thus all breeds are represented in each of the breeding policies.
Note: BP5 and BP8 are inter se matings.

The minor differences in mean body weights within each ewe population i.e. PB, F_1, F_2, are due to sampling as the ewes of each population were randomly allocated to the breeding policies specified in Table 1.

Table 2. Least-squares means (±s.e.) for parental breeds, F_1, F_2 rams in BP4, BP5, and BP6 (a)

Breed-Genotype of Ram		%Ewes Marked per 100 EJ (b)	% Ewes Lambed per 100 EJ	Litter Size at birth per EL (c)	% Lambs Alive at weaning per 100 EL	Lamb Weight at weaning (Kg) per EL	Litter Weight (Kg) weaned per EJ
DH	PB (d)	95.2±2.5	90.0±4.2	1.34±0.07	81.6±5.9	21.4±1.2	23.8±1.9
MO	PB	95.0±2.6	82.9±4.3	1.61±0.07	72.7±6.3	18.4±1.3	24.1±2.0
CO	PB	100.0±3.4	96.5±5.7	1.51±0.09	69.4±7.8	19.5±1.6	25.3±2.7
BP4	$\overline{PB}$	96.7±1.7	89.8±2.9	1.49±0.05	74.5±4.0	19.8±0.8	24.4±1.3
DH:MO	F_1 (e)	100.0±4.1	86.6±6.8	1.64±0.11	75.8±9.8	19.3±2.0	25.4±3.2
DH:CO	F_1	100.0±2.9	97.5±4.9	1.72±0.08	70.9±6.7	21.5±1.4	29.9±2.3
MO:CO	F_1	97.7±2.9	95.1±4.8	1.44±0.07	81.0±6.5	17.8±1.3	22.6±2.2
BP5	$\overline{F}_1$	99.2±2.0	93.1±3.3	1.60±0.05	75.9±4.6	19.5±1.0	26.0±1.5
DH:MO	F_2 (f)	100.0±4.1	90.9±6.8	1.36±0.11	76.8±9.5	21.4±2.0	25.7±3.2
DH:CO	F_2	99.9±2.9	92.9±4.9	1.59±0.08	74.4±6.8	20.1±1.4	27.2±2.3
MO:CO	F_2	95.5±2.9	84.1±4.9	1.35±0.08	75.0±7.1	17.6±1.5	19.3±2.3
BP6	$\overline{F}_2$	98.5±2.0	89.3±3.3	1.43±0.05	75.4±4.7	19.7±1.0	24.1±1.5
Heterosis (h)		Estimates of heterosis effect (±s.e.) and its retention by F_2 rams.					
$h_1=(\overline{F}_1-\overline{PB})$		+2.5±2.5	+3.3±4.2	+0.11±0.07*	+1.4±5.8	-0.3±1.2	+1.6±1.9
$h_2=(\overline{F}_2-\overline{PB})$		+1.8±2.5	-0.5±4.2	-0.06±0.07	+0.9±5.8	-0.1±1.2	-0.3±1.9
$h_r=(h_2-\frac{1}{2}h_1)$		+0.6±2.3	-2.1±3.8	-0.11±0.06*	+0.2±5.3	0.0±1.1	-1.1±1.8
$\%h_1=100(h_1/\overline{PB})$		+2.6 %	+3.7 %	+7.4 %	+1.9 %	-1.5 %	+6.6 %
$\%h_2=100(h_2/\overline{PB})$		+1.9 %	-0.6 %	-4.0 %	+1.2 %	-0.5 %	-1.2 %
$\%h_r=100(h_r/\overline{PB})$		+0.6 %	-2.3 %	-7.4 %	+0.3 %	0.0 %	-4.5 %

* $P<0.05$
(a) Breeding policy 4,5,6, see Table 1 for mating design
(b) EJ = Ewes joined (or exposed) for mating. (c) EL = Ewes lambing.
(d) PB = Parental purebred; DH = Dorset Horn; MO = Merino; CO = Corriedale.
(e) F_1 = Reciprocal crosses of the breeds specified.
(f) F_2 = All crosses from _inter se_ matings of F_1 breeds specified.

DISCUSSION

Only the results based on BP4, 5 and 6, involving the F_1 ewe population are presented in Table 2. Thus, the estimate of male heterosis effect on litter weight weaned per ewe joined is +1.6±1.9Kg, or +6.6% of the $\overline{PB}$. The corresponding estimate based on the PB ewe population i.e. BP3-BP2=+1.8±2.3Kg, was also obtained but, due to space limitations, no details are presented here. The results in Table 2 show that the F_1 rams used were superior to the otherwise comparable PB rams in every trait examined but the male heterosis effect (h_1) was significant only on litter size at birth of the ewes lambing. The results based on matings with F_2 rams demonstrate that the male, as well as the female (Young et al., 1986), contributes to observed recombination loss (Dickerson, 1973) in lamb production. In the present data, the h_r effect, while significant on litter size at birth per ewe lambing, did not reach statistical significance in terms of litter weight weaned per ewe joined (h_r=-1.1±1.8Kg, or -4.5% of $\overline{PB}$). In conclusion, the available evidence presented here and previously from the same population (Ch'ang and Evans, 1982) would suggest that male heterosis effect on lamb production is likely to be real, but smaller in size than the corresponding female effect; accordingly, the male heterosis retention is unlikely to have the same practical impact as the female heterosis retention.

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