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BREED DIFFERENCES AND CROSSBREEDING EFFECTS FOR LIVEWEIGHT TRAITS IN AUSTRALIAN MEAT SHEEP BREEDS

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SUMMARY

Field data on 13 meat sheep breeds and their various crosses were analysed to examine breed differences and estimate crossbreeding effects for birth weight (Bwt), weaning weight (Wwt) and post-weaning weight (Pwt). Highly significant ($P < 0.001$) breed additive effects were evident for Coopworth for Wwt (-3.18 Kg) and Pwt (-6.57 Kg). Significant additive effects on Bwt (0.18 Kg; $P < 0.01$) and Wwt (0.85 Kg; $P < 0.001$) were found for Suffolk. None of the breed combinations exhibited significant maternal heterosis. In general, direct heterosis for Bwt, Wwt and Pwt ranged from 0.2 to 1.0 Kg (4.8 to 22%), 1.0 to 1.9 Kg (3 to 5.50%), 0.2 to 2.9 Kg (0.5 to 6%), respectively.

Keywords: Crossbreeding, heterosis, sheep, breed, body weight

INTRODUCTION

Crossbreeding has long been practised as an economical and frugal method of improving efficiency in meat sheep production. It utilizes differences in breeds and exploits hybrid vigour, which enhances the performance level of crossbred progeny above that of the mid-parental mean. One of the aims of this research is to identify if adjustment for heterosis is required in LAMBPLAN (National performance recording scheme for meat sheep in Australia). The LAMBPLAN data covers several types of purebred and crossbred animals derived from different types of structured and unstructured crossbreeding systems. Since weaning and post-weaning weights are the most important traits in a prime lamb enterprise, the objective of this study was to estimate crossbreeding effects on body weight at birth, weaning and post-weaning age involving different meat sheep breeds.

MATERIALS AND METHODS

Data. Data on both purebred and crossbred animals were extracted from the Terminal Sire LAMBPLAN (National performance recording scheme for meat sheep in Australia) database involving 13 different breeds of meat and dual-purpose sheep, which were predominantly Poll Dorset, New Zealand Poll Dorset, White Suffolk, New Zealand Suffolk, Suffolk, Texel and New Zealand Texel but also with records on Coolalee, South Down, Texel Down, Coopworth, South Suffolk and East Friesian. This database consists of pedigree and performance records that are used for genetic evaluation purposes for meat sheep. The data were collected from 1999 to 2004 for Bwt, and 2000 to 2003 for Wwt and Pwt. Summary statistics for each trait are presented in Table 1.

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Traits and fixed effects. The traits examined were birth weight (Bwt), weaning weight (Wwt) and post-weaning weight (Pwt), the latter two traits being measured on average at 100 and 215 days of age, respectively. In addition, information was available on birth type (BT; single, twin and triplet), rearing type (RT; single-reared, twin-reared and triplet-reared), and contemporary group (CG), which was defined as flock-sex-year-management group.

Table 1. Summary statistics for birth, weaning and post-weaning body weight

Trait	Records	No. of sires	Minimum	Maximum	Mean
Bwt (Kg)	131,327	2,746	1.00	11.00	4.79
Wwt (Kg)	171,685	3,535	6.00	87.00	35.85
Pwt (Kg)	155,064	3,578	11.8	125	50.65

Genetic analysis. As the LAMBPLAN database only has information on the individual animal's single breed code, varying proportions of each breed (p_i, i=1,….,12) for each animal were derived using pedigree and breed of base animals. Only those animals with either both or one known parent were analyzed. In the latter case, the missing parent was assumed to be of the same breed as the other parent. The breed proportions were calculated as the average of their parents' proportion, using a recursive algorithm (Kinghorn, pers. comm.). The coefficients for the effects of heterosis were derived from the proportion of heterozygosity of the crossbred animals (Fimland 1983). The coefficients for heterosis were calculated as $[p_s (1 - p_d) + p_d (1 - p_s)]$ (Van der Werf and De Boer, 1989), where p_s and p_d are the breed proportions in the sire and dam gametes, respectively. Firstly, breed additive effects (considered fixed) were estimated using Model 1:

$$Y_{ijklmn} = \mu + BT_i + RT_j + Dage_{ko} + (Dage)_l^2 + Aage_m + CG_n + \sum_{i=1}^{12} p_i Br_i + A_{ijklmnp} + D_{ijklmn} + e_{ijklmn}$$

where Y_{ijklmn} = the individual observation, μ = the mean for Poll Dorset, BT_i = the effect owing to birth type (3 types), RT_j = the effect owing to rearing type (3 levels), $Dage_{ko}$ = the linear regression on dam age, $(Dage)_l^2$ = the second order linear regression on dam age, $Aage_m$ = the effect due to age of the animal, CG_n = the effect owing to contemporary group, p_i = breed proportion, Br_i = the effect (additive) of breeds, $A_{ijklmnp}$ = the individual random additive genetic effect of an animal, D_{ijklmn} = the random genetic effect of the dam and e_{ijklmn} = random error associated with each observation. The covariance between the additive genetic variance of the animal (σ^2_a) and the additive genetic variance of the dam (σ^2_m) was not fitted. The breed additive effects were estimated as deviations from Poll Dorset as partial regression of phenotype on breed proportion of the animal. The ASReml package (Gilmour *et al.* 2002) was used for all analyses. Subsequently, heterosis (direct and maternal) effects for each trait were estimated for all two-breed combinations with sufficient data using Model 2:

$$Y_{ijklmn} = \mu + BT_i + RT_j + Dage_k + (Dage)_l^2 + Aage_m + CG_n + p_1.Br1 + H_d + H_m + A_{ijklmn} + D_{ijklmn} + e_{ijklmn}$$

where μ = the overall mean effect common to all observations, Y_{ijklmn}, BT_i, RT_j, $Dage_{ko}$, $(Dage)_l^2$,

$Aage_m$, CG_n, $A_{ijklmnp}$, D_{ijklmn} and e_{ijklmn} are the same as in (Model 1), Br1 = the additive effect of one breed relative to the other, H_d = the direct heterosis and H_m = the maternal heterosis.

RESULTS AND DISCUSSION

Fixed effects and variance components. For all traits, all fixed effects considered were highly significant (P < 0.001).

Breed additive effects. Large additive effects for Bwt were evident for Suffolk (0.18 Kg; P < 0.01) followed by New Zealand (NZ) Poll Dorset (Table 2). Breed additive effects for Bwt of other breeds were not significant. Highly significant (P < 0.001) direct additive effects for Coopworth (-3.18 Kg and -6.57 Kg) and Suffolk (0.85 Kg and 1.81 Kg) were also found for Wwt (P < 0.001) and Pwt (P < 0.01). Although some of these estimates have high standard errors, these results are in agreement with the findings of Dickerson *et al.* (1972). NZ Poll Dorset exhibited high additive effects for Wwt (0.96 Kg; P < 0.05) and Pwt (1.66 Kg; P < 0.05; Table 2). A high additive effect of Suffolk for Wwt as found in this study is consistent with the findings of Sidwell and Miller (1971), Hohenboken *et al.* (1976) and Levine and Hohenboken (1978). In the present study, the influence of breed effects on Wwt and Pwt was considerably more significant in comparison to Bwt for most breeds (Table 2). Similar findings were reported by Vesely *et al.* (1977).

Table 2. Least squares estimates (SE) of breed additive effects (Kg) and their level of significance for the traits analyzed[1]

Breed	Traits					
	Bwt	n	Wwt	n	Pwt	n
Coolalee	0.67(0.76)	457	4.88(5.26)	609	-4.13(1.45)***	3,523
Southdown	-0.15(0.16)	1,156	0.54(1.00)	1,351	1.69(1.22)	1,226
Coopworth	-0.29(0.14)	1,523	-3.18(0.54)***	3,731	-6.57(0.65)***	2,366
Texel	-0.03(0.08)	5,020	-1.47(0.50)	4,890	-1.82(0.57)	4,821
Suffolk	0.18(0.07)**	56,568	0.85(0.37)***	79,008	1.81(0.46)	66,577
South Suffolk	-0.37(0.31)	702	-0.24(2.25)	853	0.80(2.79)	689
White Suffolk	-0.00(0.05)	51,960	-0.52(0.27)	73,231	-0.04(0.34)	62,056
Texel Down	-0.41(0.51)	14	-2.60(1.98)	251	1.09(2.42)	208
East Friesian	0.08(0.20)	1,044	-1.33(0.75)	3,242	-0.16(1.08)	2,001
NZPD[2]	0.10(0.06)	59,134	0.96(0.30)*	90,718	1.66(0.36)*	83,309
NZ Texel	0.03(0.07)	16,654	-1.60(0.42)	19,527	-1.26(0.51)	16,280
NZ Suffolk	0.04(0.15)	7,928	-0.004(0.71)	11,558	2.01(0.90)	8,954

[1] Breed effects are estimated as deviations from Poll Dorset in an animal model; [2] New Zealand Poll Dorset; *** P < 0.001; ** P < 0.01; * P < 0.05; n is the number of records

Heterosis (Direct and maternal). In general, the magnitude of heterotic effects for Bwt was too low to be of significance (Table 3). The amount of direct heterosis exhibited for Wwt was quite high for Poll Dorset x NZ Poll Dorset (1.05 Kg or 3%), Poll Dorset x NZ Texel (1.61 Kg or 4.5%), Suffolk x NZ Suffolk (1.95 Kg or 5.4%) and Poll Dorset x White Suffolk (2.09 Kg or 5.8%), although the standard errors of these estimates were relatively large. The mean heterosis (averaged over crosses) in Wwt was 1.06 Kg. Vesely et al. (1977) found a mean heterosis of 1.3 Kg in Wwt (measured at 108 days of age) of crossbred lambs. Direct heterosis for Pwt was 2.94 Kg (5.8%) and 1.88 Kg (3.7%) for Poll Dorset x NZ Texel and Poll Dorset x White Suffolk, respectively. The maternal heterosis for Pwt was not significant (P > 0.05) for all breed combinations evaluated.

Table 3. Least squares constant estimates (SE) for direct (H_D) and maternal (H_M) heterosis (Kg) for different traits and breed combinations

Breed combination	Bwt H_D	Bwt H_M	Wwt H_D	Wwt H_M	Pwt H_D	Pwt H_M
PD, WSK	0.03(0.17)	0.05(0.33)	2.09(0.81)	0.44(1.14)	1.88(0.67)	NE[1]
PD, NZPD	0.09(0.03)**	0.07(0.03)	1.05(0.13)**	0.45(0.13)	0.66(0.15)**	0.42(0.14)
TL, NZTL	0.00(0.04)	0.07(0.05)	-0.33(0.32)	-0.03(0.34)	0.25(0.35)	0.08(0.39)
SK, NZSK	0.28(0.12)*	0.03(0.09)	1.95(0.50)	0.78(0.40)	1.47(0.59)	1.57(0.48)
WSK, NZTL	0.43(0.16)	0.87(0.23)	0.22(0.58)	2.66(1.47)	0.90(0.74)	1.33(1.48)
PD, NZTL	0.03(0.15)	0.11(0.12)	1.61(0.76)	1.12(0.69)	2.94(0.58)	1.05(0.69)
SK, WSK	0.05(0.21)	0.12(0.15)	0.40(0.44)	-0.20(0.46)	1.12(0.54)	0.48(0.36)
CW, EF	1.08(0.40)**	NE	1.50(1.06)	-0.89(0.99)	No records available	

[1] Not estimable; PD – Poll Dorset, TL – Texel, SK – Suffolk, WSK – White Suffolk, NZ – New Zealand, CW – Coopworth, EF – East Friesian, NZTL – New Zealand Texel; *** P < 0.001, ** P < 0.01, * P < 0.05

CONCLUSION

The results of this study indicate that Suffolks and White Suffolks have good and average breed effects, respectively. White Suffolks have strong heterosis with Poll Dorset. Additive breed effects are generally accounted for in across breed EBVs (Estimated Breeding Values) such as produced by LAMBPLAN and are important when exploiting genetic variation across breeds. The estimation of across-breed EBVs and fitting heterosis effects in genetic evaluation procedures should be considered.

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