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ACROSS-BREED ANALYSIS OF MATERNAL TRAITS IN NEW ZEALAND BEEF CATTLE

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SUMMARY

This study assessed breed differences in the maternal traits body condition score (BCS), mature cow weight (MCWT) and hip height (HIP) using data from the Beef + Lamb New Zealand Genetics Beef Progeny Test. Age, breed effects and heterosis were estimated to inform the development of an across-breed genetic evaluation system. The results showed that breed differences exist, while positive and significant heterosis effects suggested that crossbred animals may exhibit improved maternal performance. Age effects indicated a steady increase in HIP and MCWT with age, until reaching a plateau at around 7-8 years. BCS followed a non-linear trajectory, peaking at two years before decrease upon first calving then gradually increasing with age until a decline after seven years.

INTRODUCTION

Improving maternal performance is key to enhancing the profitability of cow-calf operations in many commercial beef herds. Three maternal traits, BCS, MCWT and HIP play pivotal roles in production efficiency. MCWT, reflecting the combined weight of muscle, fat, bone, and internal organs, is an important determinant of maintenance feed requirements. While heavier cows tend to be associated with increased weaning weights of calves, they also incur higher maintenance costs due to greater energy demands. HIP, closely linked to frame size, provides insight into growth potential and mature weight, contributing to structural efficiency, and in combination with weight can assist in differentiating between cows which are heavier. This is mainly due to a larger frame-size (generally viewed as undesirable) from cows which are heavier due to increased muscle and fat with moderate frame size. BCS, as an independent measure of energy reserves and fat cover, is phenotypically important for reproductive success. It is especially important during periods of feed shortage when cows must rely on stored body reserves, and cows which naturally maintain higher condition score are generally viewed as being easier (and/or lower cost) to manage.

Exploiting genetic variation within and across breeds for maternal traits requires knowledge of age variation, breed differences, and heterosis effects. The focus in this study was BCS, MCWT and HIP on animals representing Angus and Hereford cattle breeds. By understanding both direct and maternal breed effects on these traits, this work will help to establish options to better utilise genetic resources available, including crossbreeding, in order to enhance the productivity and efficiency of the New Zealand beef industry.

MATERIALS AND METHODS

Data A total of 9,066 animals from the Beef + Lamb New Zealand Genetics beef progeny test were analysed, mainly comprising purebred Angus (5,989) and Hereford (1,515). Crossbreeding has taken place by mating sires from Angus, Hereford, and other breeds (including Stabilizer, Simmental, Shorthorn, Charolais, Limousin, Gelbvieh, and South Devon) with Angus and Hereford dams (Table 1). Since 2021, diallelic crosses between Angus and Hereford have been introduced specifically to study the effects of crossbreeding.

Table 1. Overview of the data structure for cows in the beef progeny test, with numbers representing the count of female animals that have maternal traits (MCWT, BCS, and HIP) recorded

Timeline		**2015 - 2020**					**2021 - 2024**			**Total**
Herd		A	B	C	D	E	F		G	
Dam breed		Angus	Angus	Angus	Hereford	Angus	Angus	Hereford	Angus	
Sire breed	Angus	2,018	1,471	1,162	71	430	303	36	605	6,096
	Hereford	42	122	-	1,143	-	46	372	-	1,725
	Stabilizer	-	104			-				104
	Simmental	178	137	-	7			-		322
	Shorthorn	2	1			-				3
	Charolais	82	5	-	4			-		91
	Limousin	6	6			-				12
	Gelbvieh	2	3			-				5
	South Devon	5				-				5
	Total	2,335	1,849	1,162	1,225	430	349	408	605	8,363

Cows aged two-year-old and older were measured for MCWT, BCS and HIP (Table 2). BCS were visually assessed by either a trained scorer or farmer (trained and regularly calibrated to expert scorers) on a scale of one to ten (Beef + Lamb New Zealand 2017). Repeated measurements on MCWT and BCS were taken at three timepoints within each year: prior to mating, at weaning and prior to calving.

Table 2. Summary of phenotypic records on maternal traits

Trait	**BPT cows with known breed**				**Crossbred BPT cows**			
	Number of records	Number of cows	Range	Mean (SD)	Number of records	Number of cows	Range	Mean (SD)
BCS (Score)	62,538	7,774	3 - 10	6.9 (0.93)	3,004	504	4 - 9	7.06 (0.80)
HIP (cm)	7,253	4,636	115 - 158	129 (4.30)	650	480	118 – 140	128.4 (4.07)
MCWT (kg)	66,434	8,314	264 - 820	525.8(81.06)	4,216	858	297 – 776	491.5 (71.42)

Analyses Univariate animal models were fitted to estimate both breed effects and genetic parameters:

$$y = \mathbf{X}b + \mathbf{Z}a + \mathbf{P}c + e \qquad (1)$$

where y is an $n \times 1$ column vector of phenotypes, where n represents the number of phenotypes; X is an incidence matrix for fixed effects (b), Z is an $n \times q$ incidence matrix for both additive genetic effects (a) of q animals represented in the pedigree, P is an $n \times k$ incidence matrix for permanent environment effects (c) of k dams with one or more maternal performance measures; and e is the column vector of random residual effects. Fixed effects were the age of animals (in years), contemporary groups (i.e., recording herd x date x management group), breed composition covariates (i.e., Angus, Hereford and Other) of animals and their dams (i.e., Dam - Angus, Dam - Hereford and Dam – Other for any unspecified breed composition), and the effects of heterosis (0 for purebred animals and 1 for first crosses).

Basic assumptions of mixed model equations were applied here, such as $E[y] = Xb$ and $var\begin{pmatrix} a \\ c \\ e \end{pmatrix} = \begin{pmatrix} A\sigma_a^2 & 0 & 0 \\ 0 & I\sigma_c^2 & 0 \\ 0 & 0 & I\sigma_e^2 \end{pmatrix}$, where I is the identity matrix of size k for permanent environmental effects and size n for residual effects and the pedigree relationship matrix (A) was constructed using pedigree information spanning three generations on the sire side and five generations on the dam side. Variance component estimation was achieved using ASREML 4.2 (Gilmour 2019).

RESULTS AND DISCUSSION

The lowest heritability (0.26) and repeatability (0.39) among the traits evaluated was for BCS. In comparison, MCWT showed a moderate heritability of 0.50 and a repeatability of 0.78. HIP was the most heritable trait, with an estimated heritability of 0.64 and a repeatability of 0.75. These estimates (Table 3) are consistent with the findings reported by Weik *et al*. (2021) using a subset of this dataset which did not include more recently collected data including records from the diallelic cross.

Table 3. Variance component estimates (σ_a^2= additive genetic variance, σ_{pe}^2= permanent environmental variance, σ_e^2= residual variance), heritabilities (h^2± SE) and repeatabilities (t ± SE) from univariate animal models

Trait	σ_a^2	σ_{pe}^2	σ_e^2	h^2	t
BCS	0.13	0.07	0.29	0.26 (0.02)	0.39 (0.01)
HIP	8.12	1.31	3.20	0.65 (0.03)	0.75 (0.01)
MCWT	1168.54	513.66	509.24	0.53 (0.02)	0.77 (0.01)

The breed estimates suggest that, on average, Angus animals had lower MCWT, BCS, and HIP compared to the other breeds (Table 4). However, no significant differences were observed between Angus and Hereford breed effects for these traits, likely due to the fact that only herd F with 757 animals had both dam breeds in the same contemporary groups. Among maternal breed effects, Hereford dams contributed to higher MCWT (+7.66 kg), whereas other breeds had a negative effect (-5.83 kg) compared to Angus, while maternal breed differences in BCS and HIP were negligible. Overall, breed differences in maternal traits were small relative to the mean values (a 0.5 cm difference in HIP between Angus and Hereford, with a mean of 128.9 cm). Notably, heterosis effects were larger (0.75 for HIP), accounting for approximately 26% of the genetic standard deviation, highlighting the potential benefits of crossbreeding for improving maternal traits.

Table 4. Estimated direct and maternal breed (Angus as reference) effects and heterosis effect (standard error) for maternal traits

Trait	Direct breed effects		Maternal breed effects		Heterosis
	Hereford	Other	Hereford	Other	
BCS	0.08 (0.04)	0.12 (0.04)	0.05 (0.03)	0.02 (0.02)	0.04 (0.02)
HIP	0.50 (0.50)	1.18 (0.35)	0.02 (0.36)	-0.72 (0.23)	0.75 (0.17)
MCWT	-1.50 (2.85)	6.11 (2.61)	7.66 (2.61)	-5.83 (1.77)	7.50 (1.69)

Regarding age effects, HIP was found to increase steadily until approximately seven years of age (Table 5). Likewise, MCWT continued to increase until cows reached nine years of age. In contrast, BCS followed a non-linear trajectory: cows at two years of age were well-conditioned but experienced a rapid decline in BCS upon first calving. Although BCS gradually improved with advancing age, it began to decline again after seven years.

Table 5. Estimated age effects (standard error) for maternal traits

Trait	2	3	4	5	6	7	8	9	10+
BCS	0.61 (0.03)	-0.10 (0.02)	-0.11 (0.01)	0 (0)	0.11 (0.01)	0.16 (0.01)	0.15 (0.01)	0.07 (0.02)	-0.05 (0.02)
HIP	0 (0)	2.22 (0.22)	4.33 (0.30)	4.85 (0.31)	4.95 (0.31)	5.21 (0.31)	5.24 (0.32)	5.33 (0.34)	5.14 (0.35)
MCWT	-109.3 (1.31)	-64.1 (0.90)	-30.28 (0.48)	0 (0)	22.17 (0.45)	34.38 (0.60)	40.74 (0.77)	41.89 (0.94)	41.92 (1.17)

CONCLUSION

This study provides information to aid in the development of an across-breed genetic evaluation system relevant to the NZ beef-cattle population. The estimated breed effects and heterosis highlights the importance of incorporating breed differences into a multi-breed genetic evaluation framework. Furthermore, the positive heterosis estimates emphasise the potential advantages of crossbreeding. Future work should focus on expanding the dataset of crossbred animals to enable more accurate estimation of these effects.

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