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BULL TRAITS MEASURED EARLY IN LIFE AS INDICATORS OF HERD FERTILITY

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SUMMARY

This study investigated the genetic relationships of blood hormones, scrotal size, body weight, condition score and flight time measured on young bulls to 12 months of age with key reproductive traits in Brahman and Tropical Composite breeds (n=4079). Heritability of the traits ranged from 0.17 to 0.72 indicating potential for genetic change in both populations. Genetic correlations with presence of sperm in the ejaculate at 12 months of age, percent normal sperm at 2 years old, and heifer age at puberty were moderate, in some cases up to 0.61, indicating a potential to improve the efficiency of selection of breeding replacements.

INTRODUCTION

The incorporation of traits measured early in life, especially those measured prior to any culling events (e.g. weaning), in genetic evaluation programs has the advantage of avoiding pre-selection. By conducting the measurements on larger groups of contemporaries more genetic variation can be captured. In the case of herd fertility, the potential for success of such genetic evaluation programs can be gauged by the strength of genetic relationships between the early measured traits and established measures of herd fertility.

This study updates a preliminary assessment (Corbet *et al*. 2009) and reports on genetic correlations between traits measured up to 12 months of age in pre-pubertal bulls and measures of semen quality of the bulls, and with age at puberty of their dams. The aim is to ascertain the potential value of early-in-life traits of bulls as predictors of reproductive traits associated with improved herd fertility.

MATERIALS AND METHODS

Animals. Data were obtained from bulls of two breeds (1642 Brahmans and 2437 Tropical Composites) which were progeny of cows bred for the Beef CRC northern Australia breeding project (Johnston *et al*. 2009). Tropical Composites were developed with combinations of Belmont Red, Charbray, Santa Gertrudis and Senepol breeds. Progeny were bred on 5 properties across central, northern and western Queensland over 7 years using sires selected to ensure representation of industry populations and genetic linkage across years and properties within breed. At weaning, bull calves (average of 394 per year) were relocated by road transport to Brigalow Research Station (170km SW of Rockhampton). The remaining 1321 bulls (average of 189 per year) were born at Belmont Research Station (25km NW of Rockhampton) and remained there post-weaning. At Brigalow and Belmont all bulls weaned in the same year were managed as a single group until completion of data collection as 2 year olds. Animals born at Belmont included 250 crossbreds resulting from mixed mating of the two breeds at that location.

Measurements. Birth weights (WT0) were recorded within 72hrs of parturition. At ~4 months of age, blood samples were taken to measure pre-pubertal serum inhibin (IN4) and GnRH stimulated luteinising hormone (LH4), hormones linked to reproductive function (Burns *et al.* 2011). When the bulls were weaned at ~6 months, weight (WT6), insulin-like growth factor-I (IGF6), scrotal circumference (SC6) and flight time (FLT6) were recorded. Body condition score (BC9; scored 1 to 5) was recorded at 9 months and scrotal circumference was again measured at 12 months of age (SC12). An ejaculate from bulls with SC ≥ 20cm was collected by electro-ejaculation at 12 and 24 months. Traits recorded on the ejaculate included presence or absence of sperm at 12 months (Sperm12; 1 or 0), and percent morphologically normal sperm at 24 months (Norm24; 0 to 100%). Age at first ovarian *corpus luteum* (AgeCL) as detected by ultrasound imagery was recorded on the dams of these bulls and previously documented by Johnston *et al.* (2009). The latter three traits represent aspects of herd fertility. Table 1 lists the descriptive statistics of the traits measured.

Table 1. Descriptive statistics of traits measured on tropical breed bulls and their dams

Trait*	Units	Brahman			Tropical Composite		
		N	Mean	SD	N	Mean	SD
IN4	ng/ml	1288	7.4	1.82	1895	7.8	1.92
LH4	ng/ml	1025	5.2	4.46	1520	7.1	1520
IGF6	ng/ml	1626	517	302.1	2415	532	299.4
FLT6	seconds	1642	1.18	0.626	2426	1.21	0.501
WT0	kg	1473	35.3	5.77	2424	36.3	5.93
WT6	kg	1641	204	33.5	2430	220	39.6
BC9	score 1 to 5	1421	2.4	0.33	1962	2.4	0.34
SC6	cm	1609	17.1	1.71	2398	19.3	2.56
SC12	cm	1448	21.2	3.13	2093	26.5	3.37
Sperm12	binomial	1388	0.11	0.314	1966	0.59	0.492
Norm24	%	1234	72	23.1	1912	75	19.1
AgeCL	days	1007	751	142.1	1108	651	119.5

* See text for trait definitions; N = number of animals measured; SD = standard deviation.

Statistical analyses. Significant fixed effects were identified separately for each breed using linear mixed model procedures of GenStat (13th Edition). Models included the fixed effects of year (2004 to 2010), birth location (5 properties), birth month (Sep. to Jan.), post-weaning location (Brigalow or Belmont), dam age (3 to 9 years), previous lactation status (wet or dry), dam management group, their interactions and sire as a random effect. The effect of assay or sample group was included for blood hormone traits and age nested within birth month was included as a covariate for all traits. Sire and dam breed groups were included to account for heterosis effects in Composites and crossbreds. Non-significant terms were sequentially removed from the model to yield the final model for each trait. Variances and trait heritabilities were estimated in univariate analyses using ASReml (v3.0). The animal models used included the final fixed effects identified above with an additional random common environmental effect of the dam. Genetic correlations between traits were estimated in a series of bivariate analyses. The relationship matrix was derived from a pedigree of 13,785 animals spanning several generations.

RESULTS AND DISCUSSION

Estimates of phenotypic and genetic variance parameters for the traits measured are presented in Table 2. The heritability of the traits was generally moderate indicating that genetic change could readily be made by selection. The heritability of IN4 was high and although no published estimates for the trait were cited in cattle, heritability of inhibin in humans has been reported at 80% by Kuijper *et al.* (2007). The high heritability of 64% for SC12 in Brahmans was within the range reported for young Nellore bulls (Eler *et al*. 2006). Heritability estimates for WT6 and Sperm12 suggest breed differences between Brahmans and Tropical Composites for these traits.

Table 2. Additive variance (V_a), phenotypic variance (V_p) and heritability (h^2) estimated for traits measured on young bulls and their dams

Trait*	Brahman			Tropical Composite		
	V_a	V_p	h^2	V_a	V_p	h^2
IN4	2.03	2.82	0.72 (0.13)	2.02	3.01	0.67 (0.07)
LH4	3.64	12.40	0.29 (0.10)	7.16	16.22	0.44 (0.09)
IGF6	7311.1	16536	0.44 (0.08)	5951.0	17468	0.34 (0.07)
FLT6	0.041	0.238	0.17 (0.05)	0.048	0.204	0.23 (0.05)
WT0	12.94	24.70	0.52 (0.10)	14.25	26.67	0.53 (0.09)
WT6	169.77	402.34	0.42 (0.10)	92.77	517.56	0.18 (0.05)
BC9	0.015	0.061	0.25 (0.07)	0.018	0.065	0.28 (0.07)
SC6	0.78	1.76	0.44 (0.09)	1.45	3.54	0.41 (0.08)
SC12	3.06	4.78	0.64 (0.08)	3.68	7.57	0.49 (0.09)
Sperm12	0.029	0.079	0.37 (0.09)	0.038	0.215	0.18 (0.05)
Norm24	83.1	501.0	0.17 (0.07)	87.3	360.0	0.24 (0.07)
AgeCL	7375	13050	0.57 (0.12)	5670	10980	0.52 (0.12)

* See text for trait definitions; standard error shown in parentheses.

Estimated genetic correlations between early measured bull traits and measures of semen quality and puberty in their dams are presented in Table 3. IN4 tended to have negative genetic association with semen quality traits (Sperm12 and Norm24) suggesting that lower levels of inhibin in 4 month old bulls is associated with better semen quality post-puberty. LH4 was positively associated with Sperm12 in both breeds and Norm24 in Brahmans but had a negative correlation with Norm24 in Composite bulls. Similar ambiguity between breeds is suggested for the relationship between IGF6 and Norm24. However, while IN4 and LH4 had low or negligible correlation with AgeCL, IGF6 had a moderate to strong genetic correlation with the female trait. Genetic correlations of similar magnitude were reported by Johnston *et al.* (2009) between IGF-I measured in the dams and their AgeCL.

WT0, WT6 and FLT6 tended to have small or negligible genetic correlation with herd fertility traits. The exception was a negative association between WT0 and Norm24 in Brahmans. The biological basis of this relationship is not clear but it indicates a response of lower birth weight if selecting for higher percent normal sperm in that breed. Genetic correlations between BC9 and fertility traits were inconsistent, generally suggesting genetic antagonism between body condition and semen quality but favourable association with AgeCL in females. Inconsistency may reflect low variance in the scored trait. SC6 had inconsistent genetic association with herd fertility traits especially in the Brahman bulls. The inconsistency here might reflect the difficulty in accurately measuring scrotal circumference at weaning when testes and scrotum are still developing. SC12, however, had consistent favourable correlation with herd fertility traits. The moderate to strong genetic correlations between SC12 and fertility traits indicated that improved SC12 in Brahman and Tropical Composite bulls is genetically associated with more animals producing sperm by 12 months of age, higher percent normal sperm at 24 months and lower age at puberty in females.

Table 3. Genetic correlations between early measured bull traits and herd fertility traits

	Brahman			Tropical Composite		
Trait*	Sperm12	Norm24	AgeCL	Sperm12	Norm24	AgeCL
IN4	-0.06 (0.14)	-0.42 (0.18)	-0.29 (0.11)	-0.39 (0.14)	-0.35 (0.14)	0.02 (0.10)
LH4	0.16 (0.21)	0.27 (0.30)	-0.04 (0.19)	0.36 (0.17)	-0.33 (0.18)	0.15 (0.14)
IGF6	0.18 (0.15)	0.35 (0.22)	-0.61 (0.12)	0.21 (0.15)	-0.20 (0.15)	-0.38 (0.09)
WT0	-0.13 (0.15)	-0.48 (0.21)	0.18 (0.12)	0.09 (0.13)	-0.01 (0.23)	0.06 (0.28)
WT6	-0.10 (0.20)	-0.14 (0.29)	-0.17 (0.21)	-0.27 (0.23)	0.19 (0.25)	0.13 (0.38)
FLT6	0.06 (0.19)	0.15 (0.27)	0.11 (0.17)	-0.02 (0.17)	0.00 (0.17)	-0.06 (0.13)
BC9	-0.25 (0.19)	0.18 (0.27)	-0.38 (0.18)	-0.16 (0.18)	-0.33 (0.18)	-0.17 (0.15)
SC6	0.02 (0.15)	-0.28 (0.22)	-0.34 (0.12)	0.19 (0.14)	0.32 (0.14)	-0.25 (0.10)
SC12	0.64 (0.10)	0.30 (0.20)	-0.43 (0.11)	0.56 (0.10)	0.35 (0.13)	-0.27 (0.09)

* See text for trait definitions; standard error shown in parentheses.

CONCLUSION

As a result of moderate heritability and genetic association with herd fertility traits, IGF-I measured at weaning and inhibin measured at 4 months could be flagged as traits with potential to improve the efficiency of sire selection in tropical breeds. BREEDPLAN already provides EBVs for scrotal size and this study confirms the importance of including the measurement at 12 months in genetic evaluation programs. The ultimate test for these traits as useful indicators of herd fertility will be their genetic correlation with lifetime reproductive performance.

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