Genetic relationship between growth traits in Bonsmara heifer and bull calves on different nutritional regimes

Helena E. Theron* and M.M. Scholtz
Irene Animal Production Institute, Private Bag X2, Irene, 1675 Republic of South Africa
C.Z. Roux
Department of Genetics, University of Pretoria, Pretoria, 0002 Republic of South Africa

Received 2 April 1993; accepted 16 November 1993

A system of feeder–breeder dimorphism (large, fast growing offspring in feedlots obtained from small, low maintenance cows on natural pastures) would be profitable in South Africa. The possibility of a genetic basis for feeder–breeder dimorphism was estimated by calculating genetic correlations between body mass gains achieved by beef cattle bulls in feedlots and body mass gains of half-sib heifers under natural pasture conditions (nutritional, managerial and sex differences between groups). The genetic correlations were 0.79 ± 0.11, 0.01 ± 0.19 and 0.43 ± 0.15, respectively for 12-month weight, ADG (average daily gain, weaning to 12 months) and the Kleiber ratio (ADG/ metabolic 12-month weight). The genetic correlations for ADG and the Kleiber ratio may indicate that different genes affect the measurements in half-sib bulls and heifers in different environments. The weaning to 12-month traits in bulls under feedlot conditions are probably genetically independent of the weaning to 18 months or 12 to 18 months traits in heifers under pasture conditions, as the genetic correlations for ADGs and Kleiber ratios of these traits are closer to zero than to unity (between –0.13 and +0.27). Selection for growth of bulls in feedlots would thus not affect the growth of heifers on pastures, which indicates that feeder–breeder dimorphism can be genetically induced for different nutritional environments.

'n Sisteem van slagdier–teeldierdimorfisme (groot, vinnig-groeiende nageslag in voerkrale wat geproduseer word uit klein, lae onderhoudskoeie op natuurlike weidings) sal winsgewend wees in Suid-Afrika. Die moontlikheid van 'n genetiese basis vir slagdier–teeldierdimorfisme is bepaal deur die berekening van genetiese korrelasies tussen liggaamsmassatoenames van vleisrasbulle in voerkrale en liggaamsmassatoenames van halfsib-verse op natuurlike weidings (voedings-, bestuurs- en geslagsverskille tussen die groepe). Die genetiese korrelasies was 0.79 ± 0.11, 0.01 ± 0.19 en 0.43 ± 0.15, onderskeidelik vir jaarmassa, GDT (gemiddelde daaglikse toename tussen speen en jaarouderdom) en die Kleiberverhouding (GDT/metaboliese jaarmassa). Die genetiese korrelasies vir GDT en die Kleiberverhouding mag impliseer dat verskillende gene die eienskappe van bulle en verse in verskillende omgewings beheer. Die speen- tot jaareienskappe in voerkraalbulle is waarskynlik geneties onafhanklik van die speen- tot 18 maande of jaar- tot 18 maande eienskappe van verse op weidings, aangesien die genetiese korrelasies vir GDT's en die Kleiberverhoudings van hierdie eienskappe nader aan nul as aan een lê (tussen –0.13 en +0.27). Seleksie vir groei van bulle in voerkrale sal dus nie die groei van verse op weidings beïnvloed nie, wat aandui dat slagdier–teeldierdimorfisme geneties geïnduseer kan word onder verskillende voedingstoestande.

Keywords: Bonsmara cattle, feeder–breeder dimorphism, genetic correlation, growth traits.

* Author to whom correspondence should be addressed.

Introduction

In South Africa it is common practice to keep cows on natural pasture and to feed slaughter animals to market finish in feedlots on concentrate diets. It would thus be profitable to have a system of feeder–breeder dimorphism, i.e. where large offspring for slaughter are obtained from small breeding animals (Roux, 1992). Maintenance requirements are proportionate to size at all ages; hence smaller cows have less requirements for maintenance than larger cows (Cartwright, 1970). Thus, a relatively small cow with low feed or land cost/head, early puberty and a relatively low growth rate is desirable, while the opposite is required for slaughter animals (Cartwright, 1970).

Evidence favourable to the dietary induction of feeder–breeder dimorphism follows from the observation by Scholtz & Roux (1989) that continued gains in average daily weight gain (ADG) and body mass at the end of the performance test, at central testing stations on concentrate diets, were not translated into gains in on-farm testing under extensive conditions for the major beef breeds in South Africa. The purpose of this study was to estimate the genetic relationships for growth traits between bulls in feedlots and half-sib heifers on natural pasture. This would indicate whether or not feeder–breeder dimorphism can be genetically induced and utilized by feeding regime, i.e. whether genetic gains achieved by selection of bulls in feedlots during performance testing result in higher genetic gains in the female herd under pasture conditions.

Materials and Methods

Animals

Data of Bonsmara cattle from the Roodeplaat Bonsmara herd of the Department of Agriculture and Water Supply were used.

The animals were born between 1969 and 1986. The data involved were essentially similar to those of Hunlun (1989). The data were corrected by Hunlun (1989) for environmental effects. The natural pasture conditions at the Roodeplaat farm (long. 28° 22′ E and lat. 25° 36′ S) near Pretoria are classified as sourish, mixed bushveld (Acocks, 1975). The farm is at an elevation of approximately 1200 m with 619 mm of rainfall annually, most of it during the months of October to April. The carrying capacity of the veld is 6 ha per large-stock unit (LSU).

In this herd, bulls and heifers were reared together on natural pasture until weaning. The data collected during this period (Phase A of the National Beef Cattle Performance and Progeny Testing Scheme, hereafter called the Performance Testing Scheme) included birth and weaning weights (linear age-corrected 205-day weight). After weaning, bull calves were subjected to performance testing at Irene near Pretoria under intensive conditions in Phases C and D of the Performance Testing Scheme on the same ration, location and management. The basic difference between these tests was that bulls in Phase C received individual *ad libitum* feeding (intakes were recorded), whereas Phase D bulls received shared feeding (Hunlun, 1989; Bergh, 1990). Bulls in both phases were fed a pelleted concentrate with 20% roughage and a metabolizable energy (ME) value of 11.35 MJ ME/kg DM. Bulls also received 1 kg teff hay per day. Yearling weights (linear age-corrected to 365 days) of bulls were obtained from these tests and were pooled for the present study.

The heifers remained on the natural pastures after weaning and were tested in Phase B of the Performance Testing Scheme. As growth from weaning to 12 months on sourveld in winter, with only a protein lick as additional feed, is normally very low or even negative (Bergh, 1990), two additional post-weaning growth periods, viz. weaning to 18 months and 12 to 18 months, respectively, were used in this study. As the heifers were subjected to nutritional stress, growth between weaning and 12 months was thus a period of growth that was more indicative of hardiness than post-weaning growth potential. Yearling weights (linear age-corrected 365-day weights) and 18-month weights (linear age-corrected 540-day weights) of heifers were evaluated.

Data analysis

Genetic correlations had to be estimated to determine whether genetic gains achieved by selection of bulls in feedlots during performance testing resulted in higher genetic gains in the female herd under pasture conditions. These genetic correlations had to be estimated between the same measurement in different animals and not as usual between different measurements in the same animal.

An approximate procedure for covariance component estimation suggested by Wiggans *et al.* (1980) was used. The same unweighted procedure was followed for the variance components in the present study, in contrast to the weighted procedure for variance components suggested by Wiggans *et al.* (1980), since estimates between –1 and +1 were obtained in this way. In essence, this is equivalent to doing Yamada's (1962) analysis on unweighted cell means. Restricted Maximum Likelihood (REML), using a derivative-free algorithm, would also be appropriate and could be used as an alternative method.

Robertson's (1959) formula for the variance of r_g was used as an approximation for the present study. The number of offspring in the equal numbers case was replaced by the harmonic mean.

To minimize the variance of r_g, Robertson's (1959) formula suggests maximizing the product of the sire degrees of freedom and the harmonic mean number of progeny per sire. By progressively deleting the sires with least offspring, it was found that this product reached a maximum value with the inclusion of sires with more than eight calves in each environment.

After deletion of sires with less than nine offspring in each environment, the data set included 24 sires with a total of 649 Phase B performance-tested daughters (extensive grazing conditions) and 554 Phases C and D performance-tested sons (feedlot conditions). Only animals with complete records up to 12 months were included. Each sire had a minimum of nine heifers and nine bulls tested. ADG and the Kleiber ratio (ADG/metabolic 12-month weight) between weaning and 12 months were calculated for all animals. Owing to possible compensatory growth by heifers between 12 and 18 months, the growth of heifers between weaning to 18 months and 12 to 18 months were also calculated and compared to the growth of the bulls between weaning and 12 months. The 18-month weight records of 562 daughters of the 24 sires were available.

Phenotypic correlations could not be calculated as the traits were measured on different animals. Pearson (ordinary) correlations were calculated between the sire means for heifers and bulls.

Results

The average weights and growth rates for bulls and heifers are listed in Table 1. On average, the heifers lost 4.6 kg, or 2%, of their weaning weight by 12 months of age owing to poor nutrition during winter, whereas bulls gained 147.4 kg, or 61%, of their weaning weight in feedlots during the same period. However, heifers probably grew in a compensatory

Table 1 Least-square mean weights, weight gains and standard errors for Bonsmara half-sibs

	Heifers	Bulls
Number of animals		
Birth – 12 months	649	554
18 months	562	–
Weights (kg)		
Birth	36.0 ± 0.2	39.1 ± 0.3
Weaning	220.2 ± 1.2	240.2 ± 1.2
12 months	216.6 ± 2.4	387.6 ± 2.6
18 months	349.7 ± 2.4	–
Weight gains (kg/day)		
Birth – weaning	0.898 ± 0.005	0.981 ± 0.005
Weaning – 12 months	–0.190 ± 0.012	0.921 ± 0.128
12 – 18 months	0.714 ± 0.011	–
Weaning – 18 months	0.370 ± 0.011	–

manner and gained 132.1 kg or 61% of their 12-month weight between 12 and 18 months.

The genetic correlations of growth traits between the half-sibs and Pearson correlations are listed in Table 2. If the genetic correlation is high, then performance in two different environments represents very nearly the same character, determined by very nearly the same set of genes. If it is low, then the characters are to a great extent different, with a different set of genes (Falconer, 1981).

Table 2 Genetic (r_g) and ordinary correlations (r) between sire means of growth traits between half-sib Bonsmara bulls and heifers (± *SE*, estimated according to Robertson, 1959)

	r_g	Pearson r
Birth weight	0.95 ± 0.02	0.77**
Weaning weight	1.00 ± 0.02	0.92**
12-month weight	0.79 ± 0.11	0.57**
$ADG_{birth - weaning}$	0.97 ± 0.00	0.90**
$ADG_{weaning - 12\ months}$	0.01 ± 0.19	0.01
$ADG_{12 - 18\ months}$ [a]	0.04 ± 0.21	0.02
$ADG_{weaning - 18\ months}$ [b]	−0.13 ± 0.21	−0.09
$Kleiber_{weaning - 12\ months}$ [c]	0.43 ± 0.15	0.28
$Kleiber_{12 - 18\ months}$ [a,c]	−0.13 ± 0.21	−0.07
$Kleiber_{weaning - 18\ months}$ [b,c]	0.27 ± 0.20	0.19

** $P < 0.01$.

[a] 12–18 months of heifers, and weaning–12 months of bulls.

[b] Weaning–18 months of heifers, and weaning–12 months of bulls.

[c] Kleiber ratio = ADG/(end weight)$^{0.75}$.

Preweaning

There were no nutritional or environmental differences between bulls and heifers up to weaning, as all calves were reared together on pasture. The genetic correlations between half-sibs of different sexes for birth weight, weaning weight and ADG from birth to weaning are close to unity (Table 2), which indicate that these traits in different sexes are probably controlled by the same set of genes.

Postweaning

After weaning, the sex difference was completely confounded with nutrition and management as all bulls were fed in feedlots under intensive management and all heifers were grazed on pasture under extensive management. It was thus impossible to separate the effects of sex, nutrition and management in this study.

The genetic correlations between the sexes and environments decreased with values of 0.79 ± 0.11; 0.01 ± 0.19 and 0.43 ± 0.15, respectively for yearling weight, ADG and the Kleiber ratio between weaning and 12 months (Table 2). This may indicate that different sets of genes are starting to affect the traits under different conditions. According to Robertson (1959) a genetic correlation around 0.8 has biological importance and a genetic correlation of 0.6 is a significant deviation from unity, which indicate that a genotype–environment interaction affects performance. Such an interaction may occur because the between-group variance component is different or the true ranking of groups is different (Robertson, 1959).

Discussion

Performance testing for growth rate or body mass in South Africa is often carried out under favourable (feedlot) conditions. The environment in which the selection of bulls is practised thus differs from that in which their female progeny are reared. Under some circumstances it may be advantageous to select for feeder–breeder dimorphism, i.e. large body size on concentrate feeds and small body size on pasture, since it is difficult to obtain market finish on large-framed cattle on pasture in most regions of South Africa.

According to the results of this study, feeder–breeder dimorphism can be genetically induced by feeding regime, since the genetic correlations between different sex, half-sib groups for ADG and the Kleiber ratios after 12 months of age do not differ significantly from zero. This indicates that the weaning to 12 months measurements in bulls finished under feedlot conditions are probably genetically independent from the weaning to 18 months and 12 to 18 months measurements in heifers reared under pasture conditions. Selection for growth of bulls reared in feedlots would thus not affect the growth of heifers reared on pastures. This would be advantageous to the South African industry under present circumstances.

DeNise & Ray (1987) studied the progeny of an outbred Hereford herd maintained under range conditions. All heifer progeny were retained under semi-arid grassland conditions, while bull calves were placed on a 140-day postweaning gain test and fed *ad libitum* on a 55% total digestible nutrients (TDN) diet. They concluded that selection under range conditions for 12-month weight should result in a positive correlated response in final weight of bulls, as the correlation between breeding value estimates for 12-month weight of the heifers and final weight of bulls (about 397 days old) was equal to 0.45. In agreement to the present study, they found that daily gains under range conditions may not be closely related to gain test traits, as the correlation between sire breeding values of 8 to 12 month daily gains of heifers and 140-day post weaning gain of bulls was equal to −0.03. This confirms that growth under feedlot conditions and growth under extreme pasture conditions may be different traits and it should not be ignored in the estimation of breeding values and the construction of breeding plans.

There is evidence in the literature that superiority for growth rate under *ad libitum* feeding has a different genetic basis than superiority for growth rate under limited feeding in mice (Falconer, 1977), pigs (Fowler & Ensminger, 1960) and cattle (Warwick *et al.*, 1964). Good growth on different levels of nutrition would be expected to require somewhat different physiological properties, and to be to that extent genetically distinct (Falconer, 1977). Falconer (1960) selected mice in two directions for growth rate on two diets differing in energy concentration and found that gains in environments least favourable for the expression of a trait carried over to more favourable environments, but that the converse was not true. Although not universally true, this result recurred often enough to be considered the most likely response in most situations (Bateman, 1974). Analogous to this, gains in the more favourable environment (feedlot) did not carry over to the cow herd under less favourable conditions. Selection for gain in the feedlot would thus not affect the gain of the cowherd under pasture condition. It can thus be concluded that feeder–breeder dimorphism can be genetically induced and utilized in cattle breeding programmes.

Acknowledgements

The authors are grateful for the advice and assistance of Marga Odendaal and Gabrielle Meyer.

References

ACOCKS, J.H.P., 1975. Veld types of South Africa. *Mem. bot. Soc. S.Afr.* (No. 40). Department of Agricultural Technical Services, South Africa.

BATEMAN, N., 1974. Growth in mice after selection on maize-milk diets. *Anim. Prod.* 19, 233.

BERGH, L., 1990. Die gebruik van die Kleiberverhouding in vleisbeesteelt. M.Sc.(Agric) thesis, University of the Orange Free State, Bloemfontein.

CARTWRIGHT, T.C., 1970. Selection criteria for beef cattle for the future. *J. Anim. Sci.* 30, 706.

DENISE, R.S.K. & RAY, D.E., 1987. Postweaning weights and gains of cattle raised under range and gain environments. *J. Anim. Sci.* 64, 969.

FALCONER, D.S., 1960. Selection of mice for growth on high and low planes of nutrition. *Genet. Res.* 1, 91.

FALCONER, D.S., 1977. Nutritional influences on the outcome of selection. *Proc. Nutr. Soc.* 36, 47.

FALCONER, D.S., 1981. Introduction to quantitative genetics. Longman, New York. pp. 168 & 290.

FOWLER, S.H. & ENSMINGER, M.E., 1960. Interactions between genotype and plane of nutrition in selection for rate of gain in swine. *J. Anim. Sci.* 19, 434.

HUNLUN, C., 1989. Die toepassing van gemengde model tegnieke vir die beraming van teeltwaardes en die kwantifisering van genetiese tendense by vleisbeeste. M.Sc.(Agric) thesis, University of the Orange Free State, Bloemfontein.

ROBERTSON, A., 1959. The sampling variance of the genetic correlation coefficient. *Biometrics* 15, 469.

ROUX, C.Z., 1992. Maximum herd efficiency in meat production. III. Feeder–breeder dimorphism. *S. Afr. J. Anim. Sci.* 22, 11.

SCHOLTZ, M.M. & ROUX, C.Z., 1989. Evaluasie van hulpmiddels vir praktiese teling by beeste. Unpublished invitation lecture, 28th Congr. S. Afr. Soc. Anim. Prod., Ermelo.

WARWICK, E.J., DAVIS, R.E. & HINER, R.L., 1964. Response of monozygotic bovine twins to high and low concentrate rations. *J. Anim. Sci.* 23, 78.

WIGGANS, G.R., QUAAS, R.L. & VAN VLECK, L.D., 1980. Estimating a genetic covariance from least squares solutions. *J. Dairy Sci.* 63, 174.

YAMADA, Y., 1962. Genotype by environmental interaction and genetic correlation of the same trait under different environments. *Jap. J. Genet.* 37, 498.