GENETIC AND PHENOTYPIC TRENDS FOR GROWTH AND

OVERALL EFFICIENCY IN BONSMARA BEEF CATTLE

By

AZWIHANGWISI EDWARD NESAMVUNI

Bachelor of Science in Agriculture

University of Natal
Pietermaritzburg, Rep. of South Africa
1989

Bachelor of Science in Agriculture (Honours)

University of Fort Hare
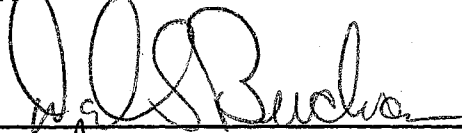Alice, Rep. of South Africa
1990

Master of Science in Agriculture

University of Fort Hare
Alice, Rep. of South Africa
1993

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
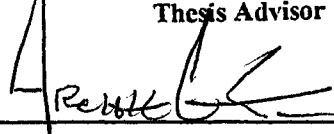the Degree of
DOCTOR OF PHILOSOPHY
December, 1995

GENETIC AND PHENOTYPIC TRENDS FOR GROWTH AND
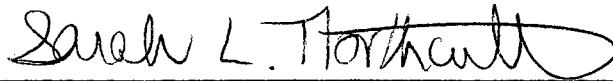
OVERALL EFFICIENCY IN BONSMARA BEEF CATTLE

Thesis Approved:

_____
Thesis Advisor

_____

_____

_____

_____
Dean of the Graduate College

ii

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER III

CHAPTER VI

LIST OF FIGURES

Figure   **Page**

CHAPTER V

CHAPTER VI

CHAPTER I

INTRODUCTION

Beef cattle production in the tropics and subtropics of Southern Africa is characterized by the predominance of *Bos Indicus* and synthetic breeds created from crosses between *Bos Indicus* and *Bos Taurus* breeds. *Bos Indicus* breeds in Southern Africa include among others the Brahman, Afrikaner, Mashona, Sahiwal, Nguni, Boran, Angoni, Barotse and the Tuli. Synthetic breeds in the region include the Bonsmara, Santa Gertrudis, Brangus, and related Brahman crosses. Davis (1993), in making reference to these tropical breeds in Australia, noted that they have the ability to grow and reproduce in more stressful environments than most of the *Bos Taurus* breeds and crosses.

Stresses in the tropics and subtropics can be described by high ambient temperatures, humidity, high incidence of parasites, diseases and poor quality of natural pastures (Bonsma, 1980). Growth rate, fertility and mortality have been reported to differ within and among breeds according to their ability to withstand these stresses (Bonsma and Skinner, 1969; Seifert, 1971; Turner and Short, 1972; Rudder, 1978; Burns, 1979; Frisch and Vercoe, 1982). Therefore, productivity in subtropics and tropics can be improved by breeding practices based on stress resistant breeds.

Most of the synthetic breeds in the subtropics and tropics were created, and may continue to be created, because the individual *Bos Taurus* and the *Bos Indicus* breeds do not perform satisfactorily in all traits of economic importance (Bonsma, 1979).

1

The *Bos Indicus* type of cattle were historically not selected for economic traits, i.e., efficiency of food utilization, fertility, milk production, growth and carcass quality. The Afrikaner breed of South Africa for example was selected on visual traits of no economic value such as the rising chine, long twisted horns and a roman nosed forehead (Bonsma, 1979). Exotic breeds mainly (*Bos Taurus*) lacked the ability to withstand the harsh environments peculiar to the subtropics and tropics of Southern Africa. Synthetic breeds created by stabilized crosses between *Bos Indicus* and *Bos Taurus* became a viable alternative to both exotic and indigenous breeds in Southern Africa.

The successful creation of Santa Getrudis for subtropics of Texas (U. S. A) from the Shorthorn and Brahman breeds motivated the idea of creating a breed with the ability to adapt to stress and have traits of economic importance. The Bonsmara cattle breed among others was created for this very purpose.

The literature review will address the development of the Bonsmara breed in the subtropics of South Africa and breed improvement through performance testing. In addition, the importance of early growth traits, mature size and calving interval will be discussed. Furthermore, non-genetic factors that influence traits of economic importance in subtropics and tropics, genetic parameters for tropical beef cattle, and evaluation of genetic and phenotypic trends in productivity, will be addressed.

This objective of this study was to (a) evaluate weaner production as a measure of cow productivity, (b) obtain estimates of genetic parameters for preweaning growth traits, cow weight and calving interval for subsequent use in genetic evaluation, and (c) evaluate the nature and magnitude of genetic change in early growth traits, cow weight and calving interval, of Bonsmara cattle in the subtropics of South Africa.

CHAPTER II

LITERATURE REVIEW

The Development of the Bonsmara Cattle

The most recent historic account of the creation of the Bonsmara cattle was given by Bosman et al. (1984). In common with the many established breeds of today, the Bonsmara breed was developed by systematic crossbreeding. The first calf in the development of a new South African beef breed was born at Mara Research Station in 1937. Mara is situated in a subtropical area in the Northern Transvaal region of South Africa with the rainfall of approximately 425 mm per annum.

The first phase of the project was carried out under the guidance of Professor Jan C. Bonsma. This fundamental phase in the development of the breed was of great importance. Success at this stage was to determine the ability of the breed to compete in an industry with many breeds.

From the crossbreeding research results including the physiology of adaptation, it became evident that the development of the Bonsmara should proceed on a 5/8 Africaner, 3/8 Exotic (Shorthorn / Hereford) breeding mixture. The first progeny of this desired and tested combination were born during 1943. Numbers were increased systematically by positive selection for growth, fertility, milk production and adaptability. Subjective standards played a secondary role in the selection process (Bonsma, 1980).

One of the first bulls to play a role in the early years of the development was N310 (Frits). He was followed by an outstanding bull N406 which produced calves with weaning weights 44 kg higher than the progeny of the second best sire at that time. Heifer progeny of N406 reared on the range weighed 366 kg at 24 month of age. The bull N406 was in turn followed by a son (T342) Edelheer which in turn formed the basis for the widely known Edelheer line (Bosman *et al.*, 1984).

3

The genetic structure of the breed, in particular the State herd, revealed in 1973 the narrowing of the genetic basis due to excessive use of the Edelheer line. Immediate attempts were made to develop two unrelated lines within the State herds to ensure greater genetic flexibility with a view to the future development of the breed (Bosman et al., 1984).

One line was developed in the Roodeplaat herd from an unrelated bull H22 which was known as Roodebos line while a second line was being developed from an original Afrikaner X Redpoll cross herd bred at Mara and later transferred to the former Department of Native Affairs. This herd was retained as a closed unit over the years and selected on fertility and weaning weight only.

From this herd a group of 29 female animals were being kept at Armoedsvlakte Research station and have been incorporated in the nucleus herd of the Bonsmara breeding program to form the third line to be known as Wesselsvlei line. The expansion of these three lines to meaningful numbers was an important phase in the development of the breed (Bosman et al., 1984).

The Bonsmara breed is probably the only breed in Southern Africa which was and is being developed along scientific lines. All registered breeders must belong to the National Beef Performance and Progeny Testing Scheme.

Performance Testing in Beef Cattle

Performance testing may be described as the system of measuring and recording the performance of each individual animal in the herd, regarding traits of economic importance under the same environmental conditions. These recorded data become a data bank which, upon proper manipulation and analysis, is used in selection and management programs in animals reared within a herd (Brinks, 1984). The main objective of performance testing is to identify superior seedstock for the production of quality progeny. The 'superior seedstock' may differ widely depending upon the environment, feed resources or the specific purposes for which they will be used. Therefore, an important part of research is the study of environmental effects on performance traits, though there may be random or chance environmental variables that may contribute to errors in estimating the breeding value of animals (BIF, 1990).

Preston and Willis (1974) indicated that the rate of genetic improvement within and between breeds depends on: heritability, selection differential, genetic correlations, and generation interval. Performance testing under the South African National Beef Performance and Progeny Testing Schemes, as may be the case with many countries, is based on certain recognized parameters stated by Bosman (1984): (a) individual animals differ with regard to their growth rate, pattern of development and mothering ability, (b) most traits of economic importance have a fairly high degree of heritability, so that the breeding value of an animal can be estimated on the basis of its own performance, (c) the performance of a breeding cow is a repeatable characteristic, so that a cow can confidently be retained or culled on the basis of the performance of her first calf.

Several studies including those of Koch et al. (1994) in temperate regions of the U. S. A. and Seifert (1975) in tropical Australia have shown that the growth rate of cattle can be increased by direct selection. Actual data obtained from herds of different breeds in the subtropics, tropics and temperate regions of South Africa indicated a major improvement as a result of the use of performance testing in a selection process (Bosman, 1984). However, Butts *et al*. (1971) found that only part of the increased growth rate can be transferred to other environments. This corroborated earlier findings by Falconer and Latyzewski (1952) and later Falconer (1977) to conclude that genes governing performance in one environment are only partly the same as those governing performance in another environment. Therefore, performance records can help breeders improve traits of economic importance through selection under the specific environmental conditions in which the animals are reared.

The South African National Beef Performance and Progeny Testing Scheme is one of the organized testing centers in the South African regions. The scheme is composed of five phases which include: (1) Phase A - evaluation of the cow herd: birth weights, preweaning weights, weaning weights, cow weights and reproduction for seedstock and commercial producers. (2) Phase B - post weaning growth: 180-day growth, 360-day growth, 360-day weights, 18-months weight and two year weights for seedstock and commercial producers.

(3) Phase C - standardized growth tests: daily gain, growth per day of age, feed conversion, measurements for seedstock bulls. (4) Phase D - farm growth tests: daily gains, growth per day of age, body measurements for seedstock and all grade bulls. (5) Phase E - carcass evaluation: total edible meat yield, carcass value and quality (Bosman et al., 1984).

Importance of Early Growth Traits, Cow Weight and Calving Interval

Growth and fertility traits are considered important in the beef cattle industry because of their relationship with profitability.

Birth Weight

Birth weight of an animal is associated with dystocia (Nelms et al., 1956; Ritchie, 1985 and Pauw, 1986), post weaning growth (Hunlun, 1985 and Bosman, 1990b) and subsequent reduction in productivity (Smith et al., 1976 and Notter et al., 1978a). Ease of calving becomes even more important under range conditions as it is impractical to closely observe and assist cows that are having difficulty in calving (Cronje, 1992).

Weaning Weight

Weaning weight is generally a direct measure of the product of the cow and a reliable indicator of beef cow efficiency (Marshall et al., 1976 and Long, 1980). Seifert et al. (1970) reported that 100-day weight of the calf was one of the best indicators of milk production of the cow, because the milk production of the dam is not always sufficient for growth after 100- days and the calf may become reliant on pastures.

Mature size

Mature size genetic prediction is important to cattle breeders to make directional changes in the mature size of their cow herd, or bring about uniformity of cow size for a production environment (Northcutt and Wilson, 1993). Several papers have been published with emphasis on estimating lifetime growth curves for weight through maturity (Brown et al., 1972a; Franke and Burns, 1975; DeNise and Brinks, 1985; Johnson et al., 1990). In a study of genetic aspects of growth curve in Hereford beef cows, Denise and Brinks (1985) reported a mature weight heritability of .44 ± .27. Johnson et al. (1990) estimated a mature weight heritability of .38 ± .30 when growth curves were fitted to lifetime records on beef cows. Using Angus field data, Northcutt and Wilson (1993) found a heritability estimate of .48 ± .10 for adjusted mature weight of Angus cattle. Mature weight is also highly correlated to hip height. Northcutt and Wilson (1993) estimated the genetic and phenotypic correlations between adjusted mature weight and mature height to be .78 and .58 respectively. Adjusted mature height heritability was reported to be .83.

Calving Interval

Calving interval is one of the several criteria by which reproductive performance can be evaluated (Bourdon and Brinks, 1983 ; Duarte-Ortuno et al., 1988). Cows with long calving intervals may eventually fail to rebreed under fixed breeding season management (BIF, 1990).

Other studies have indicated that calving date is a better criterion to evaluate cow fertility when a restricted breeding season is applied (Bourdon and Brinks, 1983; Meacham and Notter, 1987; Lopez de Torre and Brinks, 1990 and Ponzoni, 1992). A summary of some of the arguments for and against calving date and calving rate was given by Ponzoni (1992). It was shown that the inclusion of calving date as a reproductive trait in a breeding objectives resulted in smaller genetic gains than the inclusion of calving rate.

However, where calving rate is the preferred trait, it could be treated as a categorical trait in prediction and estimation procedures. This would demand greater effort in the processing of this variable, but a more adequate analysis could result in a greater advantage over calving date. It was concluded that either calving rate or calving date should be included in performance recording schemes servicing beef cattle breeds used in multiple purposes or in a maternal role. However, more work is required before the relative advantages of calving rate and calving date can be clearly established.

Environmental Influences on Beef Cattle Productivity

Productivity in subtropics and tropics of Southern Africa can be enhanced by selection for traits of economic importance, with simultaneous adjustment of major environmental factors that obscure genetic differences among animals (Wang and Marlowe, 1967). Production responses to alleviating environmental stresses are immediate and dramatic as can be noted by the necessity of supplementation to avoid body condition losses when quality and quantity of natural pastures become limiting. However, alleviating high temperature and humidity on the range is not economically feasible (Seifert, 1992). Therefore, environmental factors that influence the accuracy of predicting genetic differences among animals can be adjusted statistically.

Although there is much published information from both the subtropics and tropical regions of the world, it relates to different sets of environmental stress factors and genetic conditions from those of specific regions of Southern Africa. Variation in environmental conditions in part due to year of birth , sex of calf, season of birth / month of birth, age of dam and mature weight of dam will be discussed.

Year of Birth

Changes in the environmental conditions (climate, management, nutrition, breeding and selection) from year to year may be the main cause of the variation in growth traits from birth to 18-month weights (Lombard, 1971). Cows at a low level of nutrition gave birth to calves with decreased birth weight (Heyns, 1974 and Carles, 1984).

Several other researchers have reported a significant effect of year on birth and 100- day weights of cattle (Lombard, 1971; Sellers et al., 1970; Paterson, 1978; Van Zyl, 1982; Swanepoel, 1986; Viljoen, 1986; Kassa-Mersha and Arnason, 1986 and Kars et al., 1994). Non-significant effect of year on birth weight have also been reported by various authors (Reynolds et al., 1980; and Tawonezvi et al., 1986).

Studies that investigated the variation in weaning weights of calves also indicated significant influence of year effects (Swiger, 1961; Pheringo et al., 1969; Sellers et al., 1970; Urikk et al., 1971; Lombard et al., 1971; Wilson, 1973; Heyns, 1974; Pabst et al., 1977; Keller et al., 1978; Paterson, 1978; Van Zyl, 1982; Kassa-Mersha and Arnason, 1986; Lubout, 1988 and Kars et al., 1994). Selection for growth and improved management were reported to increase the weaning weights of calves (Swanepoel, 1986; Viljoen, 1986).

Sex of Calves

Bull calves are generally heavier at all ages from birth to 18-months. A recent study by Kars et al. (1994) indicated bull calves of the Sanga cattle were 7.3 and 8.8 percent heavier than heifers at birth and weaning , respectively. Other results in the literature that reported significant influence of sex of calf on weight include those of Pahnish et al. (1961), Anderson et al. (1965), Bair et al. (1972), Bailey et al. (1972), Pabst et al. (1977) and Kassa-Mersha et al. (1986).

Season of Birth / Month of Birth

Manipulation of the calving season is essential to ensure the most favorable conditions for both the cow and the calf (Venter, 1977). Cows should not lose weight as cow weight influences future conception rate. In the subtropic regions of Southern Africa the highest conception rate was achieved in cows that had calved from August to November (Bishop, 1992). Calves born in winter (May to July) of South African subtropics and tropics have been found to be generally lighter than calves born in summer (October to December) for all growth traits (Bosman and Harwin, 1966; Bonsma and Skinner, 1969; Lombard, 1971; Heyns, 1974; Venter, 1977; Paterson, 1978; Swanepoel, 1986; Viljoen, 1986 and Lubout, 1988).

Studies that considered specific month of birth in other countries indicated significant effects on birth weight (Pheringo et al., 1969; Sellers et al., 1970 and Burfening, 1974). However, Venter, 1977 and Seifert et al. (1970) reported a non-significant effect of month of birth on 90-day weights and weaning weights, respectively.

Age of Dam

Growth traits of Zebu type calves increase as the age of dam increases from age at first calf to eight years and then decline as the dams become older (Van Zyl, 1982 and Lubout, 1988). Other researchers have indicated that a considerable proportion of the variation in birth and preweaning weights may be explained by the age of the dam (Bosman and Harwin, 1967; Lombard, 1971; Wilson, 1973; Pabst et al., 1977; Paterson, 1981; Massey et al., 1981; Van Zyl, 1982; Swanepoel, 1986; Viljoen, 1986; Tawonezvi et al., 1986 and Kars et al., 1994).

A non-significant effect of age of dam has also been reported in the literature (Heyns, 1974; Viljoen, 1986 and Tawonezvi et al., 1986). The effect of age of dam on birth weight may be explained to a large extent by its relationship with cow size and milk production changes (Koch and Clark, 1955; Pabst et al., 1977). Brinks et al. (1962) reported that heavier cows tended to produce heavier calves. Environmental factors that affect traits of economic importance tend to be unique to the specific location and production system. Identifying genotypes aided with breeding practices that increase genetic adaptation may increase efficiency of beef production in the subtropics and tropics regions.

Genetic Parameter Estimates for Beef Cattle in Tropical Regions

Genetic parameter estimates for growth traits of *Bos indicus* cattle have been reviewed for tropical regions of America by Plasse (1979) and for tropical Australia by Davis (1993). The present review summarizes published estimates for growth traits and calving interval generated from different breeds employing different techniques. Because of the large number of estimates published, they will be presented in Tables 1 to 5. Special effort was made to present estimates published from Southern Africa and regions with similar environments.

Table 1. Heritability estimates for birth weight in beef cattle of various breeds

Heritability	Breeds	Source	Country
.38		Preston et al. (1974) (51 references)	
.28 ± .01	Zebu	Iloeje (1986)	Nigeria
.26 ± .01	South Devon	Iloeje (1986)	Nigeria
.44		Ritchie (1985)	U. S. A.
.40		Woldenhawariat et al. (1977) (Review)	
.18 ± .10	Hereford	Veseth et al. (1993)	U. S. A.
.36 ± .12	Hereford	Swanepoel et al. (1988)	South Africa
.36 ± .16	Romosinuano	Tewolde et al. (1988)	Latin America
.14 ± .06	Zebu Gorba	Sow et al. (1988)	U. S. A.
.19 ± .06	Pedi	Lubout et al. (1990)	South Africa
.35 ± .08	Pedi	Lubout (1991)	South Africa
.32 ± .08	Mashona	Tawonezvi et al. (1986)	Zimbabwe
.48		Srinivasan et al. (1970)	U. S. A.

Table 2. Heritability estimates for preweaning gain in beef cattle of various breeds

Heritability	Breeds	Source	Country
.32 ± .05	Hereford males	DeNise et al. (1988)	U. S. A.
.37 ± .05	Hereford females	DeNise et al. (1988)	U. S. A.
.17		Baker et al. (1980) (Review)	
.46	Shorthorn	Trus et al. (1988)	Canada
.20 ± .12	Hereford	Veseth et al. (1993)	U. S. A.
.27	Charolais	Trus et al. (1988)	Canada
.33	Simmentaler	Trus et al. (1988)	Canada
.25	Hereford	Trus et al.(1988)	Canada
.50	Angus	Brown et al. (1990)	U. S. A.
.74	Hereford	Brown et al (1990)	U. S. A.
.26	Angus	Trus et al. (1988)	Canada
.27	Africander cross	Hetzel et al. (1990)	Australia
.29	Hereford-Shorthorn	Hetzel et al. (1990)	Australia
.15	Brahman cross	Hetzel et al. (1990)	Australia
.32	Zebu cross	Mackinon et al. (1991)	Australia

Table 3. Heritability estimates for weaning weight in beef cattle of various breeds

Heritability	Breeds	Source	Country
.30	Bonsmara	Bosman (1990)	South Africa
.31 ± .01	Zebu	IloeJe (1986)	Nigeria
.21 ± .01	South Devon	Iloeje (1986)	Nigeria
.32		Ritchie (1985)	U. S. A
.30		Allen et al. (1980)	U. S. A
.17 ± .11	Hereford	Veseth et al. (1993)	U. S. A
.27 ± .09	Hereford	Swanepoel et al. (1988)	South Africa
.29 ± .14	Romosinuano	Tewolde et al. (1988)	Latin America
.28 ± .08	Zebu Gorba	Sow et al. (1988)	U. S. A
.19 ± .06	Pedi	Lubout et al. (1990)	South Africa
.05 ± .05	Pedi	Lubout (1991)	South Africa
.30		Preston et al. (1970) (61 refs.)	
.05 ± .05	Afrikaner	Heyns (1974)	South Africa
.31		Wodenhawariat et al. (1977) (103 refs.)	
.01 ± .03	Zebu	Rico et al. (1985)	Cuba
.41 ± .27	Hereford	Brown et al. (1972b)	U. S. A.
.30 ± .22	Angus	Brown et al. (1972b)	U. S. A.
.38 ± .12	Mashona	Tawonezvi et al. (1986)	Zimbabwe

Table 4. Heritability estimates for final weight[a] in beef cattle of various breeds

Heritability	Breeds	Source	Country
.47	Bonsmara	Hunlun (1985)	South Africa
.58		Ritchie (1985)	U. S. A.
.14 ± .06	Pedi	Lubout et al. (1990)	South Africa
.42 ± .11	Bonsmara	Hunlun (1985)	South Africa
.52 ± .20	Hereford heifers	Swanepoel (1986)	South Africa
.13 ± .05	Nellore	Mariante (1979)	Brazil
.66 ± .23	Romosinuano	Tewolde et al. (1988)	Latin America
.45 ± .10	Angus mature weight	Northcutt et al. (1993)	U. S. A.
.27 ± .14	Zebu Gorba	Sow et al. (1988)	U. S. A.
.17 ± .06	Pedi	Lubout (1991)	South Africa
.54 ± .31	Hereford 20 months weight	Brown et al. (1972b)	U. S. A.
.51 ± .27	Angus 20 months weight	Brown et al. (1972b)	U. S. A.
.58 ± .28	Angus 16 months weight	Brown et al. (1972b)	U. S. A.
.47 ± .29	Hereford 16 months weight	Brown et al. (1972b)	U. S. A.

[a]Used as an indication of mature weight

Table 5. Heritability estimates for calving interval in beef cattle of various breeds

Heritability	Breeds	Source	Country
.02 to .04		Miller et al. (1966)	U. S. A.
.03	Angus	Schalles (1967)	U. S. A.
.003 to .33	Haryana	Dhoke and Johar (1977)	India
.022	Nellore	Miranda et al. (1982)	Latin America
$.10 \pm .08$	IndoBrazil	Nodot et al. (1981)	Mexico
$.22 \pm .11$	Gir	Singh et al. (1982)	India
.03	Hereford	Fagerlin (1968)	U. S. A.
-.00	Retinta	Lopez de Torre et al. (1990)	Spain
.01	Retinta	Lopez de Torre et al. (1990)	Spain
.06	Hereford	Lindley et al. (1958)	U. S. A.

Genetic, Phenotypic and Environmental Correlations for Growth Traits of Beef Cattle

Genetic, phenotypic and environmental correlations for growth traits of the South African Pedi beef cattle are presented in Table 6. Values were taken from a study on genetic parameters and trends of Pedi cattle by Lubout (1991). Postweaning growth traits were also included to demonstrate the association between pre-and postweaning traits. Also, genetic and phenotypic correlations between growth traits were also summarized by Woldehawariat et al. (1977) for the subtropics of America, and by Davis (1993) for the tropics of Australia. Genetic and phenotypic correlations between birth weight and weaning weight reported by Woldehawariat et al. (1977) were .54 and .38, respectively. Davis (1993) found an average estimate of .55 genetic correlation based on studies in tropical Australia. Genetic correlations between weaning weight and postweaning traits obtained by Lubout (1991) were similar to those reported by Knights et al. (1984) but lower than those reported by Woldehawariat et al. (1977), Neely et al. (1982), Rico et al. (1985), Tewolde (1988) and Davis (1993). Barlow (1978) mentioned that selection for increased weaning weight would increase live weight at all ages, from birth to maturity. One of the consequences of this breeding objective would be an increase in the female mature body weight. High phenotypic and environmental correlations between pre- and postweaning traits indicate that gains made early in life are carried through into postweaning periods.

Table 6. Genetic (G), phenotypic (P) and environmental (E) correlations[a] of birth weight, weaning weight, yearling weight and final weight.

		Weaning weight	Yearling weight	Final weight
Birth weight	G	.11 ± .36	-.30 ± .18	.45 ± .21
	P	.26	.20	.15
	E	.31	.42	.35
Weaning weight	G		.40 ± .30	.39 ± .38
	P		.72	.51
	E		.81	.53
Yearling weight	G			.23 ± .23
	P			.52
	E			.61

[a]From Lubout (1991)

Variance Components and Genetic Parameters for Early Growth Traits of Beef Cattle

Univariate Analysis

Improvement of performance through selection is largely dependent on the effective use of additive genetic variation which requires the accurate estimation of genetic parameters for the traits to be selected (Kars et al., 1994). Growth performance is widely used as the selection criterion in beef cattle since weight is of economic importance and can easily be measured. Numerous variance components and heritability estimates of growth traits for direct additive and maternal additive components have been reported for beef cattle (Hohenboken et al., 1971; Burfening et al., 1981; Betrand et al., 1987; Cantet et al., 1988 Trus et al., 1988; Mackinnon et al., 1991; Meyer et al., 1991; Meyer, 1992 and 1993a & b; Waldron et al., 1993 and Kars et al., 1994).

In most early publications, the sire-maternal grandsire model was used in the estimation of variance components. Recently the increase in computing power and software capability have facilitated the use of more detailed models to estimate variance components (Cantet, 1990; Boldman et al., 1991; MacKinnon et al., 1991; Meyer and Hill, 1992). An animal model which takes into account the effects of direct genetic, maternal genetic and permanent environment can now be used to obtain more detailed partitioning of variance. Literature estimates of both direct and maternal effects for growth traits have been presented by Cantet (1990) and Meyer (1992). An updated list of early growth traits is presented in Tables 7 and 8.

According to Meyer (1992), early growth rate as measured by birth weight and weaning weight is determined not only by its own genetic potential but also by the maternal environment. These mainly represent the dam's milk production and mothering ability, though effects of uterine environment and extra-chromosomal inheritance may contribute. Therefore, dams affect the phenotype of their progeny through a sample of half her additive direct genes for growth, as well as through the maternal environment she provides the calf. For optimum efficiency of selection both direct and maternal components should be taken into account, especially if an antagonistic relationship between them exists (Meyer, 1992).

Table 7. Estimates of genetic parameters for birth weight in beef cattle

h^2	m^2	r_{AM}	c^2	c_{AM}	h^2_T	Breed[a]	Model[b]	Source[c]
.40	.19	-.42			.34			1
.21	.11	-.24			.21	SIM		2
.16	.06	-.44			.13	SIM	S-MGS	3
.34	.20	-.22			.36	SIM	S-MGS	4
.44	.12	-.38		-.09	.37	SIM	S-MGS	5
.36	.82	-.51			.35	HEF		6
.18	.21	-1.05		-.21	-.02	HEF		7
.39	.13	-.39			.32	HEF	S-MGS	4
.58	.22	-.12	.03	-.05	.62	HEF	S-D-MGS	8
.37	.13	-.34			.32	ANG	S-MGS	4
.42	.22	-.12	-.38	-.04	.47	ANG	S-D-MGS	8
.27	.20	.55			.56	SHH	S-MGS	4
.42	.17	-.39			.35	CHA	S-MGS	4
.22	.05	-.16	.05	-.02	.22	LIM	S-D-MGS	9
.25	.13	-.12	.00	-.02	.28	BRN	S-D-MGS	9
.61	.11	.01		.02	.68	ZX	AMM	11
.43	.12	.07	.02	.02	.51	HEF	AMM	12
.45	.14		.00		.52	BX	S-D-MGS	10
.47	.05		.07		.49	AX	S-D-MGS	10
.23	.03		.18		.24	HS	S-D-MGS	10

[abc]See Table 9 for abbreviations

Table 7. Estimates of genetic parameters for birth weight in beef cattle (Continued)

h^2	m^2	r_{AM}	c^2	c_{AM}	h^2_T	Breed[a]	Model[b]	Source[c]
.41	.16	-.49			.44	NGUN	AMM	18
.56					.56	HEF	AM	19
.38	.14	.05		.01	.47	HEF	AMM	19
.41	.08	.04	.05	.01	.46	HEF	AMP	19
.52					.52	ANG	AM	19
.34	.10	.27		.05	.47	ANG	AMM	19
.36	.07	.29	.03	.05	.46	ANG	AMP	19
.20					.20	CHA	AM	20
.50					.50	HS1	AM	21
.23	.14	.30			.39	HS1	AMM	21
.24	.11	.37	.03		.39	HS1	AMP	21
.48					.48	AS1	AM	21
.31	.09	.26			.42	AS1	AMM	21
.33	.04	.28	.06		.40	AS1	AMP	21
.47					.47	AS2	AM	21
.29	.14	.09			.39	AS2	AMM	21
.32	.06	.13	.07		.37	AS2	AMP	21
.58						WOLP	AM	22
.47	.08	.14				WOLP	AMM	22
.49	.05	.12	.04			WOLP	AMP	22

[abc]See Table 9 for abbreviations

Table 8. Estimates of genetic parameters for weaning weight in beef cattle

h^2	m^2	r_{AM}	c^2	c_{AM}	h^2_T	Breed[a]	Model[b]	Source[c]
.30	.52	-.72			.25			1
.12	.08	-.04			.09	SIM	S-MGS	3
.10	.13	.04		.01	.17	SIM	S-MGS	13
.12	.09	.16	.07	.02	.19	SIM	S-MGS	14
.36	.19	-.32		-.08	.33	SIM	S-MGS	5
.32					.32	SIM	AM	15
.19			.08		.19		AMP	15
.19	.07				.19		AMM	15
.18	.24	.25			.38	HEF		16
.32	.27	-.57		-.17	.20	HEF		7
.66	.43	-.08		-.04	.76	HEF	S-D-MGS	8
.24	.18	.16			.38	ANG		16
.63	.16	-.36		-.11	.63	ANG	S-D-MGS	8
.16	.15	-.30	.06	-.05	.17	LIM	S-D-MGS	9
.28	.20	-.29	.04	-.07	.28	BRN	S-D-MGS	9
.14	.29		.06		.29	AX	S-D-MGS	10
.20	.12		.19		.26	HS	S-D-MGS	10
.12	.08		.21		.16	BX	S-D-MGS	10
.34	.16				.42	BX	AMM	17
.20	.32	.00		.00	.36	ZX	AMM	11
.16	.19	-.20	.26	-.03	.20	HEF	AMM	12
.29	.20	-.39			.40	NGUN	AMM	18

[a][b][c]See Table 9 for abbreviations

Table 8. Estimates of genetic parameters for weaning weight in beef cattle (Continued)

h^2	m^2	r_{AM}	c^2	c_{AM}	h^2_T	Breed[a]	Model[b]	Source[c]
.23					.23	HEF	AM	19
.14	.46	-.59			.14	HEF	AMM	19
.14	.13	-.59	.23		.09	HEF	AMP	19
.44					.44	ANG	AM	19
.19	.18	.19			.33	ANG	AMM	19
.19	.14	.22	.04		.32	ANG	AMP	19
.34					.34	ZX	AM	19
.59	.49	-.74			.24	ZX	AMM	19
.58	.36	-.78	.11		.23	ZX	AMP	19
.22	.11	-.80	.24		.21	CHA	AMP	20
.36					.36	HS1	AM	21
.14	.41	-.40			.20	HS1	AMM	21
.15	.14	-.35	.21		.14	HS1	AMP	21
.42					.42	AS1	AM	21
.12	.28	.04			.27	AS1	AMM	21
.14	.11	.06	.15		.21	AS1	AMP	21
.38					.38	AS2	AM	21
.12	.25	.00			.25	AS2	AMM	21
.13	.15	.00	.09		.20	AS2	AMP	21
.38						WOLP	AM	22
.26	.17	.02				WOLP	AMM	22
.29	.07	-.13	.12			WOLP	AMP	22

[abc]See Table 9 for abbreviations

Table 9. Breed, type of model and authors associated with estimates of genetic parameters.

[a]**Breed,** SIM-Simmental, HEF-Hereford, ANG-Angus, LIM-Limousin, BRN-Brangus

AX-Africander cross, BX-Brahman cross, HS-Hereford-Shorthorn cross, ZX-Zebu cross

SHH-Shorthorn, CHA-Charolais, NGUN-Nguni, WOLP-Wokalup

[b]**Model** used -AM, simple animal model; AMP, animal model with a permanent environmental

dam effect; AMM, animal model with maternal genetic effect; S-MGS, sire-maternal grandsire

model; S-D-MGS, combination of S-MGS and sire-dam model

[c]**Source** -1. Baker (1980) Review; **2.** Burfening et al. (1981) U. S. A;

3. Quaas et al. (1985) U. S. A; **4.** Trus et al. (1988) Canada; **5.** Garrick et al. (1989) U. S. A;

6. Nelson et al. (1984)U. S. A; **7.** Cantet et al. (1988) U. S. A; **8.** Brown et al. (1990) U. S. A;

9. Bertrand et al. (1987) U. S. A; **10.** Hetzel et al. (1990) Australia; **11.** Mackinnon et al. (1991)

Australia; **12.** Koch (1989) U. S. A cited by Meyer (1992); **13.** Graser et al. (1985) Australia; **14.**

Wright et al. (1987) U. S. A; **15.** Mrode et al. (1990) United Kingdom; **16.** Skaar (1985) U. S. A;

17. Robinson (1990) Australia; **18.** Kars et al. (1994) Rep. of South Africa;

19. Meyer (1992) Australia; **20.** Meyer (1993a) Australia; **21.** Waldron et al. (1993) Australia;

22. Meyer et al. (1993) Australia;

Reviews of the influence of maternal effects on selection are given by Baker (1980) and

Robinson (1981). Willham (1980) and Baker (1980) outlined detailed models for maternally influenced

traits, including additive genetic, dominance and environmental effects due to the animal and its dam.

The model allowed for covariances between them and also extended to include grandmaternal effects or

recombination loss.

Methods to estimate variance components and genetic parameters have been reviewed by Foulley et al. (1978). These methods relied on the separate estimation of covariance between various types of relatives, equating these to their expectations and solving the resulting system of linear equations (Meyer, 1992). Foulley et al. (1978) concluded that: (a) such procedures combine information in a non-optimal way as they ignore the fact that the same animals may have contributed to different covariances and (b) sampling variances of estimates cannot be derived.

Maximum likelihood methods as outlined by Thompson (1976) overcome the problems, but Meyer (1992) stated that estimates derived from maximum likelihood are still unlikely to be precise. For example, in optimal experimental designs, in the presence of maternal effects sampling variances of estimates of direct heritability were three to five times as large as when there were direct effects only (Thompson, 1976). To date the animal model is considered the model of choice for a wide range of applications.

Multivariate analysis

In order to estimate the direct additive genetic correlation (r_A), maternal genetic correlation (r_M), permanent environmental correlation (r_C), residual correlation (r_E), phenotypic correlation (r_P) and genetic correlation between direct effect for trait i and maternal effects for trait j, multiple trait models are carried out considering only two traits at a time mainly to restrict computational requirements (Meyer, 1993a and 1993b). Estimates for genetic parameters for traits from different bivariate and univariate analyses tend to be similar though some fluctuations in the partitioning of variance have been found when complicated models are fitted (Meyer, 1993a and 1993b). Higher estimates of variance components are also expected in late growth traits (yearling weight and final weight) where culling has taken place based on an early growth traits like weaning weight.

Few studies have estimated genetic correlations between early growth traits in beef cattle. Moderate to high direct additive genetic correlations (r_A) between BWT and WWT of .56 and .75 were reported by Meyer (1993 a & b) and Meyer et al. (1993). Estimated maternal genetic correlations (r_M) were .14 and .71, respectively. Permanent enviromental correlations (r_E) were small between early traits included in the study, .19 and .28, respectively. The genetic corelation between direct effects for BWT and maternal effects for WWT was small and negative (-.23). A low estimate of genetic correlation between direct effects for WWT and maternal effects for BWT was reported (-.06) (Meyer, 1993b). From the results observed in a study by Meyer (1993b) selection for direct effects for BWT or WWT will result in reduced maternal effects for BWT or WWT.

Genetic, phenotypic and environmental trends for growth traits in beef cattle

Improving the rate of genetic change through selection is a primary goal of animal breeders. The accuracy of selecting superior parents for the next generation becomes the basis on which genetic improvement is dependent (van Wyk et al., 1993). In order to determine the effectiveness of genetic selection, trends in the population under consideration must be monitored (van Wyk et al., 1993).

Wilson and Willham (1986) described the use of genetic, phenotypic and environmental trends in a within-herd breeding program. Trends can be: (a) a very quick assessment of a breeder's selection in previous generations, (b) used to compare different selection and management practices in large herds, (c) an indicator of correct or wrong selection and management practices and (d) used to indicate how much selection was actually applied.

Mixed linear models methodology by Henderson (1973) is employed for animal genetic evaluation. Animal models that incorporate all known relationships in population are the method of choice in separating genetic and environmental effects under different environments (Henderson, 1973; Wiggans et al., 1987). Phenotypic and genetic trends are estimated by regressing actual performance and breeding values records on date of birth (Nadarajah et al., 1987). A detailed explanation of genetic, phenotypic, environmental and across herd trends was published by Willham (1988).

Within-herd genetic trend can be used as evidence of selection response whereas environmental trends are evidence of management effects and climatic changes. Venter (1977) stated that large fluctuations in environmental trends are expected in the preweaning period as calves are dependent on milk production of the dam, which is largely influenced by the nutrition. During the postweaning period calves are influenced by management and environmental conditions. Fluctuations in genetic trends can be influenced by the use of one good or poor sire that can cause breeding values to be all positive or negative (van der Westhuizen, 1990; Lubout, 1991).

Breeding values reported by Lubout (1991) also indicated that use of performance tested sires and progeny tested sires tended to improve the breeding values more than the use of sires which were not performance tested. Overall genetic change of early growth traits can also be attributed to the breeding values of dams (Wilkes, 1983).

Several researchers reported positive genetic change on specific phases of the genetic and environmental trends: Lubout (1991) for the South African Pedi cattle, Willham (1988) for Brangus cattle, Hunlun (1989) for Bonsmara, van der Westhuizen (1990) for Shorthorn cattle, Tewolde (1988) for Romosinuano cattle, Zollinger and Nielsen (1984) for Angus cattle and Nadarajah et al. (1987) for Angus and Hereford cattle.

Literature Cited

Allen, D., and B. Kilkenny. 1980. Beef production. Granada publishing, Frogmore, St Albans.

Andersen, H, and M. Plum. 1965. Gestation length and birth weight in cattle and buffaloes: A review. J. Dairy. Sci. 48:1224.

Bailey, C. M., Y. O. Koh, J. E. Hunter, and C. R. Torell. 1972. Environmental influence on calf weight factors. J. Anim. Sci. 34:885.

Bair, L. G., L. L. Wilson, and J. H. Ziegler. 1972. Effects of calf sex and age of dam on pre- and post-weaning performance of calves from an Angus-Holstein crossbred herd. J. Anim. Sci. 35:1155.

Baker, R. L. 1980. The role of maternal effects on the efficiency of selection in beef cattle: A review. Proc. N. Z. Soc. Anim. Prod. 40:285.

Barlow, R. 1978. Biological ramifications of selection for preweaning growth in cattle. A review. Anim. Breed. Abst. 46:469

Beef Improvement Federation. 1990. Guidelines for uniform beef improvement programs. 6th Ed. Stillwater Oklahoma.

Bertrand, J. K., and Benyshek, L. L. 1987. Variance and covariance estimates for maternal influenced beef growth traits. J. Anim. Sci. 64:728.

Bishop, E. J. B. 1992. Personal communication.

Boldman, K. G., L. D. Van Vleck, K. E. Gregory and L. V. Cundiff. 1991. Estimates of direct and maternal parameters for 200 d weight in purebred and composite lines of beef cattle. J. Anim. Sci. 69: 204 Suppl. 1 (Abstr.)

Bonsma, J. 1979. Bonsma Lectures, Invitational lectures given before 'The International Stockman's School'.

Bonsma, J. 1980. Livestock production, A global approach. Tafelberg publishers. Cape Town.

Bonsma, J. C., and J. D. Skinner. 1969. Factors influencing birth date, birth weight and preweaning growth rate of Afrikaner, Bonsmara and Hereford cattle in the subtropics. Proc. S. Afr. Soc. Anim. Prod. 8:161.

Bosman, D. J. 1984. Application of performance test results. Performance and Progeny Testing Scheme,

Dept. Agric. and water Supply. Pretoria.

Bosman, D. J. 1990. Prestasie en nageslagtoetsing. Paper delivered at the Bonsmara Spring School.

Bosman, D. J., and G. O. Harwin. 1966. Genetic and environmental factors affecting pre-weaning traits in

beef cattle under extensive ranching conditions. Proc. S. Afr. J. Anim. Sci. 5:153.

Bosman, D. J., and G. O. Harwin. 1967. Variation between herds in respect of the influence of year, sex,

season and age of cow on weaning weight of beef calves. Proc. S. Afr. Soc. Anim. Prod. 6:213.

Bosman, D. J., C. Hunlun and R. G. Gibson. 1984. Summary of performance test data (1960-1983), Meat

Board Focus 3, 6:21.

Bourdon, R. M., and J. S. Brinks. 1983. calving date versus calving interval as reproductive measure in

beef cattle. J. Anim. Sci. 57:1412.

Brinks, J. S., R. T. Clark, N. M. Kieffer and J. R. Quesenberry. 1962. Mature weight in Hereford range

cows-heritability, repeatability and relationship to calf performance. J. Anim. Sci. 62:501.

Brinks, J. S. 1984. The concept of performance testing. U. S. Range Livest. Exp. Sta. Miles City Montana.

Brown, C. J., Z. B. Johnson, and D. W. Wright. 1990. Pre- and postnatal direct and maternal additive

genetic influences on preweaning growth traits of beef cattle. In: W. G. Hill, R. Thompson, and J.

A. Wolliams (Editors). Proc. 4th World Congr. Genet. Appl. Livest. Prod., Edinburgh, 15:267

(cited by Meyer, 1992).

Brown, J. E., C. J. Brown, and W. T. Butts. 1972a. A discussion of the genetic aspects of weight, mature

weight and rate of maturing in Hereford and Angus cattle. J. Anim. Sci. 34:525.

Brown, J. E., C. J. Brown, and W. T. Butts. 1972b. Relationships among weights, gains and earliness of

maturity in Hereford and Angus females. J. Anim. Sci. 35:507.

Burfening, P. J. 1974. Dairy-beef crossbreeding: I. Growth to weaning. J. Anim. Sci. 38:1317 (Abstr.).

Burfening, P. J., D. D. Kress, and R. L. Friederich. 1981. Calving ease and growth rate of Simmentaler-

sired calves. III. Direct and maternal effects. J. Anim. Sci. 53:1210.

Burns, W. C., M. Koger, W. T. Butts, O. F. Pahnish, and R. L. Blackwell. 1979. Genotype by

environment interaction in Hereford cattle. II. Birth and weaning traits. J. Anim. Sci. 49:403.

Butts, W. T., M. Koger, O. F. Pahnish, W. C. Burns and E. J. Warwick. 1971. Performance of two Lines of Hereford cattle in two environments. J. Anim. Sci. 33:923.

Cantet, R. C. J., D. D. Kress, D. C. Anderson, D. E. Doornbos, P. J. Burfening, and R. L. Blackwell. 1988. Direct and maternal phenotypic effects on preweaning growth of beef cattle. J. Anim. Sci. 66:648.

Cantet, R. C. J. 1990. Estimation and prediction problems in mixed linear models for maternal genetic effects. Ph.D. Thesis, University of Illinois, Urbana. (Cited by Waldron et al. 1993)

Carles, A. B., and J. Riley. 1984. Methods of analyzing the effect of season of birth on weaning weight in a Zebu X Temperate beef herd in Kenya. Anim. Prod. 38:429.

Cronje, C. V. 1992. Exposition and evaluation of the Bonsmara young A. I. sire scheme. M. Sc. (Agric). Thesis. Univ. of Fort Hare, Alice (South Africa).

Davis, G. P. 1993. Genetic parameters for tropical beef cattle in Northern Australia: A Review. Aust. J. Agric. Res. 44:179.

DeNise, R. S. K., and J. S. Brinks. 1985. Genetic and environmental aspects of growth curve parameters in beef cows. J. Anim. Sci. 61:1431.

DeNise, S. K., M. Torabi, D. E. Ray, and R. Rice. 1988. Genetic parameters estimates for preweaning traits of beef cattle in a stressful environment. J. Anim. Sci. 66:1899.

Dhoke, M. V, and K. J. Johar. 1977. Variation in calving interval of Haryana cows. Indian Veterinary Journal 54:619.

Duarte-Ortuno, A., W. Thorpe, and A. Tewolde. 1988. Reproductive performance of purebred and crossbred beef cattle in the tropics of Mexico. Anim. Prod. 47:11.

Fagerlin, P. T. 1968. Aspects of calving interval in Herefords. M. S. Thesis. Colorado State Univ. Fort Collins (cited by Lopez de Torre and Brinks, 1990).

Falconer, D. S. and M. Latyszewski. 1952. Selection for size in mice on high and low planes of nutrition. (Cited by Preston and Willis, 1974)

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

Foulley, J. L., and G. Lefort. 1978. M'ethodes d'estimation des effets directs et maternels en selection animle. Ann. Genet. Sel. Anim. 10:475.

Franke, D. E., and W. C. Burns. 1975. A discussion of growth curves of Angus, Brahman, Hereford and Santa Gertrudis cows. Florida Agric. Exp. Sta. Anim. Sci. Rep. No. AL-1975-1 (cited by Northcutt, 1993)

Frisch, J. E., J. E. Vercoe. 1982. Consideration of adaptive and productive components of productivity in breeding beef cattle for tropical Australia. 2nd World. Cong. Genet. Appl. Livest. Prod., Madrid, Spain. Section RT-E-4:307.

Garrick, D. J., E. J. Pollak, R. L. Quaas, and L. D. van Vleck. 1989. Variance heterogeneity in direct and maternal weight trait by sex and percent purebred for Simmentaler-sired calves. J. Anim. Sci. 67:2515.

Graser, H. U., and K. Hammond. 1985. Mixed model procedures for the Australian beef industries. I. Multiple trait model for estimation of breeding values for 200-day and final weights of cattle. J. Aust. Agric. Res. 36:527.

Henderson, C. R. 1973. Sire evaluation and genetic trends. In Proc. Anim. Breed. Genet. Symp. in honor of Dr. J. L. Lush. Am. Soc. Anim. Sci. and Am. Dairy Sci. Assoc. Champaign.

Hetzel, D. J. S., R. L. Quaas, G. W. Seifert, K. G. Bean, H. M. Burrow, and W. J. Aspden. 1990. Genetic parameters for growth of tropical beef cattle. Proc. 8th Conf. Aust. Ass. Anim. Breed. and Genet. Hamilton, N. Z. pp. 517.

Heyns, H. 1974. Genetiese- en omgewingsparameters van 'n Afrikanerbeeskudde. D. Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Hohenboken, W. D., and J. S. Brinks. 1971. Relationship between direct and maternal effects on growth in Herefords: II. Partitioning of covariance between relatives. J. Anim. Sci. 32: 26.

Hunlun, C. 1985. Naspeense groeivermoe en voeromset verhouding. National Beef Cattle Performance and Progeny Testing Scheme (1980-1985 results).

Hunlun, C. 1989. Die toepassing van gemengde model tegnieke vir beraming van teeltwaardes en die kwantifiserring van genetiese tendense by vleisbeeste. M. Sc. (Agric). Thesis. Univ. of Orange Free State. (South Africa).

Iloeje, M. U. 1986. Components of variance for growth traits among Zebu and South Devon beef cattle in Southeastern Nigeria. Livest. Prod. Sci. 14:231.

Johnson, Z. B., C. J. Brown, and A. H. Brown, Jnr. 1990. Evaluation of growth patterns of beef cows. Arkansas Agric. Exp. Sta. Bull. No. 923 (cited by Northcutt, 1993).

Kars, A. A., G. J. Erasmus, and J. van der Westhuizen. 1994. Variance component and heritability estimates for growth traits in the Nguni cattle stud at Bartlow Combine. S. Afr. J. Anim. Sci. 24:129.

Kars, A. A., G. J. Erasmus, and J. van der Westhuizen. 1994. Factors influencing growth traits in the Nguni cattle stud at Bartlow Combine. S. Afr. J. Anim. Sci. 24:18.

Kassa-Mersha Hailu, and T. Arnason. 1986. Non-genetic factors affecting growth of Ethiopian Boran cattle. World. Rev. Anim. Prod. 22:45.

Keller, D. G., J. S. Brinks. 1978. Mating systems by environment interactions for weaning weight in Hereford cattle. J. Anim. Sci. 46:54.

Knights, S. A., R. L. Baker, D. Gianola, and J. B. Gibb. 1984. Estimates of heritabilities and of genetic and phenotypic correlations among growth and reproductive traits in yearling Angus bulls. J. Anim. Sci. 58:887.

Koch, R. M and R. T. Clark. 1955. The influence of sex, season of birth and age of dam on economic traits in range beef cattle. J. Anim. Sci. 14:386.

Koch, R. M., L. V. Cundiff and K. E. Gregory. 1994. Cumulative selection and genetic change for weaning or yearling weight or for yearling weight plus muscle score in Hereford cattle. J. Anim. Sci. 72: 864.

Lindley, C. E., G. T. Early, J. A. Whatley (Jnr.), and D. Chambers. 1958. A study of the reproductive performance of a purebred Hereford herd. J. Anim. Sci. 17:336.

Lombard, J. H. 1971. Genetic and environmental factors affecting production of beef cattle in the

    Highland Sourveld areas. D. Sc. (Agric). Thesis. Univ. Pretoria, Pretoria (South Africa).

Long, C. R. 1980. Crossbreeding for beef production: Experimental results. J. Anim. Sci. 51:1197.

Lopez de Torre, G., and J. S. Brinks. 1990. Some alternatives to calving date and intervals as measures of

    fertility in beef cattle. J. Anim. Sci. 68:2650.

Lubout, P. C. 1988. Environmental and genetic factors influencing production in a herd of Pedi cattle. M.

    Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Lubout, P. C. 1991. Genetic parameters and -trends of Pedi cattle in Lebowa. D. Sc. Agric-Thesis. Univ.

    of Fort Hare. Alice (South Africa).

Lubout, P. C., F. C. J. Swanepoel. 1990. Parameters of Sanga cattle in Developing Areas. Proc. 4th

    World. Cong. Genet. Appl. Livest. Prod. Edinburgh, Scotland. 14:386.

Mackinnon, M. J., K. Meyer, and D. J. S. Hetzel. 1991. Genetic variation and covariation for growth,

    parasite resistance and heat tolerance in tropical cattle. Livet. Prod. Sci. 27:105.

Mariante, A da S. 1979. Growth and reproduction of Nellore cattle in Brazil: Genetic parameters and

    effects of environmental factors. Diss. Abstr. Int. B. 39:5673.

Marshall, D. A., W. R. Parker, and C. A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus,

    Charolais and reciprocal cross cows. J. Anim. Sci. 43:1176.

Massey, M. E., and L. L. Benyshek. 1981. Estimates of genetic and environmental effects on performance

    traits from Limousin field data. J. Anim. Sci. 52:37.

Meacham, N. S., and D. R. Notter. 1987. Heritability estimates for calving date in Simmentaler cattle. J.

    Anim. Sci. 64:701.

Meyer, K. 1993a. Covariance matrices for growth traits of Australian Polled Hereford cattle. Anim. Prod.

    57:37.

Meyer, K. 1993b. Estimates of covariance components for growth traits of Australian Charolais cattle.

    Aust. J. Agric. Res. 44:1501.

Meyer, K., and W. G. Hill. 1992. Approximation of sampling variances and confidence intervals for

    maximum likelihood estimates of variance components. J. Anim. Breed Genet. 109: 264.

Meyer, K., K. Hammond, P. F. Parnell, M. J. Mackinnon, and P. F. Parnell. 1991. Estimates of covariance between reproduction and growth in Australian beef cattle. J. Anim. Sci. 69:3533.

Meyer, K. 1992. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. Livest. Prod. Sci. 31:179.

Meyer, K., M. J. Carrick, and B. J. P. Donnelly. 1993. Genetic parameters for growth traits of Australian beef cattle from a multibreed selection experimentation. J. Anim. Sci. 71:2614.

Miller, P., L. D. van Vleck, and Henderson, C. R. 1966. Interrelationships among herd life, milk production and calving interaction. J. Anim. Sci. 25:879 (Abstr.).

Miranda, J. J. F., G. G. de Garnerio, C. G. Fonsea, and J. A. G. Bergman. 1982. Environmental and genetic factors affecting calving interval in Nellore cows. Anim. Breed. Abstr. 51:184.

Mrode, R. A., and R. Thompson. 1990. Genetic parameters for body weight in beef cattle in Britain. In: W. G. Hill, R. Thompson, and J. A. Wolliams (Editors). Proc. 4th World. Congr. Genet. Appl. Livest. Prod. Edinburgh. 15:271.

Nadarajah, K., D. R. Notter, T. J. Marlow, and A. L. Eller (Jnr.). 1987. Evaluation of phenotypic and genetic trends in weaning weight in Angus and Hereford populations in Virginia. J. Anim. Sci. 64:1349.

Neely, J. D., B. H. Johnson, E. U. Dillard, and O. W. Robinson. 1982. Genetic parameters for testes size and sperm number in Hereford bulls. J. Anim. Sci. 55:1033.

Nelms, G. E., and R. Bogart. 1956. The effects of birth weight, age of dam and the time of birth on suckling gains of beef calves. J. Anim. Sci. 15:662.

Nelsen, T. C., R. E. Short, J. J. Urick, and W. L. Reynolds. 1984. Genetic variance components of birth weight in a herd of unselected cattle. J. Anim. Sci. 59:1459.

Nodot, P., T. Olson, M. Koger, and D. Hargove. 1981. Reproductive performance of IndoBrazil cows in Mexico. Anim. Breed. Abstr. 52:6520.

Northcutt, S. L., and Wilson, D. E. 1993. Genetic parameters estimates and expected progeny differences for mature size in Angus cattle. J. Anim. Sci. 71:1148.

Notter, D. R., L. V. Cundiff, G. M. Smith, D. B. Laster, and K. E. Gregory. 1978. Characterization of

biological types of cattle. VI. Transmitted and maternal effects on birth and survival traits in

progeny of young cows. J. Anim. Sci. 46:892.

Pabst, W., J. B. Kilkenny, and H. J. Langholz. 1977. Genetic and environmental factors influencing calf

performance in pedigree beef cattle in Britain. Anim. Prod. 24:29.

Pahnish, O. F., E. B. Stanley, R. Bogart, and C. B. Roubicek. 1961. Influence of sex and sire on weaning

weights of southern range calves. J. Anim. Sci. 20:454.

Plasse, D. 1979. Growth aspects of Bos Indicus in the American Tropics. II. Wld. Rev. Anim. Prod. 15:

21

Paterson, A. G. 1978. Statistical analysis of factors affecting preweaning growth of beef cattle under

intensive pasture conditions. M. Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Paterson, A. G. 1981. Factors affecting post weaning growth and reproduction of crossbred cattle under an

intensive production system. D. Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Pauw, P. A. 1986. Distocia by vleisbeeste. M. Sc. (Agric). Thesis. Univ. of Orange Free State,

Bloemforntein (South Africa).

Pheringo, D. L., J. V. Whiteman, R. L. Willham, and D. F. Stephens. 1969. Association between day of

birth and corrected weaning weight in beef cattle. J. Anim. Sci. 29:1.

Ponzoni, R. W. 1992. Which trait for genetic improvement of beef cattle reproduction: calving rate or

calving day? J.Anim. Breed. Genet. 109:119.

Preston, T. R., and M. B. Willis. 1974. Intensive beef production Pergamon Press. Oxford, New York,

Toronto, Sydney.

Quaas, R. L., M. A. Elzo, and E. P. Pollak. 1985. Analysis of Simmentaler data:estimation of direct and

maternal (co)variances. J. Anim. Sci. 61:221 (Suppl. 1. Abstr.).

Reynolds, W. L., W. G. Kirk, F. M. Peakock, and M. Koger. 1980. Genetic and environmental factors

affecting weaning performance of calves at the range cattle stations. J. Anim. Sci. 17:1143

(Abstr.).

Rico, C., T. Planas, and M. A. Menchaca. 1985. Preweaning growth of the Zebu cattle. II. Genetic

    parameters. Cuban J. Agric. Sci. 19:137.

Ritchie, H. D. 1985. Calving difficulty in beef cattle. Beef Improvement Federation Fact Sheet. Virginia

    Co-operation Extension Service.

Robinson, D. L. 1990. Genetic variances and covariances for live weight in Queensland beef cattle. Proc.

    8th Conf. Australian Association for Animal Breeding and Genetics, Hamilton, NZ, pp. 435

    (Cited by Meyer, 1992)

Robinson, O. W. 1981. The influence of maternal effects on the efficiency of selection: A review. Livest.

    Prod. Sci. 8:121.

Rudder, T. H. 1978. Crossbreeding beef cattle in Queensland. Beef Cattle Husbandry Branch Technical

    Bulletin No. 11. Qld. Dept. of Primary Industries.

Schalles, R. R. 1967. Reproductive and genetic patterns in a herd of Angus cows. Diss. Abstr. 27: 3361B

    (cited by Preston and Willis, 1974).

Seifert, G. W. 1971. Ecto- and endoparasitic effects on the growth rates of Zebu crossbred and British

    cattle in the field. Aust. J. Agric. Res. 22:839.

Seifert, G. W. 1975. Effectiveness of selection for growth rate in Zebu X British crossbred cattle. I. Pre-

    weaning growth. Aust. J. Agric. Res. 26:393.

Seifert, G. W. 1992. Breeding strategies for beef cattle in tropical and sub-tropical environments.

    Seminar. S. Afr. Soc. of Anim. Prod. 31st Congr. Eastern Transvaal (South Africa).

Seifert, G. W., and R. L. Willham. 1970. Beef-dairy crossbreeding rate. J. Anim. Sci. 31:1012 (Abstr.).

Sellers, H. I., R. L. Willham, and R. C. De Baca. 1970. Effects of certain factors on weaning weight of

    beef calves. J. Anim. Sci. 31:5.

Singh, A., C. M. Taylor and B. S. Ganing. 1982. A note on the study of calving interval in Gir cows.

    Indian Veterinary Journal 59:827.

Skaar, B. R. 1985. Direct and maternal effects variance component estimation from field data. In: Beef

    Improvement Federation, Madison, WI, pp. 156 (cited by Wright et al. 1987).

Smith, G. M., D. B. Laster, and K. E. Gregory. 1976. Characterization of biological types of cattle. I. Dystocia and preweaning growth. J. Anim. Sci. 43:27.

Sow, R. S., J. P. Denis, and J. C. M. Trail. 1988. Facteurs de variation genetique de la productivite du Zebu Gorba: Croissance avant et apres sevrage. Proc. 3rd World Cong. Sheep and Beef Cattle Breed. Paris, France. 2:376.

Srinivasan, G., and T. G. Martin. 1970. Genetic trends in a beef herd selected for growth. J. Anim. Sci. 31:1013 (Abstr.).

Swanepoel, F. J. C. 1986. Genetiese en omgewingsparameters van 'n vleisraskudde. Ph.D. Thesis. Univ. of Orange Free State, Bloemfontein (South Africa).

Swanepoel, F. J. C., and H. Heyns. 1988. Genetiese parameters van speenkalf eienskappe by Herefordkalwers. S. Afr. J. Anim. Sci. 18: 75.

Swiger, L. A., K. E. Gregory, R. M. Koch, and V. A. Arthaud. 1961. Effect of inbreeding on performance traits of beef cattle. J. Anim. Sci. 20:626.

Tawonezvi, H. P. R., J. W. I. Brownlee, and H. K. Ward. 1986. Studies on growth of Nkone cattle. III. Estimation of genetic parameters. Zimbabwe J. Agric. Res. 24:37.

Tewolde, A. 1988. Genetic analysis of Romosinuano cattle: Selection possibilities for beef in the Latin American Tropics. Proc. 3rd World Cong. Sheep and Beef Cattle Breed. Paris. France 2:275.

Thompson, R. 1976. The estimation of maternal genetic variances. Biometrics. 32:903.

Trus. D., and J. W. Wilton. 1988. Genetic parameters for maternal traits in beef cattle. Can. J. Anim. Sci. 68:119.

Turner, H. G., and A. J. Short. 1972. Effects of field infestation of gastrointestinal helminths and of the cattle tick (Boophilus microplus) on growth of three breeds of cattle. Aust. J. Agric. Res. 23:177.

Urick, J. I., B. W. Knapp, J. S. Brinks, O. F. Pahnish, and T. M. Riley. 1971. Relationship between cow weights and calf weaning weights in Angus, Charolais and Hereford breeds. J. Anim. Sci. 33:343.

van der Westhuizen, J. 1990. Ondersoek na die waarde van gemengde model metodologie vir die vleisbeesteler. M. Sc. (Agric.). Thesis. Univ. of Orange Free State, Bloemfontein (South Africa).

van Wyk, J. B., G. J. Erasmus, and K. V. Konstantinov. 1993. Genetic and environmental trends of early growth traits in the Elsenburg Dormer sheep stud. S. Afr. J. Anim. Sci. 23:85.

van Zyl, J. G. E. 1982. 'n Evaluasie van die gevolge van teel- en seleksie metodes soos toegepas deur die Bonsmarabeestelersgennotskap. M. Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Venter, H. A. W. 1977. Die doeltreffendheid van voorspeense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord-Transvaalse soetbosveld. D.Sc. (Agric) Thesis. Univ. of Pretoria, Pretoria (South Africa).

Veseth, D. A., W. L. Reynolds, J. J. Urick, T. C. Nelsen, R. E. Short, and D. D. Kress. 1993. Paternal half-sib heritabilities and genetic, environmental, and phenotypic correlation estimates from randomly selected Hereford cattle. J. Anim. Sci. 71:1730.

Viljoen, J. J. 1986. Die invloed van genetiese- en omgewingsfactore op produksie-eienskappe van 'n Afrikanerbeeskudde. M. Sc. (Agric). Thesis. Univ. of Orange Free State, Bloemfontein (South Africa).

Waldron, D. F., C. A. Morris, R. L. Baker, and D. L. Johnson. 1993. Maternal effects for growth traits in beef cattle. Livest. Prod. Sci. 34: 57.

Wang, G. A, and T. J. Marlowe. 1967. Environmental influences on growth and grade of yearling beef cattle. J. Anim. Sci. :541.

Warwick, E. J., R. E. Davis, and R. L. Hiner. 1964. Response of monozygotic bovine twins to high and low concentrate rations. J. Anim. Sci. 23:78.

Wiggans, G. R., and I. Misztal. 1987. Supercomputer for animal model evaluation of Ayshire milk yield. J. Dairy Sci. 70:1906.

Wilkes, D. L. 1983. The effect of adjusting beef cow performance records for service sire effects and partitioning the total genetic trend for weaning weight into direct and maternal components. Diss. Abst. Int. B: 44.

Willham, R. L. 1980. Problems in estimating maternal effects. Livest. Prod. Sci. 7:405.

Willham, R. L. 1988. Selection objectives and programs applied to breeds in order to improve efficiency: North American example. Proc. 3rd Wolrd. Cong. Sheep and Beef Cattle Breed. Paris, France. 2: 261.

Wilson, D. E., and R. L. Willham. 1986. Within-herd phenotypic genetic and environmental trend lines for beef cattle breeders. J. Anim. Sci. 63:1087.

Wilson, L. L. 1973. Effects of sire, calf, sex and age and age of dam on birth weight and body dimensions at one and three days of age. J. Anim. Sci. 36:452.

Woldehawariat, G., M. A. Talamantes, R. R. Petty (Jnr.), and T. C. Cartwright. 1977. A summary of genetic and environmental statistics for growth and conformation characters of beef cattle. Tex. Agric. Exp. Stn. Dept. Anim. Sci. Tech. Rep. no. 103.

Wright, H. B., E. J. Pollak, and Quaas, R. L. 1987. Estimation of variance and covariance components to determine heritabilities and repeatability of weaning weight in American Simmental cattle. J. Anim. Sci. 65:975

Zollinger, W. A., and M. K., Nielsen. 1984. An evaluation of bias in estimated breeding values for weaning weight in Angus beef cattle field records. I. Estimates of within herd genetic trend. J. Anim. Sci. 58:545.

CHAPTER III

Genetic and Environmental effects on preweaning growth traits of Bonsmara

calves under South African range environment

A. E. Nesamvuni[*], D. S. Buchanan[*] S. L. Northcutt[*], A. C. Clutter[*], and J. D. Ivy[+]

[*]Department of Animal Science, Oklahoma State University, Stillwater 74078-0425

and [+]Ivy Farms, Munnik, South Africa.

ABSTRACT

Preweaning growth data for 1604 Bonsmara calves under range environment were collected over a 10 year period (1980 to 1989), to evaluate weaner production as a measure of cow productivity of Bonsmara cattle under South African range conditions. Collection of records on preweaning traits was done within the specification of the South African Beef and Performance Testing Scheme. Birth weight (BWT) records were analyzed assuming a model that included the genetic effects of sire of calf and dams within sire of calf and environmental effects of sex of calf (SC), year of birth (YB), season of birth (SB), age of dam (AOD) and residual error. The mathematical model used to analyze weaning weight (WWT) and preweaning gain (PWG) was similar to that of BWT with the inclusion of the interactions of SB×AOD, YB×SB and SC×SB. Variation in preweaning traits was influenced by sire of calf (P < .001) and dam within sire (P < .01). Results of this study indicated that SC affected (P < .001)preweaning growth of calves. Bull calves were 2.15 kg heavier than heifers at birth, 19.05 kg heavier at weaning and had .09 kg greater gain over the preweaning phase.

Interaction of SB×AOD and SC×SB were found to be important for PWG. Heritability estimates for BWT, WWT and PWG were .25 ± .27, .38 ± .34 and .38 ± .34, respectively. Moderate positive genetic correlations were found between BWT and WWT (.47); and PWG (.38). Both genetic and phenotypic correlations between WWT and PWG were found (.99). There were low to moderate phenotypic correlation between BWT and PWG (.23); and WWT (.35). The low to moderate heritability estimates of traits together with moderate to high correlations offer an opportunity for selection to improve preweaning growth.

Introduction

In subtropical regions of South Africa, cow herd productivity as measured by early growth of progeny is desirable for economic production and efficiency under range environments. Productivity under range environment can be enhanced by breeding practices based on tropical breeds or stable crosses created from *Bos Indicus* and *Bos Taurus* breeds. One such breed, the Bonsmara, was created through crossbreeding (5/8 Afrikaner and 3/8 Shorthorn / Hereford) for adaptability and improved economic traits in the subtropics of South Africa.

The importance of preweaning growth traits has been well documented. Birth weight is associated with dystocia, pre- and postweaning growth and subsequent productivity (Nelms et al., 1956; Brinks et al.,1973; Smith et al., 1976; Notter et al., 1978a and Pauw, 1986). The threshold of BWT to cause dystocia in Bonsmara beef cattle has been reported to be 45 kg (Ivy, 1984). Low BWT has also been associated with lack of adaptability in tropical and subtropical regions of South Africa (Bonsma, 1948; cited by Bonsma and Skinner, 1969) and the United States (Burns et al., 1979).

Preweaning gain (PWG) is one criterion to evaluate cow herd productivity (Nelms et al., 1956). The level of milk the dam produces and the uterine environment determines the variation in growth of her progeny to weaning. Weaning weight (WWT) is considered as a direct measure of primary product of the cow and a reliable indicator of beef cow efficiency (Long, 1980; Marshall et al., 1976). Dinkel et al., (1978) found WWT to be the best single predictor of cow-calf efficiency to weaning. Venter (1977) stated that 70 percent of the variation in WWT was due to milk production of the dams. Diaz and Notter (1991) also concluded that WWT can be used as an indicator of milk production of the dam.

Genetic merit for preweaning traits can be improved through selection coupled with recognition of major environmental factors which obscure genetic differences among animals (Waugh and Marlowe, 1969).

Heritability estimates of BWT, PWG and WWT reported in literature are numerous. Estimates reported for BWT vary from .14 (Sow et al., 1988) to .48 (Srinivasan et al., 1970), for PWG from .15 (Hetzel et al., 1990) to .74 (Brown et al., 1990) and WWT from .01 (Rico et al., 1985) to .41 (Brown et al., 1972). The maternal environment provided by the dam account for most of the variation in growth traits of the calves from birth to weaning. The objective of this present study was to evaluate weaner production as a measure of cow productivity of Bonsmara cattle under South African range conditions.

Material and Methods

Source of data. Data were available from the registered Bonsmara herd of Ivy Farms, located north of Pietersburg in the Northern Transvaal, South Africa from 1980 to 1989. The area is situated at 23° 30,8' latitude and 29° 50,4' longitude at a height of 1280 m above sea level. It is classified as a Savanna mixed bushveld and Arid Sweet bushveld (area 14 and 18) (Acocks, 1975). The average monthly rainfall and temperature for a 20 year period is indicated in Table 1.

Management. Preweaning data of 1604 Bonsmara calves under range environment were collected over a 10 year period. Collection of records on preweaning traits was done within the specifications of the South African Beef and Performance Testing Scheme. Cows were bred to calve at the optimum time of the year, not earlier than one month before the first expected good rains. Observations on the farm indicated that if cows calve too early they may loose too much weight for breeding, if too late, the young calves may receive too much milk and be prone to internal parasite. October to December and April to June were chosen as the best months in Summer and Winter, respectively (Ivy, 1984).

Because of the two calving seasons the best bulls were used twice a year. All cows were screened twice a year and subsequently culled if they failed to conceive two seasons in succession. Heifers were bred one month prior to the main season so that they calved early in the season and had sufficient time to conceive again. To ensure good conception rates, supplementation was done by feeding a ration composed of maize meal (800g), urea (60g), salt (30g) and dicalcium phosphate (30g) to heifers over the winter and cows during the breeding season (Ivy, 1984).

Data analysis. Data on BWT, PWG and WWT were analyzed by least squares analysis of variance procedures for unequal subclasses (Harvey, 1990). The following general linear models (Model I for BWT and Model II WWT / PWG) were used to analyze genetic and environmental sources of variation:

Model I.:

$Y_{ijklmno} = \mu + R_i + P_j: R_i + B_k + T_l + S_m + A_n + E_{ijklmn}$, where:

Y_{ijklmn} = the oth record of BWT from the nth age of dam class, m^{th} season of birth, l^{th} year of birth, k^{th} sex of calf, j^{th} dam within the ith sire and the ith sire.

μ = overall mean; R_i = effect of the ith sire; $P_j: R_i$ = effect of the jth dam within the ith sire; B_k = effect of the kth sex of calf; T_l = effect of the lth year of birth; S_m = effect of the mth season of birth; A_n = effect of the nth age of the dam class and E_{ijklmn} = Random error effect, E' s assumed NID $(0, \sigma^2)$

Model II:

$Y_{ijklmno} = \mu + R_i + P_j: R_i + B_k + T_l + S_m + A_n + SA_{mn} + TS_{lm} + BS_{km} + E_{ijklmno}$, where all terms are defined as in **Model I** except for the following interaction: SA_{mn} = effect of interaction between the nth age of dam class in the mth season of birth; TS_{lm} = effect of interaction between the mth season of birth in the lth year of birth; BS_{km} = effect of interaction between the kth sex of calf in the mth season of birth.

The analysis of paternal half-sib families provided sire variance component (σ^2_s), and within family variance components (σ^2_e) (Harvey, 1990). Heritability estimates from paternal half-sibs were computed as a ratio of sire variance (σ^2_s) multiplied by four and divided the total phenotypic variance (σ^2_p).

$$h^2 = 4 \sigma^2_s / \sigma^2_p = 4 \sigma^2_s / \sigma^2_s + \sigma^2_e$$

The genetic correlation between two traits (i and j) measured in the same individual, denotes the relationship between two traits due to additive genetic effects of genes affecting both characters (Falconer, 1989). It was estimated by the following fomula:

$$r_{gigj} = Cov\ (G_i, G_j)\ /\ \sigma_{gi} \cdot \sigma_{gj} = Cov\ (S_i, S_j)\ /\ \sigma_{si} \cdot \sigma_{sj}, \text{ where:}$$

r_{gigj} = genetic correlation between i and j traits.

Cov (G_i, G_j) = additive genetic covariance of traits i and j.

Cov (S_i, S_j) = sire covariance for traits i and j.

σ_{gi} and σ_{gj} = additive genetic standard deviations for traits i and j; and,

σ_{si} and σ_{sj} = sire standard deviations for traits i and j.

The phenotypic correlation between two traits (i and j) was estimated by the following formula:

$$r_{pij} = \sigma_{eij} + \sigma_{sij}\ /\ \sqrt{\ [\sigma^2_{ei} + \sigma^2_{si}]\ [\ \sigma^2_{ej} + \sigma^2_{sj}]}\ \text{(Harvey, 1990), where;}$$

r_{pij} = phenotypic correlation between i and j traits.

σ_{eij} = within family covariance between traits i and j.

σ_{sij} = sire covariance for traits i and j.

$\sigma^2_{si}, \sigma^2_{sj}$ = sire variance for traits i and j; and

$\sigma^2_{ei}, \sigma^2_{ej}$ = within family variance for traits i and j.

Results and Discussions

Genetic and environmental effects: Results from the least squares analysis of variance for BWT of Bonsmara calves are presented in Table 2. Least squares means and standard errors for birth weights of Bonsmara calves are shown in Table 3. Birth weight was influenced by sire of the calf (P < .001) and by dam within sire (P < .01). Environmental effects of sex of the calf (SC), year of birth (YB) and age of the dam (AOD) were also important (P < .01) sources of variation on BWT. Kars et al. (1994) found an important effect of sire of calf on growth traits. Similar results were reported on the effect of sex on birth weight of calves (Kassa-Mersha & Arnason, 1986 and Kars, 1994). Bull calves were 2.15 kg heavier than heifer calves. This was higher than the 1.86 kg and .84 kg difference stated by Kars et al. (1994) and Kassa-Mersha for smaller breeds, Nguni and Boran, respectively.

Several studies have indicated the influence of YB on BWT in South Africa (van Zyl, 1982; Viljoen, 1986 and Kars, 1994). However, other reports indicated no influence (Reynolds et al., 1980 and Tawonzvi et al., 1986). First calf heifers had progeny with lower BWT than dams of older age classes. van Zyl (1982) and Lubout (1988) stated that growth traits of calves increase from age at first calf to eight years and then declined as the dam became older. Results of the present study indicated no pattern, partly due to small number of calves born from older dams.

Least squares analysis of variance for WWT and PWG are shown in Table 4. Least squares means and standard errors for WWT and PWG of Bonsmara calves in relation to major effects are presented in Table 5, 6 and 7. Sire of calf was an important caus of variation in WWT and PWG (P < .001), with the dams within sire effect also found to have a contribution (P < .05). This was similar to results reported by Lubout (1988) and Kars et al. (1994). Environmetal effects of SC and YB on WWT and PWG were found to be important (P < .001). Interactions of SB×AOD and SC×SB were the only other effects associated with the variation in PWG. Bull calves were 19.05 kg heavier than heifer calves at weaning, with PWG .09 kg better than heifers. Kassa-Mersha & Arnason (1986) and Kars et al. (1994) reported differences of 16.6 kg and 12.85 kg, respectively.

Heritabilities estimates, genetic and phenotypic correlations: Average number of calves per sire, heritability estimates, genetic and phenotypic correlations of preweaning growth traits are shown in Table 8. The heritability of BWT estimated from this study was .25 which was similar to estimates reported by Iloeje (1986) for Zebu and South Devon. Several authors reported estimates of heritabilities which were smaller than these (Sow et al., 1988; Lubout et al., 1990 and Veseth et al., 1993). Estimates from the present study were lower than others in literature (Woldenhawariat, 1977; Ritchie, 1985; Swanepoel et al., 1988; Tawonevzi et al., 1986; Lubout, 1991).

Moderate positive genetic correlations were found between BWT and WWT (.47); and PWG (.38). The genetic correlation between BWT and WWT was higher than that reported by Lubout (1991) but close to estimates summarized by Woldenhawariat (1977). A high genetic and phenotypic correlation of .99 between WWT and PWG was found. Both traits depend on the milk of the dam during the preweaning phase of growth. Phenotypic correlations between BWT and PWG (.23); and WWT (.35) were low to moderate.

The heritability estimate for PWG was .38, similar to that of Denise et al. (1988). This estimate was higher than the .17, .26 and .27 reported by Baker et al. (1980), Trus et al. (1988) and Hetzel et al. (1990), respectively. Other researchers have estimated higher heritability for PWG. Trus et al. (1988) with Shorthorn (.46) and Brown et al. (1990) with Angus (.50) and with Hereford (.74) cattle.

The estimate of heritability for WWT reported in this study (.38) was the same as stated by Tawonezvi et al. (1986). Brown et al. (1972) found a higher estimate of .40. Estimate of .05, .01, .19, .05, and .17 were among the lowest estimates recorded in literature stated by Heyns (1974), Rico et al. (1985), Lubout et al. (1990), Lubout (1991), and Veseth et al. (1993), respectively. The environment may have played a major role with sufficient stress that normal growth was disturbed and expression of the genetic potential of the animal inhibited (Lubout, 1991). Most estimates for WWT ranged from .27 to .32 (Ritchie, 1985; Iloeje, 1986; Swanepoel et al., 1988 and Tewolde et al., 1988).

Conclusions

Environmental changes due to climate were probably the main sources of variation in the effect of YB on preweaning growth traits. Good management may reduce the differences that may be expected between seasons, especially in the nutrition of the dams. Genetic effects of sire of calf and dam within sire were evident in this study. Selection of the best sires based on their preweaning growth traits should improve preweaning performance. Caution should be placed on sires with excessive BWT to avoid dystocia. The low to moderate heritability estimates indicated that selection based on preweaning growth traits can be beneficial, enhanced by a moderate genetic correlation between WWT and PWG. Heritability estimates found in this study, similar to many reported in literature, indicated that about 75 percent of the variation in BWT and 62 percent in WWT and PWG was due to non-additive genetic effects and the environment. Research on the magnitude of the estimates of direct additive, maternal additive and permanent environmental variation in preweaning traits may offer an insight about opportunities for selection.

Literature cited

Acocks, J. P. H. 1975. Veld types of South Africa. Mem. Bot. Surv. S. Afr. no. 40. Govt. Printer, Pretoria.

Baker, R. L. 1980. The role of maternal effects on the efficiency of selection in beef cattle: a review. Proc. N. Z. Soc. Anim. Prod. 40:285.

Bonsma, J. C. and J. D. Skinner. 1969. Factors influencing birth date, birth weight and preweaning growth rate of Afrikaner, Bonsmara and Hereford cattle in the subtropics. Proc. S. Afr. Soc. Anim. Prod. 8:161.

Brinks, J. S., J. E. Olson, and E. J. Carrol. 1973. Calving difficulty and its association with subsequent productivity in Hereford. J. Anim. Sci. 36:11.

Brown, C. J., Z. B. Johnson, and D. W. Wright. 1990. Pre- and postnatal direct and maternal additive genetic influences on preweaning growth traits of beef cattle. In: W. G. Hill, R. Thompson, and J. A. Wolliams (Editors). Proc. 4th World Congr. Genet. Appl. Livest. Prod. Edinburgh, 15:267 (cited by Meyer, 1992).

Brown, J. E., C. J. Brown, and W. T. Butts. 1972. A discussion of the genetic aspects of weight, mature weight and rate of maturing in Hereford and Angus cattle. J. Anim. Sci. 34:525.

Burns, W. C., M. Koger, W. T. Butts, O. F. Pahnish, and R. L. Blackwell. 1979. Genotype by environment interaction in Hereford cattle. II. Birth and weaning traits. J. Anim. Sci. 49: 403.

Cronje, C. V. 1992. Exposition and evaluation of the Bonsmara young A. I. sire scheme. M. Sc. (Agric). Thesis. Univ. of Fort Hare, Alice (South Africa).

DeNise, S. K., M. Torabi, D. E. Ray, and R. Rice. 1988. Genetic parameters estimates for preweaning traits of beef cattle in a stressful environment. J. Anim. Sci. 66:1899.

Dinkel, C. A., and M. A. Brown. 1978. An evaluation of the ratio of calf weight to cow weight as an indicator of cow efficiency. J. Anim. Sci. 46:614.

Falconer, D. S. 1989. Introduction to Quantitative Genetics (3rd Ed.). Longman, Inc., New York.

Harvey, W. R. 1990. User's Guide for LSMLMW and MIXMDL, mixed model least-squares and

    maximum likelihood computer program. Ohio State Univ., Columbus (Mimeo).

Hetzel, D. J. S., R. L. Quaas, G. W. Seifert, K. G. Bean, H. M. Burrow, and W. J. Aspen. 1990. Genetic

    parameters for growth of tropical beef cattle. Proc. 8th Conf. Aust. Ass. Anim. Breed. and Genet.

    Hamilton, N. Z. pp. 517.

Heyns, H. 1974. Genetiese- en omgewingsparameters van 'n Afrikanerbeeskudde. D. Sc. (Agric). Thesis.

    Univ. of Pretoria, Pretoria (South Africa).

Iloeje, M. U. 1986. Components of variance for growth traits among Zebu and South Devon beef cattle in

    Southeastern Nigeria. Livest. Prod. Sci. 14:231.

Ivy, D. J. 1984. Ranching with Bonsmara in bushveld. Manual from D. J. Ivy.

Kars, A. A., G. J. Erasmus, and J. van der Westhuizen. 1994. Factors influencing growth traits in the

    Nguni cattle stud at Bartlow Combine. S. Afr. J. Anim. Sci. 24:18.

Kassa-Mersha Hailu, and T. Arnason. 1986. Non-genetic factors affecting growth of Ethiopian Boran

    cattle. World. Rev. Anim. Prod. 22:45.

Long, C. R. 1980. Crossbreeding for beef production: Experimental results. J. Anim. Sci. 1197.

Lubout, P. C. 1988. Environmental and genetic factors influencing production in a herd of Pedi cattle. M.

    Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Lubout, P. C. 1991. Genetic parameters and -trends of Pedi cattle in Lebowa. D. Sc. (Agric). Thesis. Univ.

    of Fort Hare, Alice (South Africa).

Lubout, P. C., and F. C. J. Swanepoel. 1990. Parameters of Sanga cattle in Developing Areas. Proc. 4th

    World. Cong. Genet. Appl. Livest. Prod. Edinburgh, Scotland. 14: 386.

Marshall, D. A., W. R. Parker, and C. A. Dinkel. 1976. Factors affecting efficiency to weaning in Angus

    Charolais and reciprocal cross cows. J. Anim. Sci. 43: 1176.

Meyer, K. 1992. Variance components due to direct and maternal effects for growth traits of Australian

    beef cattle. Livest. Prod. Sci. 31: 179

Nelms, G. E., and R. Bogart. 1956. The effects of birth weight, age of dam and the time of birth on

    suckling gains of beef calves. J. Anim. Sci. 15: 662.

Notter, D. R., L. V. Cundiff, G. M. Smith, D. B. Laster, and K. E. Gregory. 1978a. Characterization of

   biological types of cattle. VI. Transmitted and maternal effects on birth and survival traits in

   progeny of young cows. J. Anim. Sci. 46:892.

Pauw, P. A. 1986. Distocia by vleisbeeste. M. Sc. (Agric). Thesis. Univ. of Orange Free State,

   Bloemfontein (South Africa).

Reynolds, W. L., W. G. Kirk, F. M. Peakock, and M. Koger. 1980. Genetic and environmental factors

   affecting weaning performance of calves at the range cattle stations. J. Anim. Sci. 17: 1143

   (Abstr.).

Rico, C., T. Planas, and M. A. Menchaca. 1985. Preweaning growth of the Zebu cattle. II. Genetic

   parameters. Cuban J. Agric. Sci. 19: 137 (cited by Cronje, 1992).

Ritchie, H. D. 1985. Calving difficulty in beef cattle. Beef Improvement Federation Fact Sheet. Virginia

   Co-operation Extension Service.

Smith, G. M., D. B. Laster, and K. E. Gregory. 1976. Characterization of biological types of cattle. I.

   Dystocia and preweaning growth. J. Anim. Sci 43:27.

Sow, R. S., J. P. Denis, and J. C. M. Trail. 1988. Facteurs de variation genetique de la productivite du

   Zebu Gorba: Crissance avant et apres sevrage. Proc. 3rd World Congr. Sheep and Beef Cattle

   Breed. Paris, France. 2:376.

Srinivasan, G., and T. G. martin. 1970. Genetic trends in a beef herd selected for growth. J. Anim. Sci.

   31:1013 (Abstr.)

Swanepoel, F. J. C., and H. Heyns. 1988. Genetiese parameters van speenkalf eienskappe by

   Herefordkalwers. S. Afr. J. Anim. Sci. 18: 75.

Tawonezvi, H. P. R., J. W. I. Brownlee, and H. K. Ward. 1986. Studies on growth of Nkone cattle. II.

   estimation of genetic parameters. Zimbabwe J. Agric. Res. 24:37.

Tewolde, A. 1988. Genetic analysis of Romosinuano cattle: Selection possibilities for beef in the Latin

   American Tropics. Proc. 3rd World Cong. Sheep and Beef Cattle Breed. Paris. France 2:275.

Trus. D., and J. W. Wilton. 1988. Genetic parameters for maternal traits in beef cattle. Can. J. Anim. Sci.

   68: 119.

van Zyl, J. G. E. 1982. 'n Evaluasie van die gevolge van teel- en seleksie metodes sos toegepas deur die Bonsmarabeestelersgennotskap. M. Sc. (Agric). Thesis. Univ. of Pretoria, Pretoria (South Africa).

Venter, H. A. W. 1977. Die doeltreffendheid van voorspense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord- Transvaalse soetbosveld. D. Sc. (Agric) Thesis. Univ. of Pretoria, Pretoria (South Africa).

Veseth, D. A., W. L. Reynolds, J. J. Urick, T. C. Nelsen, R. E. Short, and D. D. Kress. 1993. Paternal half-sib heritabilities and genetic, environmental, and phenotypic correlation estimates from randomly selected Hereford cattle. J. Anim. Sci. 71: 1730.

Viljoen, J. J. 1986. Die invloed van genetiese- en omgewingsfactore op produksie-eienskappe van 'n Afrikanerbeeskudde. M. Sc. (Agric). Thesis. Univ. of Orange Free State, Bloemforntein (South Africa).

Waugh, G. A., and T. J. Marlowe. 1969. Environmental influences on growth rate and grade of yearling beef cattle. J. Anim. Sci. 29:541.

Woldenhawariat, G., M. A. Talamantes, R. R. Petty (Jnr.), and T. C. Cartwright. 1977. A summary of genetic and environmental statistics for growth and conformation characters of beef cattle. Tex. Agric. Exp. Stn. Dept. Anim. Sci. Tech. Rep. no. 103.

Table 1. The average annual rainfall distribution by month for 20 years at Ivy farms

Month	Rainfall (mm)	Temperature (°C)
January	75	22.0
February	52	20.0
March	33	19.0
April	20	17.0
May	8	15.0
June	4	11.5
July	4	11.8
August	2	13.0
September	13	18.5
October	20	21.0
November	52	20.5
December	63	20.5

Table 2. Analysis of variance for birth weight of Bonsmara calves.

Source of variation	DF	Birth Weight (Kg)
		Mean Square
Sire of calf	73	33.12[***]
Dam : Sire	1333	14.83[**]
Sex of Calf (SC)	1	174.72[***]
Year of Birth (YB)	9	31.90[**]
Season of Birth (SB)	1	14.79
Age of Dam (AOD)	3	53.16[**]
Error	165	11.14

[**]$P < .01$

[***]$P < .001$

Table 3. Least-squares means and standard errors (LSM ± SE) for birth weights of Bonsmara calves

		Birth Weight (Kg)
Factors	No. calves	LSM ± SE
μ	**1586**	**37.41 ± .34**
Sex of calf (SC)		
Female	773	36.34 ± .43
Male	813	38.49 ± .44
Year of Birth (YB)		
1980	79	33.99 ± 1.98
1981	42	36.14 ± 1.64
1982	60	34.73 ± 1.38
1983	83	39.81 ± .92
1984	123	39.47 ± .81
1985	152	38.52 ± 1.04
1986	213	38.51 ± .92
1987	286	36.94 ± 1.02
1988	287	37.41 ± 1.36
1989	261	38.60 ± 1.73
Season of Birth (SB)		
Winter	693	38.18 ± .75
Summer	893	36.65 ± .74
Age of Dam (AOD)		
One yr. to three yr. (AOD1)	457	35.91 ± 1.16
Four yr. to six yr. (AOD2)	726	38.52 ± .75
Seven yr. to nine yr (AOD3)	293	37.16 ± .79
Ten yrs and above (AOD4)	110	38.07 ± 1.47

Table 4. Analysis of variance for weaning weight and preweaning gain of Bonsmara calves.

Source of Variation	Weaning weight (kg)		Preweaning gain (kg)	
	DF	Mean Squares	DF	Mean Squares
Sire of calf	65	1865.69***	65	4.07***
Dam : Sire	1005	636.05*	1005	1.41*
Sex of Calf (SC)	1	8975.62***	1	16.96***
Year of Birth (YB)	8	2602.82***	8	5.48***
Season Of Birth (SB)	1	91.77	1	.17
Age of Dam (AOD)	3	263.81	3	.37
SB×AD	3	994.83	3	2.53+
YB×SB	8	743.98	8	1.69
SC×SB	1	3978.93	1	.07**
Error	99	475.23	99	

+P < .1

*P < .05

**P < .01

***P < .001

Table 5. Least-squares meansand standard errors (LSM ± SE) for weaning weights and preweaning gain
of Bonsmara calves

Factors	Weaning weight (Kg)		Preweaning gain (Kg)	
	No. calves	LSM ± SE	No. calves	LSM ± SE
μ	1195	230.34 ± 3.11	1195	.94 ± .002
Sex of calf (SC)				
Female	581	220.82 ± 3.81	581	.89 ± .018
Male	614	239.87 ± 3.81	614	.98 ± .018
Year of Birth (YB)				
1980	72	169.93 ± 16.72	72	.65 ± .077
1981	40	197.37 ± 12.82	40	.78 ± .059
1982	58	208.12 ± 11.32	58	.83 ± .052
1983	76	246.95 ± 8.07	76	1.00 ± .037
1984	113	235.74 ± 7.23	113	.95 ± .033
1985	151	272.00 ± 10.86	151	1.14 ± .049
1986	204	246.29 ± 9.99	204	1.01 ± .046
1987	239	254.66 ± 12.12	239	1.07 ± .056
1988	242	242.02 ± 14.71	242	1.00 ± .067
Season of Birth (SB)				
Winter	540	234.36 ± 9.66	540	.95 ± .044
Summer	655	226.33 ± 9.64	655	.92 ± .044
Age of Dam (AOD)				
One yr. to three yr. (AOD1)	368	223.35 ± 10.13	368	.91 ± .047
Four yr. to six yr. (AOD2)	537	231.73 ± 7.04	537	.94 ± .032
Seven yr. to nine yr (AOD3)	217	230.98 ± 7.09	217	.94 ± .033
Ten yrs and above (AOD4)	73	235.31 ± 12.57	73	.96 ± .058

Table 6. Least-squares means and standard errors (LSM ± SE) for weaning weights and preweaning gain of Bonsmara calves by interactions of year of birth × season of birth (YB×SB)

Factors		Weaning weight (kg)		Preweaning gain (kg)	
		No. calves	LSM ± SE	No. calves	LSM ± SE
Intercation :					
YB×SB					
YB	SB				
1980	Winter	29	187.75 ± 20.29	29	.73 ± .09
1980	Summer	43	152.12 ± 19.62	43	.58 ± .09
1981	Winter	16	205.92 ± 16.75	16	.81 ± .08
1981	Summer	24	188.81 ± 17.89	24	.74 ± .08
1982	Winter	29	210.60 ± 18.83	29	.85 ± .09
1982	Summer	29	205.64 ± 15.26	29	.82 ± .07
1983	Winter	36	266.30 ± 14.41	36	1.09 ± .07
1983	Summer	40	227.59 ± 12.87	40	.92 ± .06
1984	Winter	62	248.48 ± 13.99	62	1.02 ± .06
1984	Summer	51	223.01 ± 11.27	51	.89 ± .05
1985	Winter	68	268.65 ± 16.45	68	1.11 ± .08
1985	Summer	83	275.35 ± 23.25	83	1.16 ± .11
1986	Winter	85	230.30 ± 13.94	85	.93 ± .06
1986	Summer	119	262.27 ± 21.64	119	1.09 ± .09
1987	Winter	111	249.11 ± 17.66	111	1.04 ± .08
1987	Summer	128	260.21 ± 23.18	128	1.08 ± .11
1988	Winter	104	242.09 ± 23.09	104	1.01 ± .11
1988	Summer	138	241.96 ± 22.58	138	.99 ± .10

Table 7. Least-squares means and standard errors (LSM ± SE) for weaning weights and preweaning gain of Bonsmara calves by interactions of season of birth × age of dam (SB×AOD) and sex of calf × season of birth (SC×SB)

Factors		Weaning weight (kg)		Preweaning gain (kg)	
		No. calves	LSM ± SE	No. calves	LSM ± SE
SB×AOD					
SB	**AOD**				
Winter	AOD1	156	226.66 ± 15.26	156	.94 ± .07
Winter	AOD2	241	222.87 ± 11.13	241	.89 ± .05
Winter	AOD3	108	235.38 ± 14.53	108	.95 ± .07
Winter	AOD4	35	252.51 ± 23.05	35	1.03 ± .11
Summer	AOD1	212	220.04 ± 15.37	212	.89 ± .07
Summer	AOD2	296	240.59 ± 12.73	296	.98 ± .06
Summer	AOD3	109	226.58 ± 11.54	109	.92 ± .05
Summer	AOD4	38	218.10 ± 19.32	38	.88 ± .08
SC×SB					
SC	**SB**				
Female	Winter	267	218.82 ± 9.83	267	.89 ± .05
Female	Summer	314	222.81 ± 10.36	314	.90 ± .05
Male	Winter	273	249.89 ± 10.52	273	1.02 ± .05
Male	Summer	341	229.85 ± 9.72	341	.94 ± .05

Table 8. Average number of calves per sire (s_h), heritabilities (h^2), genetic and phenotypic correlations

between growth traits to weaning of Bonsmara calves[a]

Growth traits	Min.	S_h	Max.	BWT	WWT	PWG
Birth weight (kg)	1	21.43	134	.25 ± .27	.47 ± .18	.38 ± .19
Weaning weight (kg)	1	21.43	134	.35	.38 ± .34	.99 ± .002
Preweaning gain (kg)	1	21.43	134	.23	.99	.379 ± .34

[a]Heritability estimates at the diagonal, genetic correlations above diagonal, and phenotypic correlations

below

CHAPTER IV

Variance Component and Heritability Estimates for Birth and Weaning Weight

of Bonsmara Calves Under South African Range Environment

A. E. Nesamvuni[*], A. C. Clutter[*], S. L. Northcutt[*], D. S. Buchanan[*], and J. D. Ivy[+]

[*]Department of Animal Science, Oklahoma State University, Stillwater 74078-0425

and [+]Ivy Farms, Munnik, South Africa

ABSTRACT

Estimates of (co)variance components and genetic parameters were obtained for birth (BWT) and weaning (WWT) weights of Bonsmara beef cattle. Data were collected from Ivy Farms, Northern Transvaal, South Africa. Data were analyzed using Derivative-Free Restricted Maximum Likelihood (DFREML) fitting six models which ranged from a simple animal model with additive genetic effects to a full model which included genetic additive, maternal additive and permanent environmental effects. Fixed effects in the models included sex of the calf, year of birth and season of birth. Linear and quadratic covariates were used to regress all records to a common age and weight of dam. Estimates of direct additive heritabilities (h^2_a) for BWT were low and similar to maternal additive heritability (h^2_m). Estimates ranged from .05 to .08. Total heritability (h^2_T) was .12 for most of the models used. Positive direct-maternal genetic correlation (r_{Gam}) ranged from .48 to .97.

Across models, direct additive variance (σ^2_a) and heritabilities additive (h^2_a) were larger than the

respective maternal values, (σ^2_m) and (h^2_m) for WWT. Direct-maternal genetic correlation for WWT was

large and negative (-.84). Estimates of the correlation between BWT and WWT were estimated using a

bivariate model. Direct additive genetic correlation (r_A) was .26, whereas those of maternal genetic (r_M),

permanent environment (r_C), residual error (r_E) were .56, -.98 and .34. Knowledge of the genetic

correlation between direct effects for BWT and maternal effects for WWT (r_{A1M2}) and similarly (r_{A2M1}),

was necessary to incorporate in a selection program. Estimates were -.01 and .16, respectively. It was

concluded that the estimates of (co)variance offer an opportunity for selection in preweaning growth traits.

Introduction

Preweaning growth traits of beef cattle are not only dependent on the calf's genetic capability for growth but also by its dam's maternal capacity which consists of both genetic and environmental components. These mainly represent the dam's milk production and mothering ability, though effects of uterine environment and extra-chromosomal inheritance may contribute (Meyer, 1992 and 1993). Dams affect the phenotype of their progeny through direct additive genetic effects for growth as well as through genetic merit for maternal effects on growth. Selection programs should consider both direct and maternal components especially if an antagonistic relationship between them exists (Meyer, 1992 and 1993).

The effect of maternal effects on the efficiency of selection have been reviewed by Baker (1980) and Robison (1981). Willham (1980) and Baker (1980) outlined detailed models for maternally influenced traits, including additive genetic, dominance and environmental effects due to the animal and its dam. Estimates of both direct and maternal effects on growth traits have been reported by Cantet (1990) and Meyer (1992).

The purpose of the present study was to analyze preweaning growth traits of Bonsmara beef cattle to obtain estimates of genetic parameters for subsequent use in genetic evaluation.

Material and Methods

Source of data. Data were available from a registered Bonsmara herd at Ivy Farms, located north of Pietersburg in the Northern Transvaal, South Africa from 1980 to 1989. The area is situated at 23° 30,8' latitude and 29° 50,4' longitude at a height of 1280 m above sea level. It is classified as a Savanna mixed bushveld and Arid Sweet bushveld (area 14 and 18) (Acocks, 1975). The average monthly rainfall and temperature for a 20 year period is indicated in Table 1.

Management. Preweaning data of 1604 Bonsmara calves under range environment were collected over a 10 year period. Collection of records on preweaning traits were done within the specifications of the South African Beef and Performance Testing Scheme. Cows were bred to calve at the optimum time of the year, not earlier than one month before the first expected good rains. Observations on the farm indicated that if cows calve too early they may loose too much weight for breeding, if too late, the young calves may receive much milk and be prone to internal parasites. October to December and April to June were chosen as the best months in Summer and Winter, respectively (Ivy, 1984).

Because of the two calving seasons the best bulls were used twice a year. All cows were screened twice a year and subsequently culled if they failed to conceive two seasons in succession. Heifers were bred one month prior to the main season so that they calved early in the season and had sufficient time to conceive again. To ensure good conception rates supplementation of maize meal (800g), urea (60g), salt (30g) and dicalcium phosphate (30g) was provided to heifers over the winter and cows during the breeding season (Ivy, 1984).

Data analysis. Estimates of variance components for traits in this study were obtained using the derivative-free restricted maximum-likelihood (DFREML) procedure developed by Meyer (1988, 1989) modified for use with a sparse matrix solver package (SPARSPAK) (Boldman *et al.*, 1991). The DFREML program was described by Smith and Graser (1986) and Meyer (1989). The SPARSPAK package (George *et al.*, 1980) was used to reorder the mixed-model equations once and then to interactively update equations repeatedly solved by Cholesky factorization to calculate the likelihood.

The procedure uses an animal model fitting an additive genetic effect not only for animals with records but also for parents included in the analysis by pedigree information. Characteristics BWT and WWT are shown in Tables 2 and 5. Estimates variance and covariance components were computed using the univariate and bivariate analysis, respectively. Bivariate analyses were used to estimate correlations between traits. A convergence criterion, which was the minimum variance of the function values (-2 log likelihood) after each round of interaction, was required to be 1×10^{-9} for each analysis. Initial priors from a paper by Kars et al. (1994) were used.

To separate direct genetic, maternal genetic and permanent environment, six different models were fitted for preweaning growth traits of calves as explained by Meyer (1992). The six models were:

I. $Y_{ijkl} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + e_{ijkl}$

II. $Y_{ijklm} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + p_m + e_{ijklm}$

III. $Y_{ijklm} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + m_m + e_{ijklm}$

with Cov $(a_l, m_m) = 0$

IV. $Y_{ijklm} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + m_m + e_{ijklm}$

with Cov $(a_l, m_m) \neq 0$

V. $Y_{ijklmn} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + m_m + p_n +$

e_{ijklmn} with Cov $(a_{l,} m_m) = 0$

VI. $Y_{ijklmn} = T_i + B_j + S_k + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + b_3 (mwt_{ijkl}) + b_4 (mwt_{ijkl})^2 + a_l + m_m + p_n +$

e_{ijklmn} with Cov $(a_{l,} m_m) \neq 0$

where, Y_{ijklmn} = observation from the lth animal; T_i = fixed effect of the ith year of birth; B_j = fixed effect of the jth sex of the calf; S_k = fixed effect of the kth season of birth; $b_1 (age_{ijkl})$, $b_2 (age_{ijkl})^2$, $b_3 (mwt_{ijkl})$ and $b_4 (mwt_{ijkl})^2$ = linear and quadratic covariates to regress all records to a common age and weight of dam, a_l = random direct additive genetic effect of the lth animal, m_m = random maternal additive genetic effect of the mth dam, p_n = random permanent environment of the mth / n^{th} dam, e_{ijklmn} = random residual effect.

The variance-covariance structure for the model is as follows: Let **a** and **m** denotes the vectors of animal's direct and maternal additive genetic effects, respectively, and **p** and **e** the vectors of maternal environmental effects and residual errors. Further, let **A** be the numerator relationship matrix between animals and **I** the identity matrix.

The (co)variance structure for the analysis can then be described as

$$V(\mathbf{a}) = \sigma^2_A \mathbf{A}, \ V(\mathbf{m}) = \sigma^2_M \mathbf{A}, \ V(\mathbf{p}) = \sigma^2_C \mathbf{I}, \ V(\mathbf{e}) = \sigma^2_E \mathbf{I}, \ \text{Cov}(\mathbf{a}, \mathbf{m}) = \sigma_{AM} \mathbf{A}$$

where σ^2_A is the additive genetic variance, σ^2_M the maternal genetic variance, σ_{AM} the direct-maternalgenetic covariance, σ^2_P the maternal environmental variance, σ^2_E = the error variance. Heritabilities were estimated as $h^2_a = \sigma^2_A / \sigma^2_P$ for additive direct, $h^2_m = \sigma^2_M / \sigma^2_P$ for maternal direct heritability and $h^2_T = (\sigma^2_A + \sigma^2_M + \sigma_{AM}) / \sigma^2_P$.

Model I, was a simple random animal model with animal's additive genetic effects as the only effects. Model II allowed for a permanent environmental effect due to the dam, fitting this as an additional random effect, uncorrelated with all other effects in the model. Model III had maternal genetic effect as a second random effect for each animal with the same covariance structure as the direct additive genetic effects. Model III assumed that direct and maternal effects was uncorrelated, i.e. $\sigma_{AM} = 0$, while Model IV allowed for a covariance between them. Models V and VI included both permanent environmental and genetic maternal effect, ignoring and accounting for a genetic correlation between direct and maternal effects.

Results and Discussions

Univariate Analysis. Estimates of variance components and genetic parameters for BWT and

WWT are presented in Tables 3 and 4. The direct additive genetic variance (σ^2_a) and heritabilities (direct

effects, h^2_a; total, h^2_T) for BWT were higher in Model I than any of the other five models. Model II

indicated a permanent environmental effect of six percent of the total variation in BWT and nine percent

in WWT. Estimates σ^2_e in Model II tended to incoporate the effects of σ^2_m and thus were overestimated.

Maternal additive genetic variance in Model III were similar to σ^2_e estimates in Model II for both BWT

and WWT. Reduction in σ^2_a, and σ^2_e from Model I to Model VI were also observed for BWT. The highest

σ^2_a for WWT was in Models IV and VI. Heritability of direct effects (h^2_a) for BWT were reduced from .08

in Model I to .05 in Models IV and VI, respectively; whereas estimates for WWT decreased from .17 in

Model I to .15 in Models III and V, respectively.

Compared with other studies done under similar conditions (Meyer, 1992; Meyer, 1993;

Meyer et al., 1993 and Waldron et al., 1993), h^2_a for BWT was much lower in the present study. This may

have been due to the large maternal variance which for BWT was almost equal to additive variance.

However, the low estimates for heritability due to maternal effects were similar to estimates indicated by

Quaas (1985), Hetzel et al. (1990), Meyer (1992), Meyer et al. (1993) and Waldron et al. (1993). Total

heritability (h^2_T) estimates for BWT were similar in all models (.12) except in Model I where a low value

of .08 was found. Different estimates for h^2_T were realized for WWT depending on the model used.

Estimates of .18, .17, .16 and .15 were associated with Models VI, I, IV and II, respectively. Highest

estimates of .24 and .25 were found in Models III and IV, respectively.

Across models, σ^2_a and h^2_a were larger than the respective maternal values, σ^2_m and h^2_m for

WWT. Similar results have been reported by Quaas et al. (1985), Bertrand and Benyshek (1987), Herd

(1990) and Kars et al. (1994). Estimates of h^2_a for WWT were similar to that stated by Hetzel et al.

(1990), Mackinnon et al (1991). Similarly, Hetzel et al. (1990), Mrode et al. (1990) and Meyer et al.

(1993) found small values associated with h^2_m .

Fitting a direct-maternal genetic covariance (σ_{am}) in Model IV reduced σ^2_a, σ^2_m and heritabilities, with subsequent direct-maternal genetic correlation (r_{Gam}) of .48 for BWT. Several studies in the literature (Koch, 1972; Trus and Wilton, 1988 ; Meyer, 1992) also reported positive estimates r_{Gam} for BWT. The situation was reversed for WWT with σ^2_a and σ^2_m increased markedly. Direct-maternal genetic correlation for WWT was negative -.84, supporting other research by Hohenboken and Brinks (1971), Van Vleck et al. (1977) and Tawah et al. (1993).

One possible explanation for the negative estimates of genetic correlations was given by Tawah et al. (1993). In harsh tropical environment, females which are inherently small utilize the suboptimal production environment more effectively both for their maintenance and for the growth of their calves than larger dams under similar conditions. Larger dams are unable to meet their maintenance requirement as well as support the growth needs of their calves from limited pastures. Consequently their calves tend to be smaller at birth and weaning than those of small dams at similar ages. This seems to be a form of adaptation under harsh tropical environment as estimates given in temperate environments tend to be consistently positive or lower (Skaar, 1985; Graser et al., 1985; Wright et al., 1987; Mackinnon et al., 1991).

A model which include both σ^2_m and σ^2_c (Model V) indicated a reduction in the contribution of σ^2_c to total variation from six to .07 percent in BWT and nine to eight percent for WWT. This was in contrast to large estimates of σ^2_c attributed to poor milk yield of Herefords reported in several studies (Meyer, 1992; Meyer, 1993; Meyer et al., 1993 and Waldron et al., 1993). Fitting a full model for BWT reduced σ^2_m and increased σ_{am} from .34 in Model 4 to .65 in Model VI. Contribution of σ^2_c to the total variation was reduced even further to .0007 percent with no change for WWT.

Bivariate analysis. Characteristics of the data structure for the bivariate analysis are presented in Table 5. Estimates of correlations from bivariate analysis for BWT and WWT are shown in Table 6. The estimated direct additive genetic correlation (r_A) was .26, lower than estimates of .56 and .75 reported by Meyer (1993a and b) and Meyer et al. (1993), respectively.

The maternal genetic correlation (r_M) estimated in this study was .56 higher than an estimate of .14 reported by Meyer (1993b) but lower than .71 stated by Meyer et al. (1993). This estimate was close to .54 given by Swalve (1993) for Simmentaler field data. Other estimates of .33, .48, .43 and .54 were given by Koots et al. (1991), Meyer et al. (1992) for experimental Polled Hereford and Meyer (1993) for experimental Angus herds, respectively. Contrary to estimates indicated by Meyer (1993a and b) and Meyer et al. (1993), r_C estimates in this study was large and negative (-.98). The residual correlation (r_E) was .34 higher than estimates mentioned by Meyer (1993) and Meyer et al. (1993), respectively.

These genetic correlation between the direct effect for BWT and maternal for WWT (r_{A1M2}) was -.01 whereas that of the direct effect for WWT and maternal for BWT(r_{A2M1}) was .16. The correlation between direct for BWT and maternal for WWT was lower than esytimates reported by Meyer (1993b). The correlation between direct for WWT and maternal for BWT was higher than estimate reported by Meyer (1993b).

Conclusions

Results of this study indicated that BWT of Bonsmara can be improved by selection using both the direct and maternal additive components of genetic variance. Direct-maternal genetic correlation for BWT was favorable (positive and high), however the low heritabilities for both direct additive and maternal additive indicated that genetic progress may be slow. On the contrary direct-maternal genetic correlation for WWT was negative suggesting that improving WWT by direct selection for growth will result in reduction in maternal performance. The large negative estimates of direct-maternal genetic correlation in WWT appears to be in part due to adaptation mechanism developed to cope with harsh tropical environments. Estimates of correlations need to be considered in a selection program to improve response to selection for preweaning growth traits.

Literature cited

Acoccks, J. P. H. 1975. Veld types of South Africa. Mem. Bot. Surv. S. Afr. no. 40. Govt. Printer, Pretoria.

Baker, R. L., 1980. The role of maternal effects on the efficiency of selection in beef cattle: A review. Proc. N. Z. Soc. Anim. Prod. 40: 285.

Betrand, J. K., and L. L. Benyshek. 1987. Variance and covariance estimates for maternal influenced beef growth traits. J. Anim. Sci. 64: 728.

Boldman, K. G., and L. D. van Vleck. 1991. Derivative-free restricted maximum likelihood estimation in animal models with a sparse matrix solver. J. Dairy Sci. 74: 4337.

Cantet, R. J. C., D. D. Kress, D. C. Anderson, D. E. Doornbos, P. J. Burfening, and R. L. Blackwell. 1988. Direct and maternal variance and covariance and maternal phenotypic effects on pre-weaning growth of beef cattle. J. Anim. Sci. 66:648.

George, A., J. Liu and E. Ng. 1980. User guide for SPAKSPAK: Waterloo sparse linear equation package. CS-78-30, Dept. of Computer Sci., Univ. of Waterloo. ON, Canada.

Graser, H. U., S. P. Smith, and B. tier. 1987. A derivative-free approach for estimation variance components in animal models by Restricted Maximum Likelihood. J. Anim. Sci. 64:1362.

Herd, R. M., 1990. The direct and maternal components of the response to divergent selection for yearling growth rate in Angus cattle. Anim. Prod. 51:505.

Hetzel, D. J. S., R. L. Quaas, G. W. Seifert, K. G. Bean, H. M. Burrow, and W. J. Aspden. 1990. Genetic parameters for growth of tropical beef cattle. Proc. 8th Conf. Aust. Ass. Anim. Breed. and Genetic. Hamilton, N. Z. pp. 517.

Hohenboken, W. D., and J. S. Brinks. 1971. Relationships between direct and maternal effects on growth in Herefords: II. Partitioning of covariance between relatives. J. Anim. Sci. 32: 26.

Ivy, D. 1984. Ranching with Bonsmara in the bushveld. Handout from D. Ivy.

Kars, A. A., G. J. Erasmus, and J. van der Westhuizen. 1994. Variance component and heritability estimates for growth traits in the Nguni cattle stud at Bartlow Combine. S. Afr. J. Anim. Sci. 24: 129.

Koch, R. M. 1972. The role of maternal effects in animal breeding: VI. Maternal effects in beef cattle. J. Anim. Sci. 35:1316.

Koots, K. R., J. P. Gibson, and J. W. Wilton. 1991. Analysis of genetic parameters of beef cattle. J. Anim. Sci. 69: Suppl. 1. (Abstr.).

Mackinnon, M. J., K. Meyer, and D. J. S. Hetzel. 1991. Genetic variation and covariation for growth, parasites resistance and heat tolerance in tropical cattle. Livest. Prod. Sci. 27: 105.

Meyer, K, M. J. Carrick, and B. J. P. Donnelly. 1993. Genetic parameters for growth traits of Australian beef cattle from a multibreed selection experimentation. J. Anim. Sci. 71: 2614.

Meyer, K. 1988. DFREML. Programs to estimate variance components for individual animal models by restricted maximum likelihood. User notes, Edinburgh Univ., Scotland, U. K.

Meyer, K. 1989. Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. Genet. Sel. Evol. 21: 317.

Meyer, K. 1992. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. Livest. Prod. Sci. 31:179.

Meyer, K. 1993a. Estimates of covariance components for growth traits of Australian Charolais cattle. Aust. J. Agric. Res. 44: 1501.

Meyer, K. 1993b. Covariance matrices for growth traits of Australian Polled Hereford cattle. Anim. Prod. 57:37.

Mrode, R. A., and R. Thompson. 1990. Genetic parameters for body weight in beef cattle in Britain. In: W. G. Hill, R. Thompson, and J. A. Wolliams (Editors). Proc. 4th World Congr. Genet. Appl. Livest. Prod. Edinburgh. 15: 271.

Quaas, R. L., M. A. Elzo, and E. J. Pollak. 1985. Analysis of Simmental data: Estimation of direct and maternal genetic (co)variances. J. Anim. Sci. 61:221 (Abstr.).

Robison, O. W. 1981. The influence of maternal effects on the efficiency of selection: A review. Livest. Prod. Sci. 8:121.

Skaar, B. R. 1985. Direct and maternal effects variance component estimation from field data. In: Beef Improvement Federation, Madison, WI, pp. 156 (cited by Wright et al. 1987).

Smith, S. P., and H. U. Graser. 1986. Estimating variance components in a class of mixed models by restricted maximum likelihood. J. Dairy Sci. 69:1165.

Swalve, H. H. 1993. Estimation of direct and maternal (co)variance components for growth traits in Australian Simmental beef cattle. J. Anim. Breed. and Genet. (cited by Meyer, 1993).

Tawah, C. L., D. A. Mbah, J. E. O. Rege, and H. Oumate. 1993. Genetic evaluation of birth and weaning weight of Gudali and two-breed synthetic Wakwa beef cattle populations under selection in Cameroon: genetic and phenotypic parameters. Anim. Prod. 57: 73.

Trus, D., and J. W. Wilton. 1988. Genetic parameters for maternal traits in beef cattle. Can. J. Anim. Sci. 68: 119.

van Vleck, L. D., D. st. Louis, and J. I. Miller. 1977. Expected phenotypic response in weaning weight of beef calves from selection for direct and maternal genetic effects. J. Anim. Sci. 44: 360.

Waldron, D. F., C. A. Morris, R. L. Baker, and D. L. Johnson. 1993. Maternal effects for growth traits in beef cattle. Livest. Prod. Sci. 34: 57.

Willham, R. L. 1980. Problems in estimating maternal effects. Livet. Prod. Sci. 7: 405.

Wright, H. B., E. J. Pollak, and Quaas, R. L. 1987. Estimation of variance and covariance components to determine heritabilities and repeatability of weaning weight in American Simmental cattle. J. Anim. Sci. 65: 975.

Table 1. The Average Annual Rainfall Distribution by Month for 20 Year Period at Ivy Farms

Month	Rainfall (mm)	Temperature (°C)
January	75	22.0
February	52	20.0
March	33	19.0
April	20	17.0
May	8	15.0
June	4	11.5
July	4	11.8
August	2	13.0
September	13	18.5
October	20	21.0
November	52	20.5
December	63	20.5

Table 2. Characteristics of the data structure for preweaning traits of Bonsmara calves from univariate analysis

Characteristics	Growth Traits	
	Birth Weight	Weaning Weight
No. of records	1592	1319
No. of animals[a]	1751	1751
Weight (Kg)		
Mean	37.75	239.18
SD	4.44	33.95
Min.	23	65
Max.	50	325
Age of dam (Covariate)		
Mean	5.18	5.09
Min.	2.69	2.69
Max	15.00	14
Weight of dam (Covariate)		
Mean	466.59	489.18
Min.	326.424	385.35
Max.	740.00	740.00
Sex of animal[b]	**2**	**2**
Female	776	657
Male	816	662
No. of years[b]	**10**	**10**
1980	79	72
1981	42	40
1982	60	59
1983	86	76
1984	123	113
1985	153	151
1986	213	204
1987	288	239
1988	287	242
1989	260	123
No. of seasons[b]	**2**	**2**
Winter	697	662
Summer	895	657

[a]In the analysis including parents without records
[b]Levels associated with number of animals

Table3. Estimates of (co)variance components and genetic parameters[a] for birth weight from univariate analysis

	Model I	Model II	Model III	Model IV	Model V	Model VI
σ^2_a	1.16	.86	.86	.76	.85	.81
σ^2_m			.89	.66	.89	.57
σ_{am}				.34		.65
σ^2_c		.89			.01	1.00×10^{-4}
σ^2_e	14.02	13.42	13.42	13.51	13.42	13.45
σ^2_p	15.17	15.17	15.17	15.26	15.16	15.48
σ_{am} / σ^2_p				.02		.04
σ^2_c / σ^2_p		.06			7.00×10^{-4}	7.00×10^{-6}
σ^2_e / σ^2_p	.99	.88	.88	.89	.88	.87
r_{Gam}				.48		.97
h^2_a	.08	.06	.06	.05	.06	.05
h^2_m			.06	.04	.06	.04
h^2_T	.08	.12	.12	.12	.12	.13

[a] σ^2_a direct additive genetic variance; σ^2_m maternal additive genetic variance; σ_{am} direct-maternal genetic covariance; σ^2_c permanent environmental variance; σ^2_e error variance; σ^2_p phenotypic variance; σ_{am} / σ^2_p, σ^2_c / σ^2_p, σ^2_e / σ^2_p direct-maternal genetic covariance, maternal environmental variance and error variance expressed as proportion of σ^2_p; h^2_a heritability of direct effects; h^2_m heritability of maternal effects; h^2_T total heritability; r_{Gam} direct-maternal genetic correlation.

Table 4. Estimates of (co)variance components and genetic parameters[a] for weaning weight from univariate analysis

	Model I	Model II	Model III	Model IV	Model V	Model VI
σ^2_a	118.70	106.62	106.54	146.95	106.55	147.09
σ^2_m			63.05	115.42	5.36	61.13
σ_{am}				-84.47		-84.68
σ^2_c		63.27			57.82	54.36
σ^2_e	594.99	550.39	550.69	526.94	550.67	526.98
σ^2_p	713.69	720.29	720.29	704.85	720.40	704.89
σ_{am} / σ^2_p				-.12		-.12
σ^2_c / σ^2_p		.09			.08	.08
σ^2_e / σ^2_p	.83	.76	.76	.75	.76	.75
r_{Gam}				-.65		-.89
h^2_a	.17	.15	.15	.21	.15	.21
h^2_m			.09	.16	.01	.09
h^2_T	.17	.15	.24	.25	.16	.18

[a] σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ_{am}, direct-maternal genetic covariance; σ^2_c, permanent environmental variance; σ^2_e, error variance; σ^2_p, phenotypic variance; σ_{am} / σ^2_p, σ^2_c / σ^2_p, σ^2_e / σ^2_p, direct-maternal genetic covariance, maternal environmental variance and error variance expressed as proportion of σ^2_p; h^2_a, heritability of direct effects; h^2_m, heritability of maternal effects; h^2_T, total heritability; r_{Gam}, direct-maternal genetic correlation

Table 5. Characteristics of the data structure for preweaning traits of Bonsmara calves from bivariate analysis

Characteristics	Growth Traits	
	Birth Weight	Weaning Weight
No. of records (both traits)[a]	1453	1453
No. of records and animals	797	656
No. of animals (both traits)[a]	1751	1751
Weight (Kg)		
Mean	37.61	238.88
SD	4.49	33.86
Min.	23	65
Max.	50	320
Age of dam (Covariate)		
Mean	5.18	5.09
Min.	2.69	2.69
Max	14	14
Weight of dam (Covariate)		
Mean	464.28	487.01
Min.	326.424	385.35
Max.	700.00	700.00
Sex of animal[b]	2	2
Female	378	320
Male	419	336
No. of years[b]	10	10
1980	43	38
1981	18	18
1982	35	34
1983	41	35
1984	57	55
1985	80	79
1986	106	101
1987	143	123
1988	147	124
1989	127	49
No. of seasons[b]	2	2
Winter	353	336
Summer	444	320

[a]In the analysis including parents without records
[b]Levels associated with number of animals

Table 6. Estimates of correlations[a] from bivariate analysis for birth and weaning weight

Parameter	Correlation
r_A	.26
r_M	.56
r_C	-.98
r_E	.34
r_{A1M2}	-.01
r_{A2M1}	.16

[a] r_A direct additive genetic correlation; r_M maternal genetic correlation; r_C permanent environmental correlation; r_E residual correlation; r_{AiMj} genetic correlation between direct effect for trait I and maternal effects for trait j.

CHAPTER V

WITHIN-HERD PHENOTYPIC, GENETIC AND ENVIRONMENTAL TRENDS FOR EARLY GROWTH TRAITS OF BONSMARA CALVES UNDER SOUTH AFRICAN RANGE CONDITIONS

A. E. Nesamvuni[*], S. L. Northcutt[*], A. C. Clutter[*], D. S. Buchanan[*], and J. D. Ivy[+]

[*]Department of Animal Science, Oklahoma State University, Stillwater 74078-0425 and [+]Ivy Farms, P. O. Box 15, Munnik, South Africa

ABSTRACT

Preweaning data of Bonsmara calves were used to estimate genetic (direct, maternal) and permanent environment, environmental and phenotypic trends from 1974 to 1989. Breeding values were obtained as a by-product from the Derivative-Free Restricted Maximum Likelihood (DFREML) program to estimate variance-covariance components. The procedure uses an animal model fitting an additive genetic effect not only for animals with records but also for parents included in the analysis by pedigree information. A statistical model which included both permanent environmental and genetic maternal effect accounting for a genetic correlation between direct and maternal effects was used to describe the data. Direct genetic, maternal genetic and permanent environmental trends were calculated as the regression of average predicted breeding values on year of birth. Environmental trends and phenotypic trends span the duration of the data analyzed i.e. associated with the calves.

Genetic trends included all animals in the data set. Linear trends did not produce a good fit; R^2 values obtained were low ranging from .01 to .06. Genetic and maternal trends for BWT were overall low and changing (P = .25) at -.01 ± .01 / year. This may indicate the response of the herd to selection against high BWT which was a common practice in this population. Permanent environmental trends were practically zero for BWT. Direct genetic change for WWT was positive but small (.17 ± .07) whereas those of maternal and permanent environment were low and negative (-.09 ± .04) and (-.01 ± .04) kg / year, respectively. Estimates of environmental trends for BWT were small and changing (P < .08) at -.29 / year. Phenotypic trends were changing (P = .14) at -.28 / year. Environmental and phenotypic trends for WWT changed in a curvilinear format. Trends increase from low levels in 1980 to highest levels in years 1983 to 1985 and then dramatically decrease to lowest levels again in 1989. It conclusion WWT genetic trends were increasing in response to sufficient adaptation to stresses in the prevailing conditions.

Introduction

Assessment of past selection procedures and successful planning of future breeding programs depend on methods to determine genetic progress for economic traits. In tropical and subtropical regions of South Africa weaner production is still an important economic activity (Van Zyl et al., 1992). Improvement in early growth traits due to genetic selection can be determined by monitoring trends in populations under consideration. The use of genetic, environmental and phenotypic trends within-herd has been described by Wilson and Willham (1986). Among other uses, trends can be used (a) to compare different selection and management practices in large herds, (b) as an indicator of positive or negative selection and management practices and (c) to indicate how much selection was actually applied.

Mixed linear models methodology by Henderson (1973) is employed for animal genetic evaluation. Animal models that incorporate all known relationships in population are method of choice to separate genetic and environmental effects under different production conditions (Henderson, 1973; Wiggans et al., 1987). Within-herd genetic trend can be used as evidence of selection response whereas environmental trends as evidence of management effects and climatic changes. Venter (1977) stated that large fluctuations in environmental trends are expected in preweaning period as calves are dependent on milk production of the dam, which is largely influenced by the nutrition while during post weaning period calves are influenced by management and environmental conditions.

The purpose of this study was to evaluate the nature and magnitude of genetic change in early growth traits in of Bonsmara cattle under subtropical regions of South Africa.

Material and Methods

Source of data. Data were available from the registered Bonsmara herd at Ivy Farms, located north of Pietersburg in the Northern Transvaal, South Africa from 1974 to 1989. The area is situated at 23° 30,8' latitude and 29° 50,4' longitude at a height of 1280 m above sea level. It is classified as a Savanna mixed bushveld and Arid Sweet bushveld (area 14 and 18) (Acocks, 1975). The average monthly rainfall and temperature for a 20 year period is indicated in Table 1.

Management. Preweaning data of 1604 Bonsmara calves under range environment were collected over a 10 year period. Collection of records on preweaning traits was done within the specifications of the South African Beef and Performance Testing Scheme. Cows were bred to calve at optimum time of the year, not earlier than one month before the first expected good rains. Observations on the farm indicated that if cows calve too early they may lose too much weight for breeding, if too late, the young calves may receive much milk and be prone to internal parasite. October to December and April to June were chosen as the best months in Summer and Winter, respectively (Ivy, 1984).

Because of the two calving seasons the best bulls were used twice a year. All cows were screened twice a year and culled if they failed to conceive two seasons in succession. Heifers were bred one month prior to the main season so that they calve early in the season and have sufficient time to conceive again. To ensure good conception rates, supplementation of maize meal (800g), urea (60g), salt (30g) and dicalcium phosphate (30g) was provided to heifers over the winter and cows during the breeding season (Ivy, 1984).

Data analysis. Direct and maternal breeding values were calculated for each trait by single trait mixed model analyses using the derivative-free, restricted maximum-likelihood (DFREML) procedure developed by Meyer (1988, 1989) modified for use with SPARSPAK (Boldman *et al.*, 1991). The DFREML program was described by Smith and Graser (1986) and Meyer (1989). The SPARSPAK package (George *et al.*, 1980) is used to reorder the mixed-model equations once and then the interactively update equations repeatedly solved by Cholesky factorization to calculate the likelihood.

The procedure uses an animal model fitting an additive genetic effect not only for animals with records but also for parents included in the analysis by pedigree information. A statistical model which included direct additive, maternal additive, permanent environmental, and accounting for a genetic correlation between direct and maternal effects was used to describe the data:

$$Y_{ijklmn} = T_i + B_j + S_k + b_1 \, (age_{ijkl}) + b_2 \, (age_{ijkl})^2 + b_3 \, (mwt_{ijkl}) + b_4 \, (mwt_{ijkl})^2 + a_l + m_m + p_n + e_{ijklmn}$$

$$\text{with Cov } (a_l, \, m_m) \neq 0$$

where, Y_{ijklmn} = observation from the lth animal; T_i = fixed effect of the ith year of birth; B_j = fixed effect of the jth sex of the calf; S_k = fixed effect of the kth season of birth; $b_1 \, (age_{ijkl})$, $b_2 \, (age_{ijkl})^2$, $b_3 \, (mwt_{ijkl})$ and $b_4 \, (mwt_{ijkl})^2$ = linear and quadratic covariates to regress all records to a common age and weight of dam, a_l = random direct additive genetic effect of the lth animal, m_m = random maternal additive genetic effect of the mth dam, p_n = random permanent environment of the mth / n^{th} dam, e_{ijklmn} = random residual effect.

The variance-covariance structure for the model was as follows: Let **a** and **m** denotes the vectors of animal's direct and maternal additive genetic effects, respectively, and **p** and **e** the vectors of maternal environmental effects and residual errors. Further, let **A** be the numerator relationship matrix between animals and **I** the identity matrix.

The (co)variance structure for the analysis can then be described as

$$V\ (\mathbf{a}) = \sigma^2_A\mathbf{A}, \ V\ (\mathbf{m}) = \sigma^2_M\mathbf{A}, \ V\ (\mathbf{p}) = \sigma^2_C\mathbf{I}, \ V\ (\mathbf{e}) = \sigma^2_E\mathbf{I},$$

$$\mathrm{Cov}\ (\mathbf{a},\ \mathbf{m}) = \sigma_{AM}\mathbf{A}$$

where σ^2_A is the additive genetic variance, σ^2_M the maternal genetic variance, σ_{AM} the direct-maternal genetic covariance, σ^2_P the permanent environmental variance, σ^2_E = the error variance.

Breeding values were obtained as a by-product from the DFREML program described by Boldman et al. (1991). Direct, maternal genetic and permanent environmental trends were calculated as the regression of average predicted breeding values on year of birth. Environmental trends and phenotypic trends spans the duration of the data analyzed i.e. associated with the calves and not the ancestors in the pedigree. Genetic trends included not only the breeding values of the calves but also parents without records.

Results and Discussions

Direct, maternal genetic and permanent environmental trends for BWT and WWT of Bonsmara calves are presented in Tables 2 and 3, respectively. Linear trends did not produce a good fit, R^2 values obtained were low ranging from .01 to .06. Genetic and maternal trends for BWT were overall low and negative changing at -.01 ± .01 / year, similar to trends indicated by Frisch (1981) when selecting for increased growth under stressful conditions. Fluctuations between the years 1974 to 1980 were mainly due to use of sires with marked different BV during the creation of the Bonsmara. The average breeding values (ABV) for BWT trends ranged from -.22 kg in 1974 to .31 kg in 1975 and 1977 for direct effects. Estimates for maternal effects ranged from -.19 kg in 1974 to .27 kg in 1977. During this period (1974 to 1980) sires used were from the South Devon to improve lack of milk by Hereford and lines within the Bonsmara to establish a stable cross. Direct and maternal trends stabilized later from the year 1981 but still negative (Figure 1). This may indicate the response of the herd to selection against high BWT which was a common practice in this population. Permanent environmental trends were practically zero for BWT.

Direct genetic trends for WWT was positive but small (.17 ± .07) whereas those of maternal and permanent environment were low and negative (-.09 ± .04) and (-.01 ± .04) kg / year, respectively (Table 3). The ABV estimates for direct effects on WWT ranged from -3.52 kg in 1977 to 1.96 kg in 1988. The maternal effects trends ranged from -1.09 kg in 1988 to 1.89 kg in 1977. Permanent environment trends were estimated in years 1974 to 1986. Estimates ranged from -.82 kg in 1980 to .75 kg in 1974. Highest ABV estimates for maternal effects were realized in the years 1975 to 1978 and low positive values from 1980 to 1983. At the same time periods the ABV for direct effects were the lowest.

Trends in the present study were higher than those found Lubout (1991) who indicated low trend of .08 kg / year for WWT of Pedi cattle. Other researchers stated much higher genetic trends for WWT. Nadarajah et al. (1987) reported trends of 1.27 kg / year for Angus and .75 kg / year for Herefords over a period of 30 years, while Zollinger and Nielsen (1984) reported within herd trends that varied from .21 to 1.51 kg / year for Angus cattle.

Estimates of fixed year effects as a measure of environmental trends for BWT is shown in Figure 3. Phenotypic trends followed a similar pattern as indicated in Figure 4. Large fluctuations were observed in this study over the calf birth year 1980 to 1989. Environmental trends were small and changing (P < .08) at -.29 / year. Phenotypic trends were changing (P = .14) at -.28 / year. Fixed year effects for WWT and phenotypic trends are presented in Figures 5 and 6, respectively.

Contrary to fluctuations indicated for BWT, trends for WWT followed an increase from low levels in 1980 to highest levels in years 1983 to 1985 and then dramatically decrease to lowest levels again in 1989. The trends could not be described using linear regression. Quadratic or cubic may be the best fit for BWT and WWT environmental and phenotypic trends. Preweaning fluctuations in environmental trends have also been reported by Venter (1977) and Lubout (1991), both stated the calf's reliance on the milk production of the dam, which is largely determined by nutrition (natural pastures). Decrease in environmental and phenotypic trends to negative values both in BWT and WWT was a response to deterioration of conditions due to droughts in the years 1984 to 1987. Selection for increased preweaning traits under the prevailing conditions should increase the genetic potential of the animals to withstand stress if adaptation was lacking. Evidence from selection studies done by Frisch (1981) indicated that if the animals are adapted response to selection for preweaning growth will increase related to the amount of stress the animals were exposed (Frisch, 1981).

Conclusions

Selection for increased preweaning traits under the prevailing conditions increased direct WWT genetic trends over the 16 years. Low direct BWT genetic trends may have been in part due to deliberate selection against high BWT in this populations. Indications are that selection for high preweaning traits increased the genetic potential of the animals to withstand stress and increased growth as observed in the positive change in direct genetic trends for WWT during the period of negative environmental trends. Similar conclusions were stated by Frisch (1981) who mentioned that if animals are adapted, response to selection for growth will increase related to the amount of stress the animals were exposed.

Literature cited

Acoccks, J. P. H. 1975. Veld types of South Africa. Mem. Bot. Surv. S. Afr. no. 40. Govt. Printer, Pretoria.

Boldman, K. G., and L. D. van Vleck. 1991. Derivative-free restricted maximum likelihood estimation in animal models with a sparse matrix solver. J. Dairy Sci. 74: 4337.

Frisch, J. E. 1981. Changes occurring in cattle as a consequence of selection for growth rate in a stressful environment. J. Agric. Sci. Camb. 96: 23.

George, A., J. Liu and E. Ng. 1980. User guide for SPAKSPAK: Waterloo sparse linear equation package. CS-78-30, Dept. of Computer Sci., Univ. of Waterloo. ON, Canada.

Henderson, C. R., 1973. Sire evaluation and genetic trends. In: Proc. Anim. Breed. Genet. Symp. in honour of Dr J. L. Lush. Am. Soc. Anim. Sci. and Am. Dairy Sci. Assoc. Champaign, Illinois, pp. 10-41.

Ivy, D. 1984. Ranching with Bonsmara in the bushveld. Handout from D. Ivy.

Lubout, P. C. 1991. Genetic parameters and -trends of Pedi cattle in Lebowa. D. Sc. (Agric.) Thesis. Univ. of Fort Hare.

Meyer, K. 1988. DFREML. Programs to estimate variance components for individual animal models by restricted maximum likelihood. User notes, Edinburgh Univ., Scotland, U. K.

Meyer, K. 1989. Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. Genet. Sel. Evol. 21: 317.

Nadarajah, K., D. R. Notter, T. J. Marlowe, and A. L. Eller, Jr. 1987. Evaluation of phenotypic and genetic trends in weaning weight in Angus and Hereford populations in Virginia. J. Anim. Sci. 64: 1349.

Smith, S. P., and H. U. Graser. 1986. Estimating variance components in a class of mixed models by restricted maximum likelihood. J. Dairy Sci. 69:1165.

Van Zyl, J. G. E., S. J. Schoeman, and R. J. Coertze. 1992. Sire breed and breed genotype of dam effects in crossbreeding beef cattle in the subtropics. 1. Birth and weaning mass of calves. S. Afr. J. Anim. Sci. 22:161.

Venter, H. A. W. 1977. Die doeltreffendheid van voorspeense groei by sekere vleis-, dubbeldoel- en kruisrasse in die Noord-Transvaalse Soetbosveld. D. Sc. (Agric.) - Thesis. Univ. Pretoria.

Wiggans, G. R., and I. Misztal. 1987. Supercomputer for animal model evaluation of Ayrshire milk yield. J. Dairy Sci. 70: 1906.

Wilson, D. E., and R. L. Willham. 1986. Within-herd phenotypic, genetic and environmental trend lines for beef cattle breeders. J. Anim. Sci. 63: 1087.

Zollinger, W. A. and M. K. Nielsen. 1984. An evaluation of bias in estimated breeding values for weaning weight in Angus beef cattle field records. I. Estimates of within herd genetic trends. J. Anim. Sci. 58: 545.

Table 1. The Average Annual Rainfall Distribution by Month for 20 Year Period at Ivy Farms

Month	Rainfall (mm)	Temperature (°C)
January	75	22.0
February	52	20.0
March	33	19.0
April	20	17.0
May	8	15.0
June	4	11.5
July	4	11.8
August	2	13.0
September	13	18.5
October	20	21.0
November	52	20.5
December	63	20.5

Table 2. Direct genetic, maternal genetic and pemanent environmental trends[a] for birth weight of Bonsmara calves.

Year	Birth Weight (kg)		
	Direct	Maternal	Permanent Environment[b]
1974	-.22 ± .05	-.19 ± .04	0.00
1975	.31 ± .08	.26 ± .07	0.00
1976	.07 ± .05	.06 ± .04	0.00
1977	.31 ± .06	.27 ± .05	0.00
1978	.25 ± .05	.21 ± .04	0.00
1979	-.15 ± .04	-.13 ± .03	0.00
1980	-.02 ± .03	-.01 ± .03	0.00
1981	.01 ± .04	.01 ± .03	0.00
1982	.03 ± .03	.03 ± .03	0.00
1983	-.05 ± .03	-.04 ± .02	0.00
1984	-.04 ± .02	-.03 ± .02	0.00
1985	-.01 ± .03	-.01 ± .02	0.00
1986	-.04 ± .03	-.04 ± .02	0.00
1987	-.07 ± .03	-.05 ± .02	-
1988	.02 ± .03	.02 ± .02	-
1989	-.08 ± .03	-.01 ± .02	
Coefficients	-.01 ± .01	-.01 ± .01	$-1.12 \times 10^{-6} \pm 1.45 \times 10^{-6}$
R^2	.04	.04	.06

[a]Average breeding values
[b]Estimates ranged from -3.16×10^{-22} to 0.00

Table 3. Direct genetic, maternal genetic and permanent environmental trends[a] for weaning weight of Bonsmara calves.

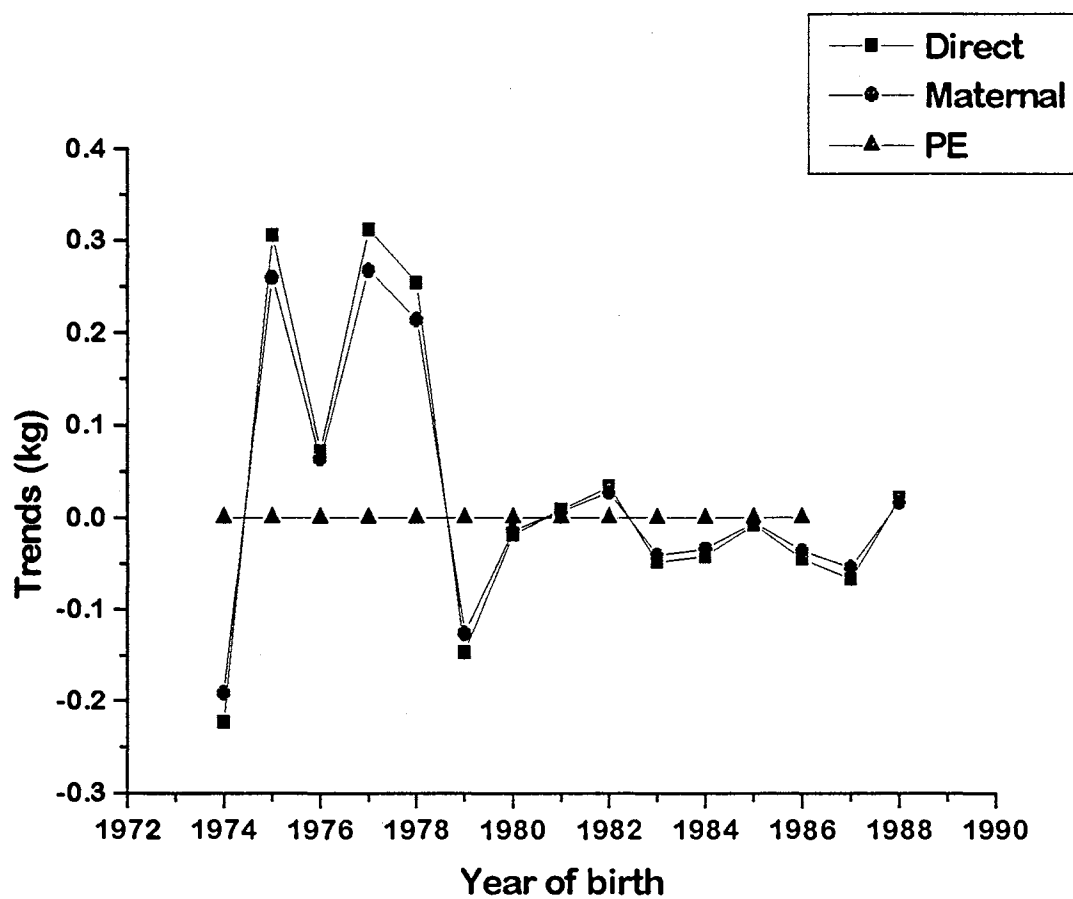| Year	Weaning Weight (kg)		
	Direct	Maternal	Permanent Environment
1974	.27 ± .51	-.51 ± .30	.75 ± .31
1975	-1.17 ± .88	.67 ± .53	-1.21 ± .54
1976	-1.88 ± .49	1.03 ± .29	.00 ± .47
1977	-3.52 ± .63	1.89 ± .38	.21 ± .59
1978	-1.39 ± .55	1.58 ± .33	.27 ± .54
1979	.69 ± .40	-.15 ± .24	-.17 ± .33
1980	-.35 ± .33	.28 ± .19	-.82 ± .36
1981	-1.26 ± .37	.57 ± .22	-.21 ± .26
1982	-.19 ± .36	.19 ± .21	-.17 ± .27
1983	-.24 ± .31	.21 ± .19	.12 ± .23
1984	.95 ± .26	-.64 ± .15	-.18 ± .38
1985	-.10 ± .29	.09 ± .17	-.01 ± .38
1986	-.04 ± .26	.04 ± .15	-.23 ± .26
1987	.11 ± .28	-.02 ± .17	-
1988	1.96 ± .29	-1.09 ± .17	-
1989	1.16 ± .30	-.64 ± .18	-
coefficients	.17 ± .07	-.09 ± .04	-.01 ± .04
R^2	.04	.04	.01

[a]Average breeding values

Figure 1. Direct genetic , maternal genetic and permanent environmental trends for birth weight of Bonsmara calves.
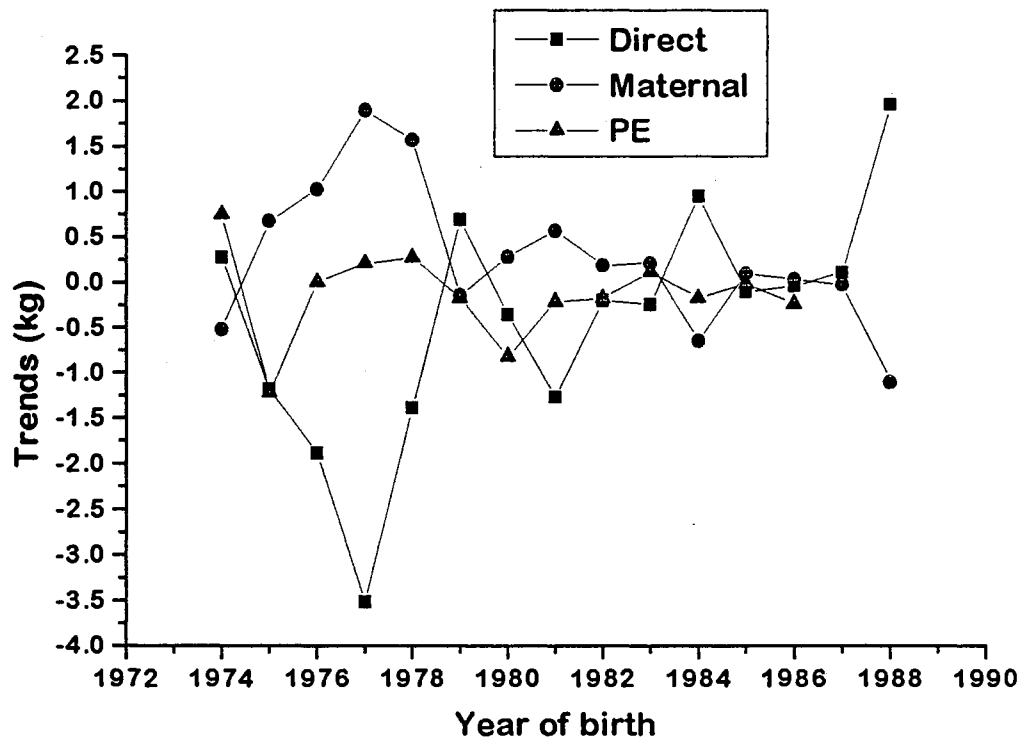
Figure 2. Direct genetic, maternal genetic and permanent environmental trends for weaning weight of
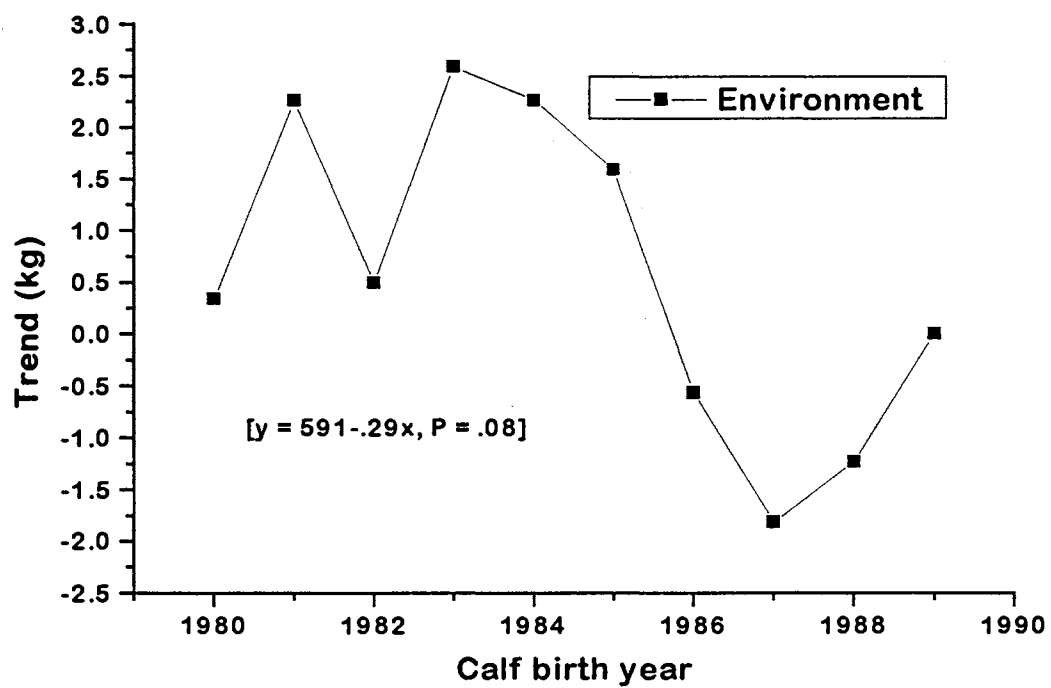Bonsmara calves.

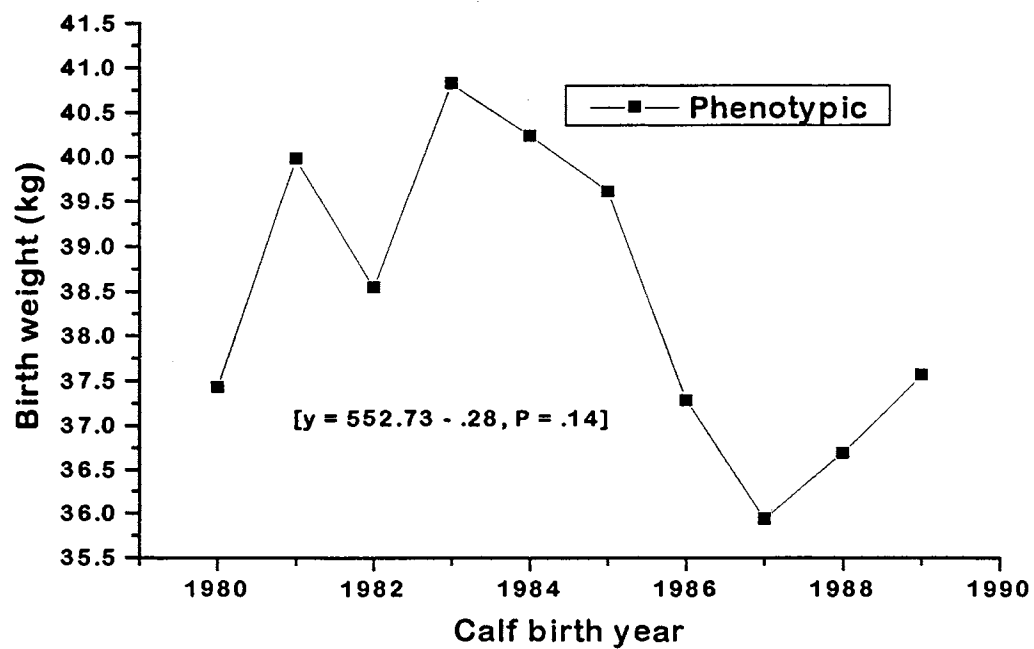Figure 3. Environmental trends for birth weight of Bonsmara calves.

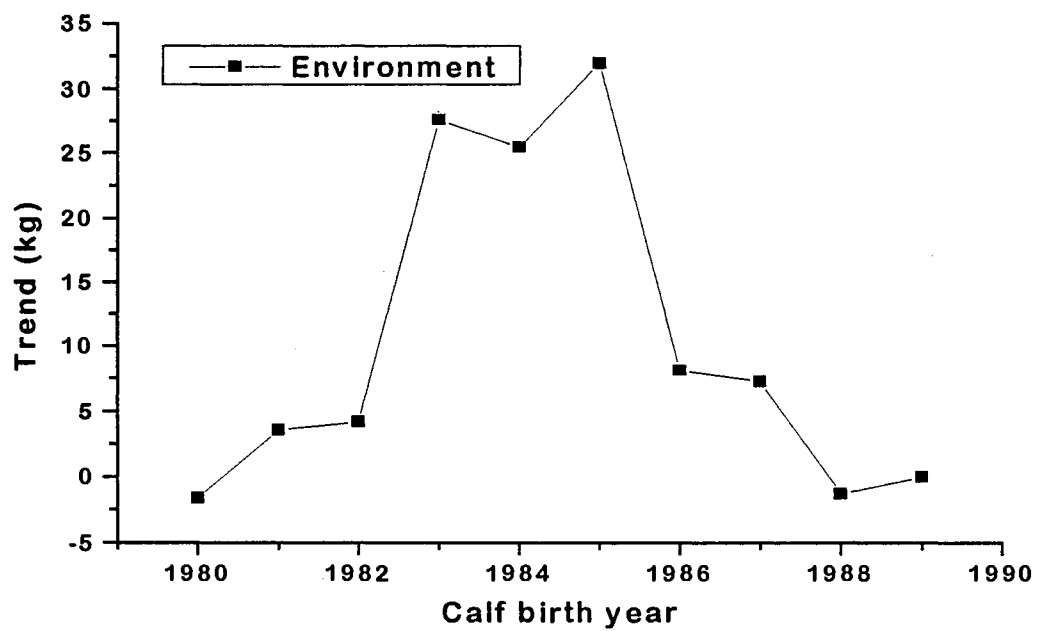Figure 4. Phenotypic trends for birth weight of Bonsmara calves.

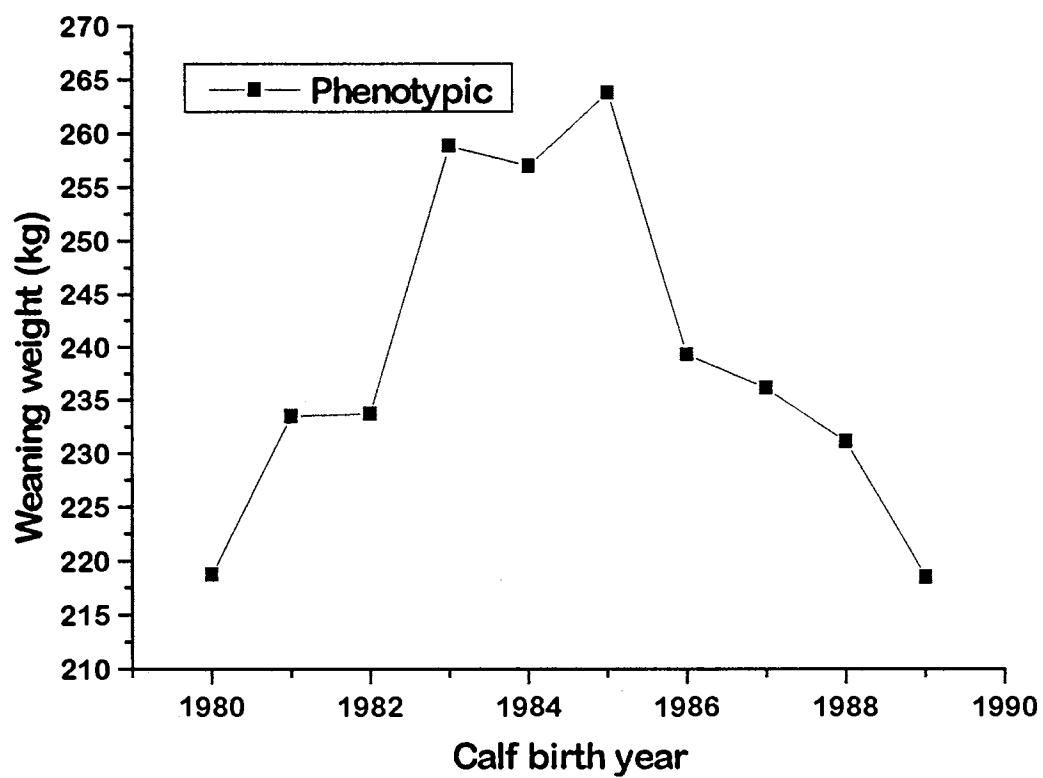Figure 5. Environmental trends for weaning weight of Bonsmara calves.

Figure 6. Phenotypic trends for weaning weight of Bonsmara calves.

CHAPTER VI

Genetic Parameter Estimates and Breeding values for Body Weights

and Calving Interval of Bonsmara Cows Under

South African Range Environment

A. E. Nesamvuni[*], S. L. Northcutt[*], D. S. Buchanan[*], A. C. Clutter[*] and J. D. Ivy[+]

[*]Department of Animal Science, Oklahoma State University, Stillwater 74078-0425

and [+]Ivy Farms, Munnik, South Africa

ABSTRACT

Cow weight and calving interval records of 1603 Bonsmara cows were available to estimate

heritabilities, genetic correlations and breeding values. Data were analyzed using the derivative-free,

restricted maximum-likelihood (DFREML). To separate direct genetic, maternal genetic and permanent

environment, six different models were fitted for cow weight (CWT) and calving interval (CI). Model

used to estimate covariance between traits, genetic correlations and breeding values (BV) included both

permanent environmental and genetic maternal effect accounting for a genetic correlation between direct

and maternal effects. Fixed effects were similar in all the models which included cow birth year, season

cows were born and linear and quadratic covariates to regress all records to a common age of dam.

Total heritability (h^2_T) for CWT was .55 consistent in all models used, with slight increase to .56. The lowest estimates of heritabilities (h^2_a, h^2_m) were .40 and .16, respectively. Low additive genetic correlation (r_A) of .02 was found in this study. The maternal genetic correlation (r_M) was -.57. A small estimate of permanent environmental correlation for CI was found in this study (r_C = .18). Selecting dams directly for CWT should result in an improvement in maternal performance for CI (r_{A1M2} = .33). On the contrary selecting directly for shorter CI should resulted in large CWT (r_{A2M1} = -.12). Based on genetic, environmental and phenotypic trends it was concluded that cow weight selection procedure was progressively changing to an optimum compatible with prevailing environmental stresses.

Introduction

The determination of optimum levels of growth and mature cow weight under the specific production conditions is of importance especially in stressful environments. This is because suboptimal production environments tend to favor cows that are small and can meet requirements of maintenance and the growth of their calves (Tawar et al., 1993). Cows that are inherently big are unable to meet their maintenance requirements and ultimately fail to breed in a particular year under suboptimal conditions.

More emphasis has been put on growth traits as a means of beef cattle evaluation with many studies on cow weight estimating lifetime growth curves and efficiency (Brown et al., 1972; Franke and Burns, 1975; Morris and Wilton, 1976; DeNise and Brinks, 1985; Johnson et al., 1990 and Lopez de Torre et al., 1992). Genetic trends of CWT and CI can be used to determine optimum weight and as a measure of adaptability in stressful environments. Mackinnon et al. (1990) presented evidence of genetic variation both in male and female reproductive performance indicating that there should be a considerable scope for selection though the heritability estimates for CI were low (Lopez de Torre and Brinks, 1990). Estimates of (co)variance components and genetic parameters for CWT and CI, together with the prediction of breeding values for CWT and CI will be made in this study.

Material and Methods

Source of data. Data were available from a registered Bonsmara herd at Ivy Farms, located north of Pietersburg in the Northern Transvaal, South Africa from 1974 to 1986. The area is situated at 23° 30,8' latitude and 29° 50,4' longitude at a height of 1280 m above sea level. It is classified as a Savanna mixed bushveld and Arid Sweet bushveld (area 14 and 18) (Acocks, 1975). The average monthly rainfall and temperature for a 20 year period is indicated in Table 1.

Management. Cow weight and CI data of 1603 Bonsmara dams under range environment were collected over a 13 year period. Collection of records were done within the specifications of the South African Beef and Performance Testing Scheme. Cows were bred to calve at optimum time of the year, not earlier than one month before the first expected good rains. Observations on the farm indicated that if cows calve too early they may lose condition for breeding, if too late, the young calves may receive much milk and be prone to internal parasite. October to December and April to June were chosen as the best months in Summer and Winter, respectively (Ivy, 1984).

Because of the two calving seasons the best bulls were used twice a year. All cows were screened twice a year and subsequently culled if they fail to conceive two seasons in succession. Heifers were bred one month prior to the main season so that they calve early in the season and have sufficient time to conceive again. To ensure good conception rates supplementation composed of maize meal (800g), urea (60g), salt (30g), dicalcium phosphate (30g) was provided to heifers over the winter and cows during the breeding season (Ivy, 1984).

Data analysis. Estimates of variance components for traits in this study were obtained using the derivative-free, restricted maximum-likelihood (DFREML) procedure developed by Meyer (1988, 1989) modified for use with sparse matrix solver package (SPARSPAK) (Boldman *et al.*, 1991). The DFREML program was described by Smith and Graser (1986) and Meyer (1989). The SPARSPAK package (George *et al.*, 1980) is used to reorder the mixed-model equations once and then the interactively update equations repeatedly solved by Cholesky factorization to calculate the likelihood.

The procedure uses an animal model fitting an additive genetic effect not only for animals with records but also for parents included in the analysis by pedigree information. Northcutt et al. (1992) found that body condition score was a significant source of variation in Angus Cow weights accounting for 16 percent of total variation in weights. In this study condition score data were not available thus cow weights were not adjusted for condition score. Bivariate analysis were also used to estimate covariance between traits and correlations thereof. A convergence criterion, which was the minimum variance of the function values (-2 log likelihood) after each round of interaction, was required to be 1×10^{-9} for each analysis. Initial priors from a paper by Meyer (1992) were used. To separate direct genetic, maternal genetic and permanent environment, six different models were fitted for mature weights and calving interval as explained by Meyer (1992). The six models were:

$$Y_{ijkl} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + e_{ijkl} \qquad \text{I}$$

$$Y_{ijklm} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + p_l + e_{ijklm} \qquad \text{II}$$

$$Y_{ijklm} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + m_l + e_{ijklm} \qquad \text{III}$$

$$\text{with Cov } (a_k, m_l) = 0$$

$$Y_{ijklm} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + m_l + e_{ijklm} \qquad \text{IV}$$

$$\text{with Cov } (a_k, m_l) \neq 0$$

$$Y_{ijklmn} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + m_l + p_m + e_{ijklmn} \qquad \text{V}$$

$$\text{with Cov } (a_k, m_l) = 0$$

$$Y_{ijklmn} = T_i + B_j + b_1 (age_{ijkl}) + b_2 (age_{ijkl})^2 + a_k + m_l + p_m + e_{ijklmn} \qquad \text{VI}$$

$$\text{with Cov } (a_k, m_l) \neq 0$$

Where, Y_{ijklmn} = observation from the kth animal; T_i = fixed effect of the ith year of birth; B_j = fixed effect of the jth season of birth; b_1 (age_{ijk}) and b_2 $(age_{ijk})^2$ = linear and quadratic covariates to regress all records to a common age of dam, a_k = random direct additive genetic effect of the kth animal, m_l = random maternal additive genetic effect of the lth dam, p_m = random permanent environment of the mth dam, e_{ijklmn} = random residual effect.

The variance-covariance structure for the model is as follows: Let **a** and **m** denotes the vectors of animal's direct and maternal additive genetic effects, respectively, and **p** and **e** the vectors of maternal environmental effects and residual errors. Further, let **A** be the numerator relationship matrix between animals and **I** the identity matrix. The (co)variance structure for the analysis can then be described as

$$V(\mathbf{a}) = \sigma^2_A \mathbf{A}, \ V(\mathbf{m}) = \sigma^2_M \mathbf{A}, \ V(\mathbf{p}) = \sigma^2_C \mathbf{I}, \ V(\mathbf{e}) = \sigma^2_E \mathbf{I},$$

$$Cov(\mathbf{a}, \mathbf{m}) = \sigma_{AM} \mathbf{A}$$

where σ^2_A is the additive genetic variance, σ^2_M the maternal genetic variance, σ_{AM} the direct-maternal genetic covariance, σ^2_P the maternal environmental variance, σ^2_E = the error variance.

Model I, was a simple animal model with animal's additive genetic effects as the only random effects, ignoring any maternal influence. Model II allowed for a permanent environmental effect due to the dam, fitting this as an additional random effect, uncorrelated with all other effects in the model. Model III had maternal genetic effect as a second random effect for each animal with the same covariance structure as the direct additive genetic effects. Model III assumed that direct and maternal effects was uncorrelated, i.e. $\sigma_{AM} = 0$, while Model IV allowed for a covariance between them. Models V and VI included both permanent environmental and genetic maternal effect, ignoring and accounting for a genetic correlation between direct and maternal effects.

Breeding values were obtained as a by-product from the DFREML program using model VI. Genetic trends for cows and their pedigree were calculated as the regression of average predicted breeding values on year the cows were born. Environmental trends were computed by regressing the year solution on year cows were born.

Results and Discussions

Univariate Analysis. Variance components and genetic parameters for CWT from univariate analysis are reported in Table 3. Direct additive genetic variance (σ^2_a) was highest for Model I. Including maternal environmental variance (σ^2_c) in Model II reduced σ^2_a slightly. Fitting maternal additive genetic variance (σ^2_m) reduced σ^2_a to the lowest value in Model IV mainly due to the large negative covariance (σ_{am}). Maternal environmental variance (σ^2_c) decreased from a high estimate in Model II to low values when fitted in combination with σ^2_m (Model V) and slightly increased when σ_{am} was added in Model VI. Estimates of heritabilities (h^2_a, h^2_m) were lower in Model III and V, .40 and .16, respectively. These estimates were expected to be low because of the low σ^2_a and σ^2_m. Total heritability (h^2_T) was consistent in all the models (.55) with a minor increase to (.56) in Models III, V and VI. Heritability estimates reported in this study were comparable to estimates stated by Northcutt and Wilson (1993) using a two traits sire models. An exception was the low estimates of h^2_a under Model III and V.

Estimates for (co)variance components for CI from the univariate analysis are shown in Table 4. Direct additive genetic variance (σ^2_a) and maternal additive variance (σ^2_m) were comparatively larger in Models IV and VI which included σ_{am}. Contrary to CWT direct-maternal genetic correlations (r_{Gam}) were positive but converged to bounds. This was probably due to small number of animals (760) in the pedigree. Estimates of heritabilities (h^2_a, h^2_m, h^2_T) estimated in this study were too low to indicate any opportunity for response to selection. The most recent estimates of heritability for CI were -.00 and .01 reported by Lopez de Torre et al. (1990).

Bivariate Analysis. Estimates of correlations from the bivariate analysis for CWT and CI are presented in Table 5. A low additive genetic correlation of .02 was found in this study. This was expected since the CI error variance was high, while the direct genetic variation was low. Indications are that bigger dams tends to have longer CI than smaller dams. However, this may be specific to stressful conditions where the environment becomes the determinant factor to growth and body weight. There was a moderate maternal genetic correlation (r_M) (-.57). Selecting for large maternal effects for CWT should results in lower maternal effects for CI. Environment provided by the dam was also positively correlated (r_C = .18) to CI. Selecting dams directly for CWT resulted in a positive low correlation (r_{A1M2} = .33) with maternal effects for CI. On the contrary selecting directly for shorter CI should resulted in large CWT (r_{A2M1} = -.12).

Trends. The average breeding values (trends) for body weight in cows, dams and sires are presented in Table 6. Trends were regressed to the year the cows were born . The year the dams and sires were born were not available and thus separated to explain their influence on cow trends. Environmental and phenotypic trends for cow weights are shown in Table 7. Graphic representation of all CWT trends are presented in Figures 1 to 4. Positive genetic trends lines for cow weight occurred in this study as indicated in Table 6 and Figure 2. Cow weight significant increased (P = .05) during the 13 year at 1.19 kg per year. Trends for dams at the same period were increasing (P = .24) at the rate of .28 kg per year and that of sires increasing (P = .04) at the rate of 1.99 kg per year (Table 6). Positive trends for sire mature weight EPD reported by Northcutt and Wilson (1993) increased at .9 kg per year. Dam genetic trends were smaller than that of sires for CWT. This may be due to their values regressed more towards the mean because of fewer numbers of progeny and the longer time dams spend on a herd which result in small change from year to year (Wilson and Willham, 1986). Sires with high breeding values were used in specific years (1976, 1983 and 1985) that increased the breeding values of cow weight.

Environmental trends showed a negative trend over the 13 year period indicating suboptimum conditions over the years. Similar trends were observed for phenotypic trends as indicated in Table 8 and Figure 4. Decrease in phenotypic trends may have been due to culling of cows that did not give birth to a calf thus indirectly select for relatively smaller cows over the years. Trends were decreasing at 3.21 kg and 8.93 kg, respectively. High positive trends and low CWT which occurred between the year 1982 and 1986 seems to indicate that selection for relatively smaller cow weight was more appropriate in this study. Fluctuations in the environment was also influencing the change in phenotypic variation over the 13 years. Genetic trends for CI were practically zero over the 13 year period. Environmental trend for CI was decreasing ($P < .001$) at five days per year whereas phenotypic trend was increasing ($P = .5$) at .5 days per year (Table 8 and Figures 5 and 6). High negative environmental trends in the years from 1981 to 1986 contributed to the sustenance of high CI during that period.

Conclusions

High direct genetic and maternal variation offer one possibility to select for CWT. However, optimum rather than large cow weight should be the objective in production systems. Heritability estimates, both additive and maternal, indicated that response to selection based on CWT can be dramatic. Estimates compared well with values in the literature. Low estimates of variation and heritabilities for CI was expected which offered very little opportunity to select for fertility. Small genetic correlations were observed with the tendency to indicate that relatively smaller dams may perform better under the prevailing conditions. Selection procedures based on the breeding values of animals seems to be the best method of evaluating CWT. Phenotypic values decreased over time while genetic values increased indicating that selection based on genetic trends for CWT was the best procedure. Environmental influences were large enough to contribute to the overall variation observed in this study.

Literature cited

Acocks, J. P. H. 1975. Veld types of South Africa. Mem. Bot. Surv. S. Afr. no. 40. Govt. Printer, Pretoria.

Boldman, K. G., and L. D. van Vleck. 1991. Derivative-free restricted maximum likelihood estimation in animal models with a sparse matrix solver. J. Dairy Sci. 74: 4337.

Brown, J. E., C. J. Brown, and W. T. Butts. 1972. A discussion of the genetic aspects of weight, mature weights and rate of maturing in Hereford and Angus cattle. J. Anim. Sci. 34:525.

DeNise, R. S. k., and J. S. Brinks. 1985. Genetic and environmental aspects of the growth curve parameters in beef cows. J. Anim. Sci. 61:1431.

Franke, D. E., and W. C. Burns. 1975. A discussion of growth curves of Angus, Brahman, Hereford and Santa Gertrudis cows. Florida Agric. Exp. Sta. Anim. Sci. Rep. NO. AL-1975-1.

George, A., J. Liu and E. Ng. 1980. User guide for SPAKSPAK: Waterloo sparse linear equation package. CS-78-30, Dept. of Computer Sci., Univ. of Waterloo. ON, Canada.

Ivy, D. 1984. Ranching with Bonsmara in the bushveld. Handout from D. Ivy.

Johnson, Z. B., C. J. Brown, and A. H. Brown, Jr. 1990. Evaluation of growth patterns of beef cows. Arkansas Agric. Exp. Sta. Bull. No. 923.

Lopez de Torre, G., J. J. Candotti, A. Reverter, M. M. Bellido, P. Vasco, L. J. Garcia, and J. S. Brinks. 1992. Effects of growth curve parameters on cow efficiency. J. Anim. Sci. 70:2668.

Lopez de Torre, G., and J. S. Brinks. 1990. Some alternative to calving date and interval as measure of fertility in beef cattle. J. Anim. Sci. 68:2650.

Mackinnon, M. J., J. F. Taylor, and D. J. S. Hetzel. 1990. Genetic variation and covariation in beef cow and bull fertility. J. Anim. Sci. 68:1208.

Meyer, K. 1988. DFREML. Programs to estimate variance components for individual animal models by restricted maximum likelihood. User notes, Edinburgh Univ., Scotland, U. K.

Meyer, K. 1989. Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. Genet. Sel. Evol. 21: 317.

Meyer, K. 1992. Variance components due to direct and maternal effects for growth traits of Australian beef cattle. Livest. Prod. Sci. 31:179.

Morris, C. A., and J. W. Witon. 1976. Influence of body size on the biological efficiency of cows: A review. Can. J. Anim. Sci. 56:613.

Northcutt, S. L., D. E. Wilson, and R. L. Willham. 1992. Adjusting weight for body condition score in Angus cows. J. Anim. Sci. 70:1342.

Northcutt, S. L., and D. E. Wilson. 1993. Genetic parameter estimates and expected progeny differences for mature size in Angus cattle. J. Anim. Sci. 71:1148.

Smith, S. P., and H. U. Graser. 1986. Estimating variance components in a class of mixed models by restricted maximum likelihood. J. Dairy Sci. 69:1165.

Tawah, C. L., D. A. Mbah, J. E. O. Rege, and H. Oumate. 1993. Genetic evaluation of birth and weaning weight of Gudali and two-breed synthetic Wakwa beef cattle populations under selection in Cameroon: genetic and phenotypic parameters. Anim. Prod. 57: 73.

Wilson, D. E., and R. L. Willham. 1986. Within-herd phenotypic, genetic and environmental trends lines for beef cattle breeders. J .Anim. Sci. 63: 1087.

Table 1. The Average Annual Rainfall Distribution by Month for 20 Years Period at Ivy Farms

Month	Rainfall (mm)	Temperature (°C)
January	75	22.0
February	52	20.0
March	33	19.0
April	20	17.0
May	8	15.0
June	4	11.5
July	4	11.8
August	2	13.0
September	13	18.5
October	20	21.0
November	52	20.5
December	63	20.5

Table 2. Characteristics of the data structure for cow weight and calving interval of Bonsmara dams from univariate analysis

| Characteristics | Traits | |
	Cow Weight	Calving Interval
No. of records	1508	1170
No. of animals[a]	762	760
Weight (Kg)		
Mean	498.22	389
SD	70.91	63
Min.	265	278
Max.	740	931
Age of dam (Covariate)		
Mean	5.27	6.00
Min.	2.69	2.69
Max	15.00	15.00
No. of years[b]	13	13
1974	79	84
1975	29	28
1976	92	87
1977	60	53
1978	79	70
1979	148	129
1980	136	116
1981	140	117
1982	116	99
1983	151	119
1984	228	154
1985	123	70
1986	123	44
No. of seasons[b]	2	2
Winter	795	635
Summer	709	535

[a]In the analysis including parents without records
[b]Levels associated with number of animals

Table 3. Estimates of (co)variance components and genetic parameters[a] for cow weight from univariate analysis

	Model I	Model II	Model III	Model IV	Model V	Model VI
σ^2_a	1630.85	1594.11	1159.11	1540.63	1158.56	1627.35
σ^2_m			457.73	1571.64	457.37	17.99
σ_{am}				-1556.13		-2.53
σ^2_c		5.68			.22	.31
σ^2_e	1308.19	1304.19	1288.77	1276.66	1289.44	1298.14
σ^2_p	2939.04	2903.97	2905.61	2832.88	2905.59	2941.26
σ_{am}/σ^2_p				-8.9×10^{-4}		-8.61×10^{-4}
σ^2_c/σ^2_p		1.95×10^{-3}			7.69×10^{-5}	1.06×10^{-4}
σ^2_e/σ^2_p	.45	.45	.44	.45	.44	.44
r_{Gam}				-1		-.01
h^2_a	.55	.55	.40	.54	.40	.55
h^2_m			.16	.55	.16	.01
h^2_T	.55	.55	.56	.55	.56	.56

[a] σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ_{am}, direct-maternal genetic covariance; σ^2_c, permanent environmental variance; σ^2_e, error variance; σ^2_p, phenotypic variance; σ_{am}/σ^2_p, σ^2_c/σ^2_p, σ^2_e/σ^2_p, direct-maternal genetic covaraince, maternal environmental variance and error variance expressed as proportion of σ^2_p; h^2_a, heritability of direct effects; h^2_m, heritability of maternal effects; h^2_T, total heritability; r_{Gam}, direct-maternal genetic correlation.

Table 4. Estimates of (co)variance components and genetic parameters[a] for calving interval from univariate analysis

	Model I	Model II	Model III	Model IV	Model V	Model VI
σ^2_a	1.25×10^{-3}	9.56×10^{-3}	.02	.11	.01	.11
σ^2_m			3.50×10^{-4}	.26	.01	.26
σ_{am}				.17		.17
σ^2_c		2.00×10^{-5}			4.00×10^{-5}	4.5×10^{-4}
σ^2_e	3415.09	2054.85	3415.48	3413.89	3414.07	3413.89
σ^2_p	3415.09	2054.86	3415.49	3414.45	3414.09	3414.45
σ_{am}/σ^2_p				5.02×10^{-5}		5.02×10^{-5}
σ^2_c/σ^2_p		1.00×10^{-8}			1.20×10^{-8}	1.32×10^{-7}
σ^2_e/σ^2_p	1.00	1.00	1.00	1.00	1.00	1.00
r_{Gam}				1.00		1.00
h^2_a	3.66×10^{-7}	4.65×10^{-6}	4.51×10^{-6}	3.27×10^{-5}	3.31×10^{-6}	3.27×10^{-5}
h^2_m			1.02×10^{-7}	7.71×10^{-5}	4.19×10^{-6}	7.71×10^{-5}
h^2_T	3.66×10^{-7}	4.65×10^{-6}	.02	1.60×10^{-4}	7.51×10^{-6}	1.60×10^{-4}

[a] σ^2_a, direct additive genetic variance; σ^2_m, maternal additive genetic variance; σ_{am}, direct-maternal genetic covariance; σ^2_c, permanent environmental variance; σ^2_e, error variance; σ^2_p, phenotypic variance; σ_{am}/σ^2_p, σ^2_c/σ^2_p, σ^2_e/σ^2_p, direct-maternal genetic covaraince, maternal environmental variance and error variance expressed as proportion of σ^2_p; h^2_a, heritability of direct effects; h^2_m, heritability of maternal effects; h^2_T, total heritability; r_{Gam}, direct-maternal genetic correlation.

Table 5. Estimates of correlations[a] from bivariate analysis for cow weight and calving interval

Parameter	Correlation
r_A	.02
r_M	-.57
r_C	.18
r_E	.00
r_{A1M2}	.33
r_{A2M1}	-.12

[a]r_A direct additive genetic correlation, r_M maternal genetic correlation, r_C permanent environmental correlation, r_E residual correlation, r_{AiMj} genetic correlation between direct effect for trait i and maternal effects for trait j.

Table 6. Genetic trends for body weight in Bonsmara cows, dams and sires.

Year of birth[b]	Number	AVB[a] ± Stderr (kg)		
		Cows body weight	Dams body weight	Sires body weight
1974	79	-17.54 ± 2.78	-8.17 ± 1.44	-15.55 ± 2.50
1975	29	-.87 ± 4.81	-.29 ± 2.49	-6.41 ± 4.34
1976	92	15.23 ± 2.70	3.35 ± 1.40	26.99 ± 2.44
1977	60	-4.32 ± 3.46	-.74 ± 1.79	-10.12 ± 3.12
1978	79	-3.51 ± 2.99	.04 ± 1.55	-7.64 ± 2.70
1979	148	4.29 ± 2.19	3.29 ± 1.13	4.49 ± 1.97
1980	136	3.92 ± 2.28	-.74 ± 1.18	5.96 ± 2.06
1981	140	-.47 ± 2.25	1.84 ± 1.17	.42 ± 2.06
1982	116	4.48 ± 2.39	4.20 ± 1.24	6.74 ± 2.15
1983	151	10.57 ± 2.09	1.60 ± 1.09	21.41 ± 1.89
1984	228	4.71 ± 1.70	.38 ± .88	9.31 ± 1.53
1985	123	9.54 ± 2.31	-1.69 ± 1.20	22.69 ± 2.09
1986	123	7.62 ± 2.25	1.11 ± 1.17	12.39 ± 2.03
Coefficients		1.19 ± .53	.28 ± .23	1.99 ± .83

[a]Average breeding values
[b]Year the individual cows were born

Table 7. Environmental and phenotypic trends for body weight and calving interval in Bonsmara cows.

| Year of birth[b] | Number | Cow body weight (kg) | | Calving Interval (days) | | |
		Environmental	Phenotypic	Number	Environment	Phenotypic
1974	79	29.79	523.73	84	-1.58	382
1975	29	41.74	557.93	28	1.76	383
1976	92	25.84	544.54	87	1.87	384
1977	60	48.27	537.83	53	12.85	396
1978	79	36.34	526.77	70	10/03	395
1979	148	22.66	521.79	129	12.13	402
1980	136	48.19	538.01	116	2.18	394
1981	140	24.78	504.46	117	-18.76	379
1982	116	11.97	494.14	99	-7.28	393
1983	151	8.59	484.54	119	-35.42	376
1984	228	15.79	470.25	154	-28.95	389
1985	123	20.42	466.95	70	-37.67	391
1986	123	-15.59	418.58	44	-48.75	401
Coefficients		-3.21 ± .96	-8.93 ± 1.37		-4.47 ± .90	.48 ± .62

[a]Average breeding values
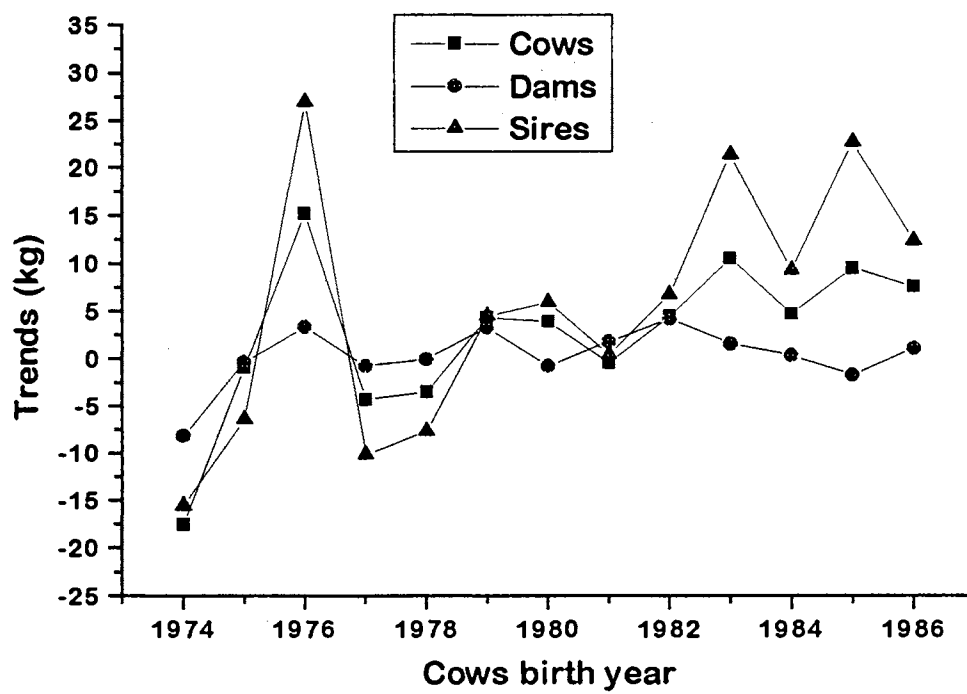[b]Year the individual cows were born

TRENDS[a]

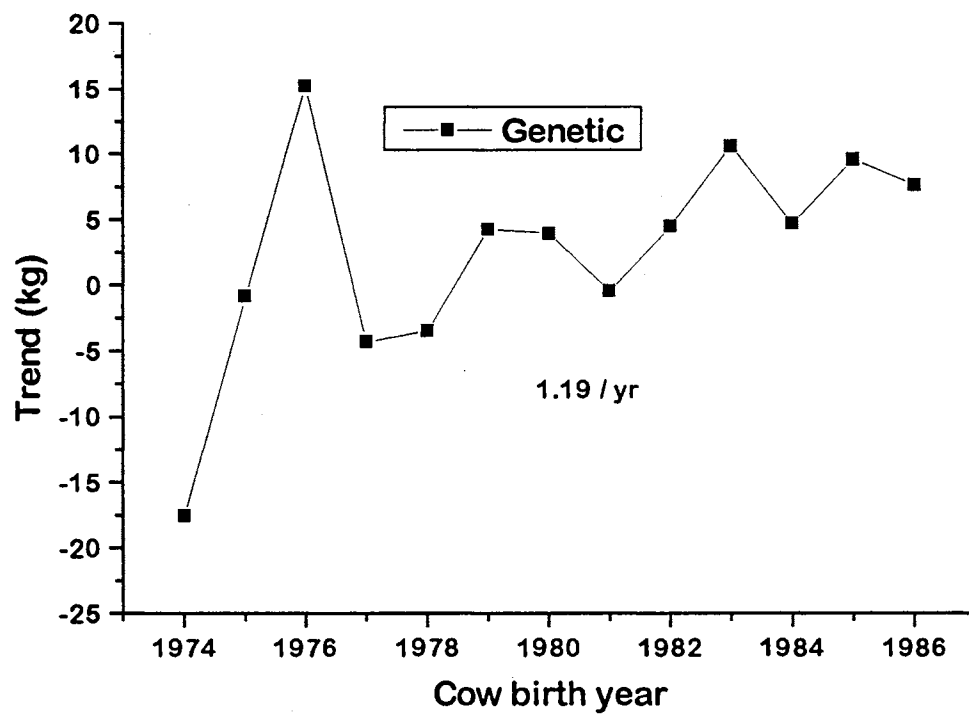Figure 1. Direct genetic trends for body weight in Bonsmara cows, dams and sires (Model VI)

Figure 2. Direct genetic trend for body weight in Bonsmara cows (Model VI).
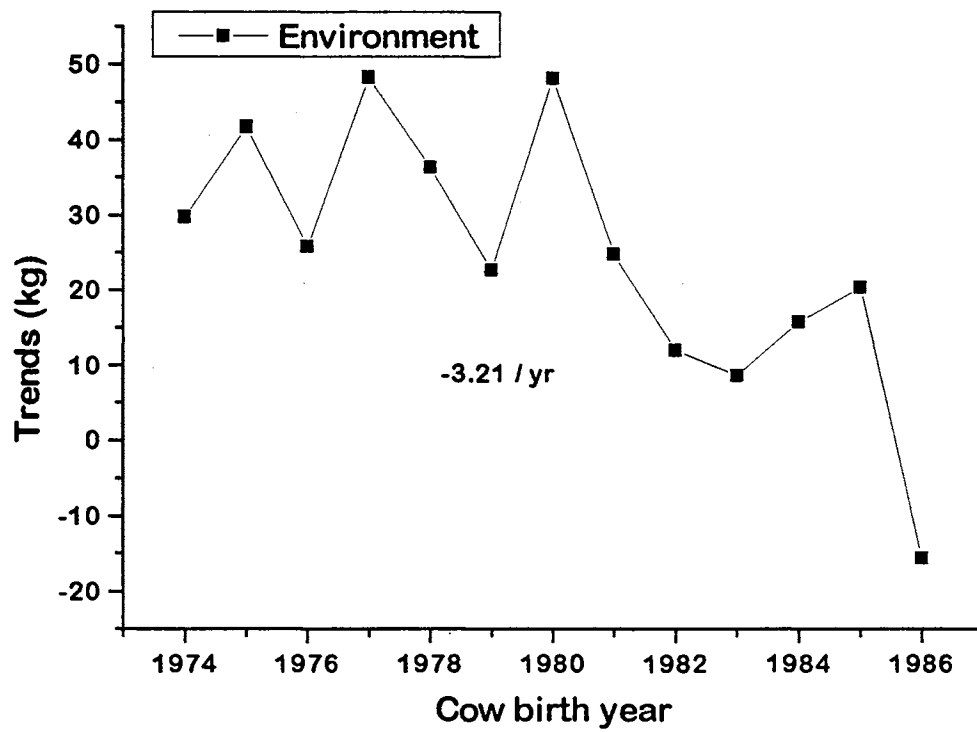
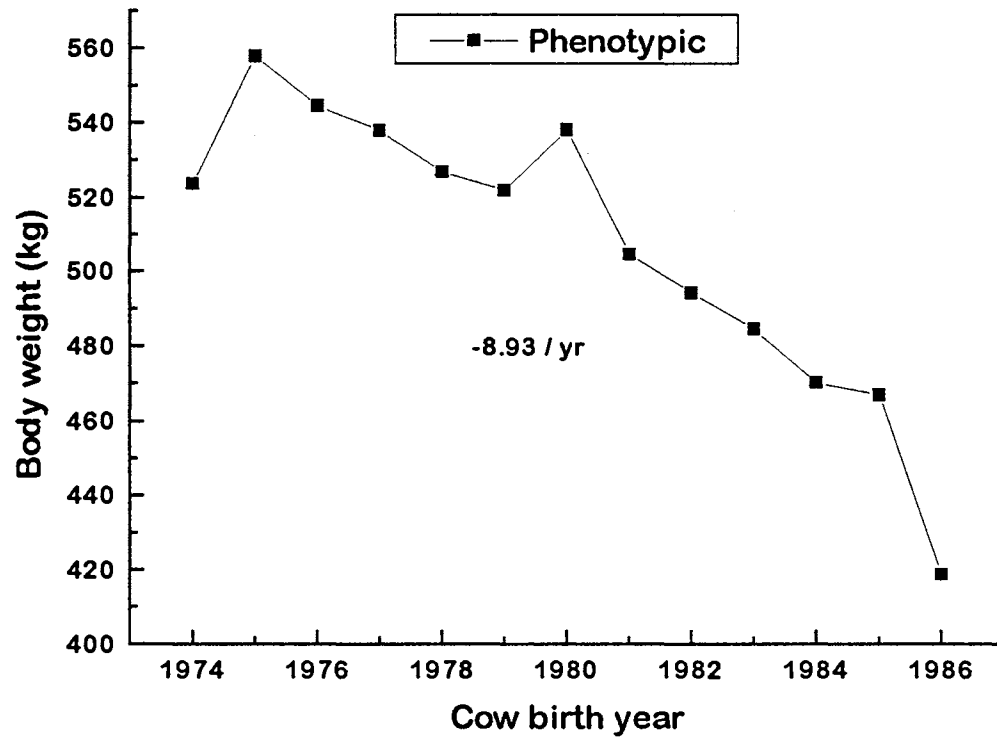Figure 3. Environmental trend for body weight in Bonsmara cows (Model VI).

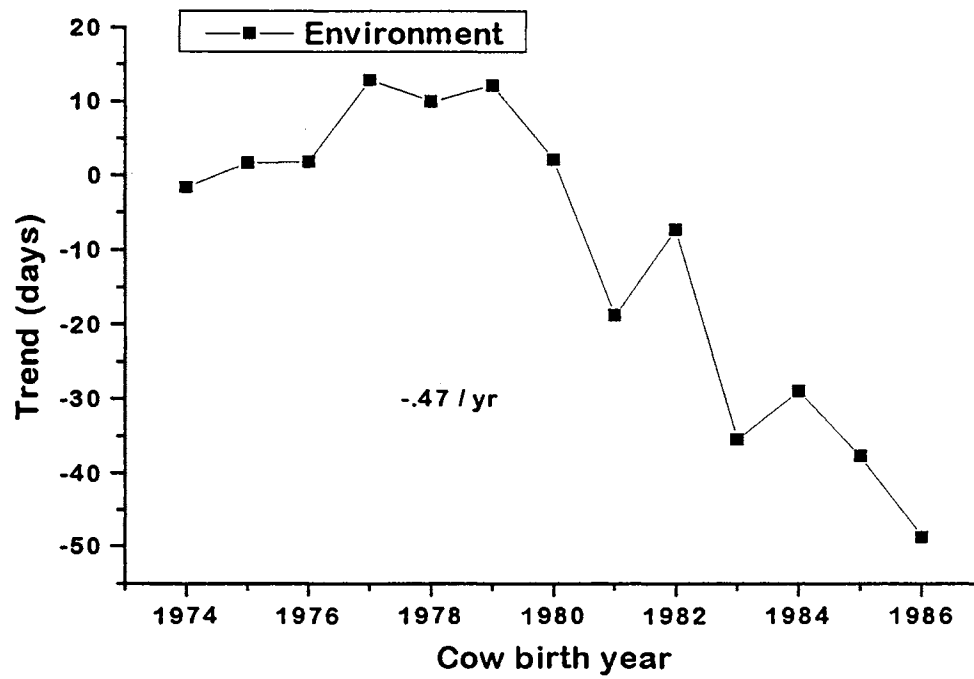Figure 4. Phenotypic trend for body weight in Bonsmara cows (Model VI).

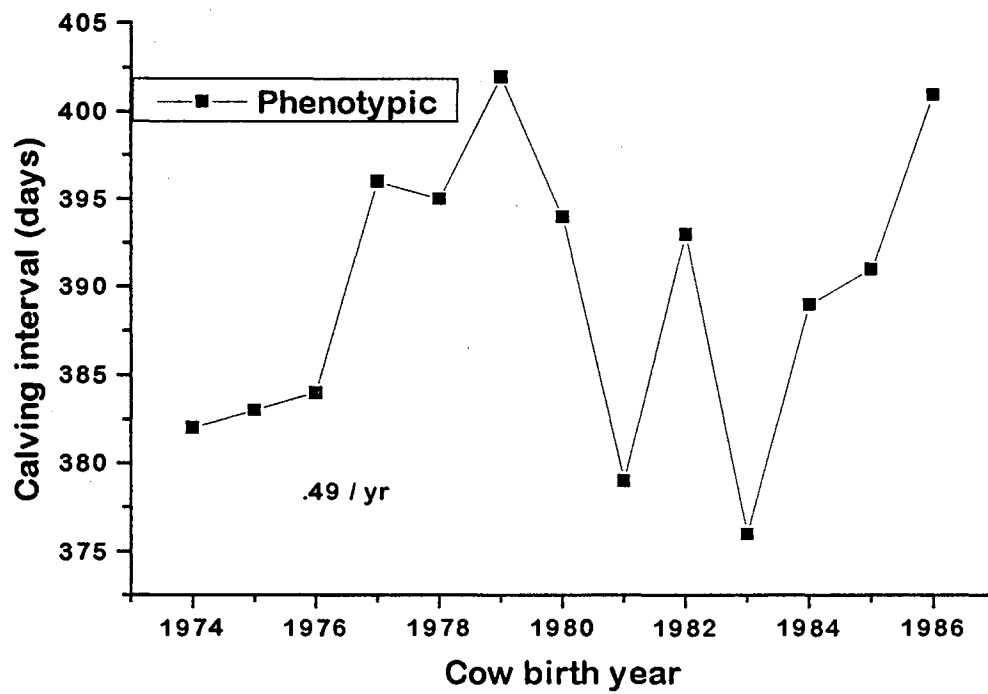Figure 5. Environmental trend for calving interval in Bonsmara cows (Model VI).

Figure 6. Phenotypic trend for calving interval in Bonsmara cows (Model VI)

SUMMARY

The Bonsmara beef cattle breed was created at Mara Research Station, Northern Transvaal Province, Republic of South Africa. The research station is situated in a subtropical environment. It has been established that individual Bos Indicus and Bos Taurus breeds do not perform satisfactorily in subtropical regions in all traits of economic importance. This is because subtropical environments are characterized by high ambient temperature, high incidence of parasites, diseases and poor low quantity and in some cases poor quality pastures. Growth rate, feed efficiency, fertility and mortalities have been observed to differ within and between breeds according to their ability to withstand stress. The establishment of the Bonsmara as a synthetic breed was based on scientific research of physiology of adaptation. The Afrikaner breeds being indigenous and selected by nature to adapt to subtropics had more proportion 5/8 as compared to Shorthorn and Hereford 3/8. Data that constituted the basis of this study was collected in a stud breeding herd Northern Transvaal Province, Munnik. The South Devon was introduced in the cross of this stud farm to improve milk yield of the Hereford. All registered breeders must belong to the National Beef Performance and Testing Scheme. The scheme supervises the recording of performance data and with the breed associations setting breeds standards.

In subtropical environments of South Africa, weaner production is still an important economic activity. Emphasis in research should therefore be to improve preweaning growth traits under these conditions. It was established in this present study that variation in preweaning traits was influenced by the environment. Selection programs in this situation should also consider adjustment of environmental effects that may obscure genetic differences among animals. Some of the most common effects are: year of birth, season of birth, sex of calf and age of dam. In this present study environmental effects estimated Least Square Means accounted for 75 percent of the variation in birth weight (BWT) and 62 percent in weaning weight (WWT) and preweaning gain (PWG).

126

Response to selection depend on the amount of additive genetic variation in a population. This is the only variation that is passed from one generation to the next. Preweaning growth traits therefore depend on calf's genetic capacity for growth and the dam's capacity that consists of both genetic and environmental. It is of importance to consider both direct and maternal components especially when there is an antagonistic relationship between them. Direct-maternal genetic correlation (r_{Gam})was positive and favorable for BWT, inferring that improving BWT through maternal genetic component will result in improvement in direct additive genetic component. Estimate of direct-maternal genetic correlation for WWT was large and negative, suggesting that improving WWT by direct selection for growth will results in maternal performance.

A large difference in estimates of r_{Gam} between BWT and WWT may have been in part due to suboptimal conditions prevailing during the period of droughts. Females that are inherently small tend to utilize the production environment more efficiently for both maintenance and for the growth of their calves than larger dams under the same conditions. Larger dams are unable to meet their maintenance requirement as well as support the growth needs of their calves from limited pastures. Consequently their calves tend to be smaller at birth and weaning than those of small dams at similar ages.

Estimates of correlations need to be considered in a selection program to improve response to selection for preweaning traits. Beef cattle producers should be encouraged to utilize selection index. A restricted selection index in this case will be appropriate. The technique maximizes genetic progress in one trait while holding expected genetic gain of the other specified trait to zero. For the purposes of this study a restricted index will be controlling BWT to reduce calving difficulty while incorporating (co)variance components and estimates of correlations to improve genetic progress in maternal and direct additive for WWT.

Selection response based on past selection procedures were evaluated in the present study. Birth weight was controlled in this population by restrictive use of all sires that had progeny with BWT of above 45 kg. Stabilizing selection were practiced by ranking all potential replacements on their phenotypic merit and select as parents those individuals that were close to the average. This was done in this stud herd by expressing each adjusted phenotypic trait as a ratio of their contemporary that was again expressed as a ratio of the whole herd. These cause the progeny of parents selected on this basis to be near the average in gene frequency, breeding values and phenotype (assuming constant environment). Results of this study indicate large fluctuations in direct genetic breeding values during the creation phase of the stud herd (1974 to 1978) and introduction of sires from different lines within the Bonsmara. Trends started to stabilize around the average from the year 1980, though BWT direct and maternal trends decreased over the 16 year period. It appears that direct genetic trends for WWT increased over the study period in part due to the ability to withstand stress.

The cowherd was selected based on subjective and objective methods, though the efficiency index played a major role. Efficiency index is expressed as the ratio of WWT to the weight of the dams or metabolic body weight of the dams. Cow weight (CWT) direct additive heritability estimate was comparable to estimates in literature (.55). Indications are that response to selection based on CWT can be dramatic. Results of this study also confirmed many estimates in literature about the low heritability estimates of calving interval. Because of the moderate to high heritability estimates for CWT, phenotypic measurements became a good indication of the BV of the animal.

It was evident from this study that BV estimates are the best methods to evaluate animals for breeding purposes. Implementation of this procedure on the national level can have a major impact in the beef cattle industry in South Africa. Stabilizing selection as practiced in this population have selected animals on the average and cause the phenotypic trends to responded to variation in environmental status.

VITA

Azwihangwisi Edward Nesamvuni

Candidate for the Degree of

Doctor of Philosophy

Thesis: GENETIC AND PHENOTYPIC TRENDS FOR GROWTH AND OVERALL
EFFICIENCY IN BONSMARA BEEF CATTLE

Major Field: Animal Breeding

Biographical:

Personal Data: Born in Sibasa, Thohoyandou, Northern Province, Republic of South Africa, July
04, 1964, the eldest son of Alpheus Mphireni Nesamvuni and Tshimangadzo Reginah
Nesamvuni. Married to Cebisa Noxolo Nesamvuni, August 8, 1993.

Education: Graduated from Mbilwi High School, Sibasa, Thohoyandou, Northern Province,
Republic of South Africa, December, 1982; received Bachelor of Science degree in Animal
Science and Poultry Science from the University of Natal, Pietermaritzburg, Kwazulu
Natal Province, Republic of South Africa in April, 1989; received Bachelor of Science
(Honours) degree in Animal Sciences Cum Laude from the University of Fort Hare, Alice,
Eastern Province, Republic of South Africa in May, 1990; received Masters of Science
degree in Animal Breeding from the University of Fort Hare, Alice, Eastern Cape
Province, Republic of South Africa in May, 1993; Completed the Requirements for the
degree of Doctor of Philosophy at Oklahoma State University in December, 1995.

Professional Experience: Assistant Agricultural Extension Officer, Madzivhandila Agricultural
College and Agricultural Co-operation in Venda, Sibasa, Thohoyandou, Northern
Province, Republic of South Africa, 1986-1988; Graduate Assistant, Department of
Livestock and Pasture Sciences, University of Fort Hare, Alice, Eastern Cape, Republic of
South Africa, 1989; Junior Lecturer, Department of Animal Production, University of
Venda, Sibasa, Thohoyandou, Northern Province, Republic of South Africa; Junior
Lecturer, Department of Livestock and Pasture Sciences, University of Fort Hare, Alice,
Eastern Cape, Republic of South Africa, 1991-1992. Fulbright Scholar, Department of
Animal Science, Oklahoma State University, Stillwater, Oklahoma, United States of
America, August, 1992-1995.

Professional Organization: South African Society of Animal Production; American Society of
Animal Science.