Genetic and environmental effects on performance traits of Simmentaler cattle on the Transvaal Highveld

Tina Rust*

Highveld Region Agricultural Development Institute, Private Bag X804, Potchefstroom, 2520 Republic of South Africa

J. van der Westhuizen

Department of Animal Science, University of the Orange Free State, P.O. Box 339, Bloemfontein, 9300 Republic of South Africa

Received 26 July 1993; revised 3 February 1994; accepted 11 October 1994

Simmentaler cattle of the Highveld Region Development Institute were used in this study to determine the genetic and environmental effects on birth mass, weaning mass and the mass gain from birth to weaning. During winter the animals were kept in four groups of roughly 40 cows each. The groups were: (i) Group 1— animals were fed maize silage (Silage group), (ii) Group 2 — animals were fed foggage and hay as well as maize crop residues (Hay group), (iii) Group 3 — animals were kept only on veld (Veld group) and (iv) the Control group. Starting in 1982, data were collected over a period of nine years. The General Linear Models (GLM) procedure of SAS was used to analyse the data. The random effect of sire of calf was, for all traits investigated, highly significant ($P < 0.01$). Birth mass, weaning mass and the mass gain from birth to weaning was significantly ($P < 0.01$) lower for the silage group calves. There were no significant differences for birth mass, weaning mass and mass gain from birth to weaning between Groups 2 and 3. The combined mass gain of the cows and calves from birth to weaning for Group 3 was significantly ($P < 0.05$) higher than for Group 2.

Simmentalerbeeste van die Hoëveldstreek Landbou Ontwikkelingsinstituut is in die studie gebruik om die invloed van genetiese- en omgewingseffekte ten opsigte van geboortemassa, speenmassa en die massatoename vanaf geboorte tot speen te ondersoek. Gedurende die winter is die koeie in vier groepe van ongeveer 40 koeie elk verdeel. Die groepe was: (i) Groep 1— die koeie is mieliekuilvoer gevoer (Kuilvoergroep), (ii) die koeie is aangehou op staandehooi, hooi en mielie oesreste (Hooi-groep), (iii) Groep 3 — die koeie is alleenlik op veld aangehou (Veldgroep) en (iv) die kontrole. Data is oor 'n periode van nege jaar, vanaf 1982 tot 1990, versamel. Die GLM prosedure van SAS is vir analise van die data gebruik. Die toevallige effek van vaar van kalf was vir alle kenmerke hoogs betekenisvol ($P < 0.01$). Die geboortemassas, speenmassas en massatoenames van geboorte tot speen, was hoogs betekenisvol ($P < 0.01$) minder vir die kuilvoergroep kalwers. Daar was geen betekenisvolle verskil ten opsigte van geboortemassa, speen-massa en die massatoename van geboorte tot speen tussen Groepe 2 en 3 gevind nie. Die gekombineerde massatoename van die koeie en kalwers vanaf geboorte tot speen van Groep 3 was betekenisvol ($P < 0.05$) groter as vir Groep 2.

Keywords: Beef cattle, birth mass, environmental effects, gain, genetic effects, weaning mass.

* Author to whom correspondence should be addressed.

Introduction

Weaner production forms the backbone of beef production in most of the ranching areas of South Africa (Van Zyl *et al.*, 1992). Obviously the viability or profitability of most beef enterprises depends primarily on herd fertility and the birth of strong healthy calves. Furthermore, efficiency of production depends on a relatively high weaning mass (Harvin *et al.*, 1966; Venter *et al.*, 1980). Efficient cattle, performing well under local production systems, result in relatively lower management costs per unit produced. Although cattle should be able to adjust to the environment to be productive (Dowling, 1981), it is unrealistic to assume that cattle of the same breed (genotype) will perform at the same level under different environmental conditions (Swanepoel & Heyns, 1988).

Various management systems, from intensive to extensive, are adopted during the winter on the Transvaal Highveld. To optimize the use of available genetic material through matching genotypes with environments, one must consider the constraining resources before making any recommendations (Armstrong *et al.*, 1990).

The known genetic and environmental sources, including sire of calf and the winter management system, which contribute to the variation in production traits, were investigated. The traits under consideration were: birth mass, weaning mass, mass gained by calf from birth to weaning (Gain 1) as well as the combined mass gained by the cow plus her calf from birth to the weaning of the calf (Gain 2).

Materials and Methods

Environment

Data were collected at the Highveld Region Agricultural Development Institute (27°00′ E, 26°45′ S) in the Western Transvaal from 1982 to 1990. The average rainfall for this area is 600 mm per annum. The average grazing capacity, on veld, of the experimental farm is 6 ha/large stock unit.

Animals

Simmentaler cattle of the Highveld Region Agricultural Development Institute were used to study the genetic and environmental influences on birth mass, weaning mass and the mass gain from birth to weaning. During the winter the herd was divided into four groups. The first three groups were divided into: (i) an intensive management system, where the animals were kept in feedlots during the winter and fed maize silage (Silage group),

(ii) a semi-intensive system, where animals were kept on maize crop residues, *Digitaria eriantha* Steud. foggage as well as on *Digitaria eriantha* Steud. hay during the winter (Hay group), and (iii) an extensive system, where the animals were kept on veld for the duration of winter (Veld group). The fourth group of cattle (Control group) was a component group, used in mineral supplement trials, and was kept on veld as well as on *Digitaria eriantha* Steud. foggage during the winter. All the cows grazed on veld during the summer. Twenty per cent of the cows were replaced by pregnant heifers annually. In the silage group, the heifers were mated at 13 – 15 months of age, and in the other three groups at the more commonly used 25 – 27 months of age. The breeding season for all heifers was from 20 November to 2 January and for all cows from 10 December to 10 February annually. Thirty cows were allocated to each bull. All bulls were brought in from outside the herd and were kept for a maximum of three years. The bulls were randomly used in all four groups. All the animals received the same dosing, dipping and inoculation treatments. Calves were weaned as close as possible to the 5th of May every year.

Recording procedure

The following data were recorded for each calf born from 1982 to 1990: sire of calf, year and month in which calf was bom, sex of calf, wintering treatment, inter-calving period (ICP) of the dam, the production status of the dam for the year $n - 1$ (n = year of calf's birth), the body condition score of the cow at calving, dam age, dam mass at birth of her calf, birth date, birth mass, 100-day mass, dam mass at weaning and weaning mass.

Statistical procedure

The General Linear Model (GLM) procedure of SAS (1985) was used to analyse the data. The random effect, sire of calf; fixed effects: year, sex of calf, wintering treatment (groups) and month of birth as well as the linear and quadratic regressions of weaning age of calf, cow mass and cow age at birth were included in the models for all traits. The final operational models for each trait included effects making a significant ($P < 0.05$) contribution to the variance only. Because of the number of effects involved, the complexity and the unbalanced nature of the data, no higher-order interactions were included in the model.

The final models derived were:

$$Y_{ijklmn} = \mu + S_i + Y_j + M_k + X_l + T_m + bW + bA + bD + e_{ijklmn}$$

Where:

Y_{ijklmn} = observation on the n^{th} calf subjected to the m^{th} management system of the l^{th} sex born in the k^{th} month in the j^{th} year for sire i,

μ = population mean of the trait,

S_i = random effect of the i^{th} sire (i = 1, ... 40),

Y_j = effect of the j^{th} year of measurement (j = 1, ... 9),

M_k = effect of the k^{th} month of birth (k = 1,2,3),

X_l = effect of the l^{th} sex of calf (l = 1,2),

T_m = effect of the m^{th} management system (m = 1,2,3,4),

bW = linear regression of the appropriate deviation from the mean of individual age at weaning (in the model for weaning mass),

bA = linear regression of the appropriate deviation from the mean of individual age of dam at birth of the animal (in the models for weaning mass, Gain 1 and Gain 2),

bD = linear regression of the appropriate deviation from the mean of individual mass of dam at birth of the animal (in the models for birth mass, weaning mass and Gain 1) and,

e_{ijklmn} = random error.

Results and Discussion

Although sires appear to be allocated randomly to management systems, the random effect of sire influenced all the traits significantly ($P < 0.01$) (Table 1). This is an indication that the use of mixed model methodology should always be considered in an analysis of this kind. A significant ($P < 0.01$) regression of dam age at birth on the mass of the dam at birth was found, but the R^2 of the regression was 0.068 and it was decided that both parameters could be included in the model.

Birth mass

The random effect of the sire of the calf was significant at a significance level of $P < 0.01$. The effect of age of the dam at calving was not significant on birth mass of the calf when the mass of the dam at birth of the calf was included in the operational model. All the management systems, except for the control, differed significantly ($P < 0.05$) from one another. The silage group

Table 1 Analysis of variance for birth weight, weaning weight, Gain 1 and Gain 2

	Birth mass		Weaning mass		Gain 1		Gain 2	
Source	*df*	*F*	*df*	*F*	*df*	*F*	*df*	*F*
Sire	39	3.89**	39	3.50**	39	2.81**	39	2.10**
Year	8	8.34**	8	23.04**	8	30.15**	8	46.10**
Month	2	36.63**	2	5.69**	2	232.31**	2	46.60**
Sex	1	114.73**	1	229.81**	1	155.45**	1	55.37**
Manage.system	3	16.27**	3	12.80**	3	8.86**	3	12.29**
Weaning age	–	–	1	107.94**	–	–	–	–
Dam age at birth	–	–	1	24.78**	1	34.08**	1	5.67*
Dam mass at birth	1	131.49**	1	287.75**	1	201.39**	–	–
R^2 =	0. 347		0.538		0.508		0.405	

* = ($P < 0.05$); ** = ($P < 0.01$)
Gain 1 = gain of the calf from birth to weaning
Gain 2 = gain of cow plus calf from birth to weaning

Table 2 The significant differences between the various management system groups for all traits investigated

	Birth mass	Weaning mass	Gain 1	Gain 2
Silage group vs. rest	**	**	**	**
Hay group vs. rest	**	*	*	–
Veld group vs. rest	**	**	**	**
Control vs. rest	–	–	–	–
Silage vs. Hay	**	**	**	**
Silage vs. Veld	**	**	**	**
Silage vs. Control	*	**	–	–
Hay vs. Veld	–	–	–	–
Hay vs. Control	–	–	–	–
Veld vs. Control	**	–	*	**

* = $P < 0.05$ significance level; ** = $P < 0.01$ significance level
Gain 1 = gain of the calf from birih to weaning
Gain 2 = gain of cow plus calf from birth to weaning

differed highly significantly ($P < 0.01$) from Groups 2 and 3 for all traits investigated, and significantly ($P < 0.05$) from the control for birth mass (Table 1 & 2). The mean birth mass of all the calves in the maize silage group was lower (Table 3) than those of the other three groups. It is important to note that all the heifers of the silage group were mated at 13 – 15 months of age. Scholtz *et al.* (1991) found that the mean birth mass of the progeny of a group of heifers mated at 13 – 15 months of age, was significantly lower than that of a group of heifers mated at 25 – 27 months of age. A further possible explanation may be the higher stress levels experienced by animals in the feedlots. There were no significant differences between the hay and the veld groups as well as between the hay group and the control, but the veld group differed significantly ($P < 0.01$) from the control.

Weaning mass

The random effect of the sire of the calf was significant at a level of $P < 0.01$. The silage group and the veld group differed highly significantly ($P < 0.01$) from the rest. The silage group differed highly significantly ($P < 0.01$) from the hay, the veld and the control groups (Table 2), and the mean weaning mass of the silage group was lighter than those of the hay, veld and control groups (Table 3). This is also in accordance with the findings of Scholtz *et al.* (1991). They found that heifers mated at the age of 13 – 15 months weaned lighter calves than heifers mated at 25 – 27 months, and that this effect remained throughout their productive life. The main reason for the differences in weaning mass of the early calving silage group heifers seems to be a lower milk production owing to reduced udder development (Scholtz *et al.*, 1991). The hay group differed significantly ($P < 0.05$) from the rest, but did not differ from either the veld group or the control. The control did not differ from the rest and did not differ from the veld group (Table 2). The differences in weaning mass are possibly an effect of the birth mass differences. It is known that birth mass is genetically controlled, subject to environmental influences (Dowling, 1981) and that birth mass and post-partum growth are positively correlated (Smith *et al.*, 1988). Reynolds *et al.* (1990) calculated that a one-kilogram increase in birth mass increased weaning mass by 1.4 kg.

Table 3 Least Square means for birth weight, weaning weight, Gain 1 and Gain 2

	Birth mass	Wean mass	Gain 1	Gain 2
Management system	kg ± *SE* of estimate	kg ± *SE* of estimate	kg ± *SE* of estimate	kg ± *SE* of estimate
Silage group	38.71 ± 0.31	242.90 ± 1.51	197.70 ± 1.51	204.54 ± 2.71
Hay group	40.65 ± 0.31	251.85 ± 1.50	204.78 ± 1.51	216.04 ± 2.69
Veld group	41.02 ± 0.30	252.73 ± 1.46	205.76 ± 1.46	223.30 ± 2.62
Control	39.80 ± 0.39	249.14 ± 1.93	200.63 ± 1.92	212.95 ± 3.42

Gain 1 = gain of the calf from birth to weaning
Gain 2 = gain of cow plus calf from birth to weaning

Gain 1

Gain 1 represents the gain of the calf from birth to weaning. The random effect of sire of calf was significant at a level of $P < 0.01$. The silage and veld groups both differed highly significantly ($P < 0.01$) from the rest, but the hay group, is well as the control, did not differ from the rest (Table 2). The calves of the hay and veld groups showed a significantly ($P < 0.01$) better gain than the silage group, but the silage group did not differ from the control. The hay group did not differ from either the veld group or the control, but the veld group gained significantly ($P < 0.05$) more weight than the control. The least square means of Gain 1 for all the groups are given in Table 3.

Gain 2

Gain 2 represents the combined gain of the cow and the calf from birth to weaning. Again, the random effect of sire of calf was significant at a level of $P < 0.01$. Only the silage and veld groups differed highly significantly ($P < 0.01$) from the rest of the groups (Table 2). The silage group gained significantly ($P < 0.01$) less mass than the hay and veld groups and significantly ($P < 0.05$) less than the control . The silage group cows had difficulty in adapting to the pastures after spending the winter in the feedlots and showed a mass loss before they started to gain. The hay group gained significantly ($P < 0.05$) less mass than the veld group, but did not differ from the control. The veld group gained significantly ($P < 0.01$) more mass than the control. The least square means of Gain 2 for all the groups are given in Table 3.

Conclusions

Because random effect of the sire influenced all the traits significantly ($P < 0.01$), it is concluded that the random effect of the sire of the calf should always be included in an analyses of this kind. The value of mixed model analysis should therefore not be limited to genetic evaluations.

Although the veld group seems to be the most productive for all traits investigated, it must be noted that the maize silage (Group 1) and the foggage and hay (Group 2) groups were not fed *ad libitum*. An economic evaluation of the three management systems indicated that the gross margin per hectare for all three systems for the nine years are almost the same and that they fluctuate according to the year's climate (Genis, 1989).

Acknowledgements

We thank the Director, Highveld Region Agricultural Development Institute, for making the data available, as well as L.M. Vermaak, C.B. Visser, N. Barrie and the Pasture Science division of the Highveld Region.

References

ARMSTRONG, S.L., WILTON, J.W., PFEIFFER, W.C. & SCHAEFFER, L.R., 1990. Influence of variations in biological and economical parameters on beef production net returns. *J. Anim. Sci.* 68, 1857.

DOWLING, D.F., 1981. Effect of environment on birth weight in cattle. Proc. of the 9th Int. Biometeor. Congress, 148.

GENIS, A.J., 1989. Die invloed van verskillende voedingsstrategieë op die biologiese en ekonomiese doeltreffendheid van vleisbeesboerdery in die somerreënsaaigebied. Ekonomiese evaluasie 1986/1987. Departement Landbou-Ontwikkeling (Finale verslag).

HARVIN, G.O., FOURIE, P.C. & LOMBARD, J.H., 1966. Factors influencing efficiency and gross return under intensive beef production systems. *Proc. S. Afr. Soc.Anim. Prod.* 5, 147.

REYNOLDS, W.L., URICK, J.J. & KNAPP, B.W., 1990. Biological type effects on gestation length, calving traits and calf growth rate. *J. Anim. Sci.* 68, 630.

SCHOLTZ, M.M., LOMBARD, P.E. & ENSLIN, C.B., 1991. A note on early calving of beef heifers. *S. Afr. J. Anim. Sci.* 21, 206.

SMITH, A., PAUW, D.A. & WILKE, P.I., 1988. Invloed van geboortemassa op die voorkoms van distokie in die Noord-Transvaalse Bosveld. *S. Afr. J. Anim. Sci.* 18, 168.

SAS, 1985. SAS User's Guide. Carey, Norih Carolina.

SWANEPOEL, F.J.C. & HEYNS, H., 1988. Die invloed van ouderdom en produksiestatus van Afrikaner- en Herefordkoeie op die eienskappe van hul speenkalwers. *S. Afr. J. Anim. Sci.* 18, 47.

VAN ZYL, J.G.E., SCHOEMAN, S.J. & COERTZE, R.J., 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., ELOFF, H.P. & LÜDEMANN, F., 1980. The efficiency of Afrikaner, Bonsmara, Simmentaler and Hereford cattle in a subtropical environment. *Int. J. Biometeor.* 24, 149.