Relationship between production performance, visual appraisal and body measurements of young Dorper rams

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Abstract
The body measurements of 433 young Dorper rams participating in the Free State and Northern Cape veld-ram projects were correlated with their production performance. These measurements included a selection index, body weight (kg), average daily gain (g/day) and scrotal circumference (cm). The performance of the animals in the two projects compared well, although the means in the Free State project were slightly higher. A high phenotypic correlation (0.80) was found between heart girth (cm) and body weight (kg) and a correlation of 0.76–0.79 was found between body length and body weight. Heart girth had the most significant influence on all growth parameters. Shoulder height, which is regarded as a good indicator of frame size, had medium correlation (0.55–0.58) with body weight and low-medium (0.28–0.36) correlation with selection index. The later maturing animals do not, therefore, necessarily perform better than the early maturing ones. Low correlations (0.04–0.11) were found between coat type and the selection index and between masculinity (0.27–0.28) and selection index. The correlation between canon bone circumference and the selection index (0.41–0.45) was higher than the correlation (0.23–0.33) between canon bone circumference and canon bone length. Scrotal circumference had low to medium correlations with growth parameters.

Keywords: Body measurements, visual appraisal, post-weaning growth, Dorper sheep
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Introduction
Body size and body shape of rams can be described, using measurements and visual assessments. How these measurements of size and shape relate to the functioning of the individual is of paramount importance in livestock production. Therefore, constant checks on the relationships between body measurements and performance traits are vital in selection programmes (Maiwashe, 2000).

The Dorper is a synthetic sheep breed developed in South Africa from a cross between the Dorset Horn and Black Head Persian sheep breeds, and arose from a need for a sheep breed suitable for the production of slaughter lambs under the adverse conditions of the arid regions of the country (Cloete & De Villiers, 1987; Neser *et al.,* 1995; Cloete *et al*., 2000). In terms of numbers, the Dorper is the second largest sheep breed in South Africa, and, therefore, has a major impact on slaughter lamb production in the country. The objective of this investigation was to determine the relationship between the growth performance of young Dorper rams under extensive conditions and their body measurements, as well as to quantify factors affecting body measurements.

Materials and methods
Four hundred and thirty-three Dorper rams (4–6 months of age) participating in either the Free State (FS) (n = 177) or Northern Cape (NC) (n = 256) veld-ram projects were used in the investigation. The data of the projects were analysed separately and all the animals in the respective projects were subjected to the same conditions and were performance tested for growth traits (extensively) for approximately 160 d.

The following parameters were recorded at the end of the trial:

i. Body weight (kg) following a 12-h fasting period;
ii. Selection index where equal economical weights were placed on average daily gain (ADG) and final live weight;
iii. Average daily gain (g/day);
iv. Shoulder height (cm), measured vertically from the thoracic vertebrae to the ground;

v. Shoulder width (cm), determined with the aid of a calliper, as the horizontal distance between the processes on the left shoulder and those on the right shoulder blade;
vi. Body length (cm) as measured from the sternum (manubrium) to the aitchbone (tuber ischiadicum);
vii. Heart girth was measured with a measuring tape around the chest just behind the front legs;
viii. Chest depth was measured from the spianus process to the xyfoid process of the sternum;
ix. The diameter (cm) of the canon bone (metacarpus) measured in the middle of the right foreleg between the knee and the pastern;
x. The length of the metacarpus (cm) measured from the proximal to the distal epiphysis;
xi. Hind quarter width was measured as the distance between the left and right thurl;
xii. Scrotal circumference (cm) was measured at the widest point of the scrotum;
xiii. Coat type was categorised as woolly, mixture of hair and wool and hairy;
xiv. Masculinity (secondary masculinity traits) was scored on a 10 point scale;
xv. Scrotal appearance (length, size, attachment) was scored on a 10 point scale;
xvi. Wedge shape from the side was scored on a nine point scale;
xvii. Skin thickness was measured with a calliper on the hairy surface between the brisket and the left foreleg.

Data were analysed using the General Linear Model procedures of SAS (1989). Product moment correlations between the different variables were calculated. A stepwise regression was carried out to determine the individual influence of body measurements on performance. A significant level of $P < 0.10$ was used to determine the significance of the partial contribution of each effect. Starting weight and age were included as covariates.

Results and Discussion

Body weight is a frequently recorded variable in animal research. It is the measurement most used to evaluate growth (Otte *et al.,* 1992). Although it is an important indicator of growth, it fails to indicate the body composition of the animals. Other measurements most commonly used in cattle include heart girth, wither height and body length. However, heart girth is generally accepted as the single most reliable variable (Benyi, 1997) for growth. Swanepoel (1984) regarded wither height as a good indication of growth in cattle. Another important body measurement is scrotal circumference which is an indicator of testicle size. It is highly correlated with sperm production (Hoogenboezem, 1995), an easy parameter to measure and is highly repeatable with a heritability estimate of 0.26 (Meyer *et al*., 1990).

In Table 1 the mean, standard deviation and coefficient of variation (c.v.) of the variables in the NC and FS projects are presented.

Table 1 Mean, standard deviation (s.d.) value and coefficient of variation (c.v.) of parameters measured at the end of the trials

Parameter	Free State		Northern Cape	
	Mean± s.d.	c.v. (%)	Mean± s.d.	c.v. (%)
Body length (cm)	71.8 ± 2.5	3.5	70.9 ± 2.3	3.3
Body weight (kg)	57.5 ± 7.0	12.1	50.8 ± 5.7	11.3
Shoulder height (cm)	63.7 ± 2.6	4.1	62.9 ± .8	4.5
Shoulder width (cm)	24.1 ± 1.7	6.8	23.21 ± 1.6	6.7
Heart girth (cm)	92.8 ± 5.0	5.4	88.3 ± 4.2	4.8
Hindquarter width (cm)	26.6 ± 1.7	6.3	25.3 ± 1.4	5.7
Canon bone circumference (mm)	10.3 ± 0.6	5.8	10.2 ± 0.5	5.1
Canon bone length (mm)	13.0 ± 0.7	5.1	12.3 ± 0.5	3.8
Scrotal circumference (cm)	33.0 ± 2.3	6.8	32.1 ± 2.4	7.5
Skin thickness (mm)	3.1 ± 0.4	13.7	3.1 ± 0.4	13.1
	n = 177		n = 256	

Table 2 Phenotypic correlations between parameters in Dorper rams in the Northern Cape (below diagonal) and Free State (above diagonal) veld-ram projects

VARIA-BLE	BL	SH	SW	CD	HW	CBL	CBC	HG	ST	CT	M	SA	WS	SC	BW	ADG	SI
BL		0.5539	0.5353	0.6972	0.4901	0.3125	0.5336	0.6326	0.2563	0.1504	0.4982	0.2427	0.4067	0.3408	0.7901	0.1503	0.4141
SH	0.5704		0.2581	0.4480	0.3370	0.3959	0.3746	0.4250	0.2958	0.1657	0.2770	0.1616	0.2665	0.2202	0.5529	0.0738	0.2785
SW	0.4919	0.3456		0.5226	0.4476	0.1831	0.4954	0.6687	0.1670	0.1146	0.4321	0.2049	0.2075	0.2662	0.6482	0.1304	0.3512
CD	0.6026	0.4910	0.4123		0.5393	0.4299	0.5388	0.7581	0.2186	0.2150	0.4894	0.2543	0.3997	0.3421	0.7864	0.1041	0.4099
HW	0.3397	0.2086	0.4392	0.3181		0.2973	0.4520	0.5007	0.0364	0.1009	0.3713	0.1370	0.1937	0.1535	0.5909	0.2153	0.4173
CBL	0.3830	0.4416	0.2705	0.4339	0.2568		0.3720	0.3602	0.1470	0.0919	0.0676	0.0027	0.1356	0.1720	0.4237	0.1173	0.2337
CBC	0.4043	0.2682	0.2949	0.3481	0.2501	0.5020		0.5486	0.2963	0.0697	0.4389	0.0187	0.2681	0.1375	0.6537	0.2421	0.4459
HG	0.6245	0.4661	0.5834	0.6701	0.4545	0.4177	0.4614		0.1829	0.3513	0.4616	0.1530	0.3175	0.2590	0.8004	0.1355	0.4302
ST	0.1987	0.1195	0.1255	0.2327	0.1624	0.0506	0.1510	0.2665		0.1106	0.1703	-0.1378	0.1254	-0.0127	0.2525	0.1464	0.1959
CT	0.0920	0.0678	0.0121	0.0947	0.0647	0.0784	0.0162	0.0568	0.1781		0.1901	0.1772	0.1772	0.0595	0.2255	-0.1176	0.0397
M	0.3669	0.2241	0.3893	0.2886	0.2965	0.2160	0.2812	0.4222	0.1673	0.0345		0.3193	0.5176	0.3160	0.5419	0.0634	0.2849
SA	0.3624	0.2353	0.3041	0.3259	0.2965	0.2160	0.2812	0.3394	0.1396	-0.0466	0.6207		0.3262	0.5826	0.2560	-0.0352	0.0373
WS	0.2630	0.2087	0.1436	0.1417	0.1420	0.0062	0.2266	0.2905	0.1670	0.0627	0.4660	0.3380		0.2410	0.3401	-0.0675	0.0446
SC	0.3624	0.2353	0.3041	0.3259	0.3002	0.2830	0.2667	0.4795	0.1512	0.0506	0.4460	0.5587	0.2230		0.3671	0.0560	0.1840
BW	0.7556	0.5875	0.6148	0.6938	0.4864	0.4772	0.4628	0.7993	0.2193	0.1157	0.4202	0.2918	0.3125	0.5014		0.3110	0.6160
ADG	0.1143	0.0910	0.1253	0.1319	0.1055	0.1424	0.2207	0.2708	0.1376	0.0922	0.0904	0.1234	0.0464	0.1585	0.2841		0.8742
SI	0.0483	0.3588	0.3965	0.4448	0.3195	0.3336	0.4132	0.5944	0.2086	0.113	0.2737	0.2259	0.1846	0.3596	0.6847	0.8423	

Body length (BL), shoulder height (SH), shoulder width (SW), chest depth (CD), hindquarter width (HW), canon bone length (CBL), canon bone circumference (CBC), heart girth (HG), skin thickness (ST), coat type (CT), masculinity (M), scrotal appearance (SA), wedge shape (WS), scrotal circumference (SC), body weight (BW), average daily gain (ADG) and selection index (SI).

The measurements in the two projects compared well, although the means in the Free State project were in general slightly higher than those in the Northern Cape project. The high c.v. for skin thickness is surprising. A possible reason could be that the measurement of skin thickness in small stock is extremely difficult. The high c.v. for body weight was expected, since the initial weight of the rams varied between 30 and 54 kg. In Table 2 the product moment correlations between parameters in the NC and the FS veld-ram projects are presented.

The highest correlation of 0.80 ($P < 0.001$) in both projects was found between heart girth and body weight. This correlation was even higher than the correlation between body length and body weight (NC = 0.76, $P < 0.001$; FS = 0.79, $P < 0.001$). Campbell (1983) reported correlations of 0.72 between heart girth and body weight and a correlation of 0.74 between body length and body weight. Shoulder height, which is regarded as a good indicator of frame size (Vargas *et al.,* 1998) had high-medium correlations with body weight (NC = 0.59, $P < 0.001$; FS = 0.55, $P < 0.001$) and low-medium correlations (NC = 0.36, $P < 0.05$; FS = 0.28, $P < 0.05$) with the selection index. In this trial, however, the later maturing animals did not necessarily perform better than the early maturing types. A small body size may have very important biological advantages for adaptation to climate, feed resources, seasonal grazing and marketing (Dickerson, 1978). Larger animals normally grow faster, but will take longer to reach the same stage of maturity as smaller animals and will consume more food than smaller animals (Schoeman & De Wet, 1993). Bosman (1997) reported low correlations between body measurements (height, length and scrotal circumference and ADG in cattle.

Amongst all the body measurements, the highest correlation was found between heart girth and selection index. The selection index is regarded as the most important indicator of growth in the projects. The low correlation between coat type and performance (FS = 0.04, $P > 0.05$; NC = 0.11, $P > 0.05$) indicates that there was no difference in the growth ability of animals with hair, a mixture of hair and wool, and wool. These findings are in agreement with Snyman & Olivier (2002). The skin thickness of animals with the specified coat types did not differ ($P > 0.05$). Canon bone circumference was higher correlated with selection index than with canon bone length. There has been considerable interest in canon bone length since the 1930's. Canon bone length relative to body size was identified as an indicator of an individual's rate of approach to maturity (Meyer, 1995).

Table 3 Partial contribution of factors to growth parameters (in top row) in the Northern Cape veld-ram project (n = 256)

	Body Weight	Average Daily Gain	Selection Index	Scrotal Circumference
Body length	0.130	NS	0.070	NS
Shoulder height	0.005	NS	NS	NS
Shoulder width	0.011	NS	NS	NS
Chest depth	0.007	NS	NS	NS
Hindquarter width	0.005	NS	NS	NS
Canon bone length	0.010	NS	0.070	NS
Canon bone circumference	NS	0.060	0.033	NS
Heart girth	0.767	0.437	0.777	0.025
Skin thickness	NS	NS	NS	NS
Coat type	NS	0.057	0.015	NS
Masculinity	NS	NS	NS	0.206
Scrotal appearance	NS	NS	0.022	NS
Wedge shape	NS	NS	NS	NS
Scrotal circumference	0.006	NS	NS	NS
Body weight	NS	NS	NS	0.769
Age	NS	0.446	0.085	NS
R^2	0.833	0.168	0.455	0.327

Only the partial contribution of factors significant at the $P < 0.10$ level was listed

Skin thickness and masculinity (indication of the ram's secondary masculinity characteristics such as horns, pleads, scrotum, muscling, bone structure, etc.) had a low correlation with selection index. Scrotal circumference, which is a very important component of masculinity, had a low to medium correlation with growth parameters. Selection for increased scrotal circumference is considered to be an important method of genetically improving the inherent fertility in the herd (Keeton *et al*., 1996). Scrotal circumference is also an important component in examining beef bulls for breeding soundness. Various researchers have indicated that scrotal circumference is genetically and phenotypically correlated with important growth traits and other body measurements used in most selection programmes (Kriese *et al.,* 1991; Keeton *et al.,* 1996). This is, however, in contrast with Maiwashe (2000) who reported correlations close to zero between scrotal circumference and post-weaning ADG in Bonsmara cattle. In Tables 3 and 4 the partial contribution of various factors to growth parameters is presented.

The effects of breeder and breed (Dorper/White Dorper) on body weight were tested, and did not contribute significantly to differences in body weights. Heart girth and body length had the biggest influence on body weight in both projects. Shoulder width, chest depth, age, shoulder height and scrotal circumference also had an influence on body weight in both projects (Tables 3 and 4).

Heart girth yielded the highest partial contribution (0.777 and 0.586) in both projects and was, therefore, the most important contributor to the selection index. Age, body length and canon bone circumference also contributed to the selection index in both projects. It is interesting to note that the four major factors that influenced the selection index in the NC project also had an influence at the FS project, although the importance of factors varied slightly.

Table 4 Partial contribution of body measurements to the model in the Free State veld-ram project (n=177) with dependant variables in the top row and independent variables on the left-hand side

	Body Weight	Average Daily Gain	Selection Index	Scrotal Circumference
Body length	0.167	0.147	0.092	NS
Shoulder height	0.007	NS	NS	NS
Shoulder width	0.034	0.254	NS	NS
Chest depth	0.014	NS	NS	0.583
Hindquarter width	NS	NS	NS	NS
Canon bone length	NS	NS	NS	NS
Canon bone circumference	0.023	NS	0.152	NS
Heart girth	0.741	NS	0.5866	NS
Skin thickness	NS	NS	NS	0.134
Coat type	NS	NS	NS	NS
Masculinity	NS	NS	NS	0.095
Scrotal appearance	NS	NS	NS	NS
Wedge shape	NS	0.258	0.068	NS
Scrotal circumference	0.007	NS	NS	NS
Final body weight	NS	NS	NS	NS
Age	0.010	0.341	0.103	NS
Horns	NS	NS	NS	0.188
R^2	0.846	0.141	0.269	0.196

Only the partial contribution of factors significant at the $P < 0.10$ level was listed

Differences in pre-test treatment could have influenced the ADG and eventually could have contributed to the low R^2 value of the model for ADG. Only masculinity had an influence in both projects as far as scrotal circumference was concerned. In an investigation into the relationship between growth parameters and scrotal circumference in Simmentaler bulls, Swanepoel & Heyns (1986) found that pre-weaning growth had a more significant influence on testicular development than post-weaning growth. The presence of horns had some effect in the rams in the FS project, but was unfortunately not measured in the NC project.

Body weight, body length and canon bone length were the most important factors influencing shoulder height. Body weight also made the biggest contribution to shoulder width, while heart girth and masculinity influenced the shoulder width in both projects. Body weight, chest depth and shoulder width had an influence in both projects. According to Heinrichs & Hargrove (1994) and Mulaudzi (2000) heart girth increases linearly with age in cattle. Different factors had an influence on skin thickness in the two projects. However, very little of the variation could be explained. The very low R^2 was not unexpected due to the difficulty of measuring skin thickness in small stock. The mean of the scores for wedge shape was 4.6, indicating that shape type 5 was representative in most of the animals. Animals with a wedge shape score of 5 were heavier ($P < 0.05$) and longer than the animals with a wedge shape score of 3.

Body length was highly correlated with hearth girth (NC = 0.62, $P < 0.001$; FS = 0.63, $P < 0.001$) and breast depth (NC = 0.60, $P < 0.001$; FS = 0.70, $P < 0.001$) in both projects. Body length also had a medium-high correlation with shoulder height (NC = 0.57, $P < 0.001$; FS = 0.55, $P < 0.001$), shoulder width (NC = 0.49, $P < 0.001$; FS = 0.54, $P < 0.001$) and hindquarter width (NC = 0.34, $P < 0.001$; FS = 0.49, $P < 0.001$). Maiwashe (2000) and Vermeulen (2001) reported high positive correlations of 0.76 and 0.61, respectively between body length and shoulder height. The same tendency, although less dramatic, was observed by Venter (1987) in beef cattle. Shoulder height had a medium correlation with chest depth (NC = 0.49, $P < 0.001$; FS = 0.45, $P < 0.001$) and heart girth (NC = 0.46, $P < 0.001$; FS = 0.43, $P < 0.001$). Shoulder width had a medium correlation with hindquarter width (NC = 0.44, $P < 0.001$; FS = 0.45, $P < 0.001$) and was highly correlated with heart girth (NC = 0.58, $P < 0.001$; FS = 0.67, $P < 0.001$). Chest depth showed the highest correlation with heart girth (NC = 0.67, $P < 0.001$; FS = 0.76, $P < 0.001$). Hindquarter width was also highly correlated with heart girth at (NC = 0.45, $P < 0.001$; FS = 0.50, $P < 0.001$). Canon bone circumference was in general more highly correlated with other parameters than canon bone length and resulted in the highest correlation with body length (NC = 0.40, $P < 0.001$; FS = 0.53, $P < 0.001$). This is not in agreement with Greyling & Taylor (1999) who recorded no significant correlations between canon bone circumference and other body measurements in Dorper lambs. Skin thickness and coat type showed no significant ($P > 0.05$) correlation with any other parameter.

Conclusions

The positive correlation between heart girth and post-weaning growth rate indicates that selection for heart girth could possibly lead to faster growing animals. It may also lead to an increase in shoulder height and a larger frame size, which might lead to reduced adaptability. Venter (1987) reported an increase in ADG of Afrikaner bulls when shoulder height increased. Shoulder height also had a more significant effect on ADG than body length. The low to medium correlation between scrotal circumference and growth parameters indicates that the growth potential and the reproductive ability are not strongly compliant in young performance-tested rams.

In general, large heart girth, body length, width and depth and canon bone circumference were positively related to growth under extensive conditions. This is, however, not a hard and fast rule, as there were animals with all these characteristics that performed poorly. Venter (1987) came to a similar conclusion and reported that high-performing bulls occurred in all frame types, although the larger frame types had the highest percentage of high performers. Body measurements and visual appraisal should, therefore, always be combined with performance test results and breeding values.

Bringing science into the realm of visual appraisal is a challenge. Visual appraisal directed at functional efficiency in a balanced combination with performance test results, breeding values and pedigrees has been a winning combination in the beef cattle industry, and can also be adopted by the Dorper sheep industry.

References

Benyi, K., 1997. Estimation of live weight from chest girth in pure and crossbred West African goats. Trop. Anim. Health Prod. 29, 124-128.

Bosman, D.J., 1997. Body measurements and their application in beef cattle. National Beef Cattle Performance Testing Scheme. Newsletter 79, 9-13.

Campbell, Q.P., 1983. Make money with mutton sheep. Dreyer Printers, Bloemfontein.

Cloete, S.W.P. & De Villiers, T.T., 1987. Production parameters for a commercial Dorper flock on extensive pastures. S. Afr. J. Anim. Sci. 17, 121-127.

Cloete, S.W.P., Snyman, M.A. & Herselman, M.J., 2000. Productive performance of Dorper sheep. Small Rumin. Res. 36, 119-135.

Dickerson, G.E., 1978. Animal size and efficiency: Basic concepts. Anim. Prod. 27, 367-379.

Greyling, J.P.C. & Taylor, G.J., 1999. The effect of the anabolic agent, nandrolone laurate, on certain production and reproduction parameters in ram lambs, under intensive and extensive feeding regimes. S. Afr. J. Anim. Sci. 29, 179-188.
Heinrichs, A.J. & Hargrove, G.L., 1994. Standards of weight and height for Ayrshire, Brown Swiss and Milking Shorthorn heifers. J. Dairy Sci. 81, 1479-1482.
Hoogenboezem, J.M., 1995. Zootechnological aspects of bull fertility evaluation. MSc (Agric) dissertation, University of the Orange Free Sate, South Africa.
Keeton, L.L., Green, R.D., Golden, B.L. & Anderson, K.J., 1996. Estimation of variance components and prediction of breeding values for scrotal circumference and weaning weight in Limousin cattle. J. Anim. Sci. 74, 31-36.
Kriese, L.A., Bertrand, J.K. & Benyshek, L.L., 1991. Age adjustment factors, heritabilities and genetic correlations for SC and related growth traits in Hereford and Brangus bulls. J. Anim. Sci. 69, 478-489.
Maiwashe, A.N., 2000. The value of recording body measurements in beef cattle. MSc (Agric) dissertation, University of the Orange Free Sate, South Africa.
Meyer, K., 1995. Estimates of genetic parameters for mature weight of Australian beef cows and its relationship to early growth and skeletal measures. Livest. Prod. Sci. 44, 125-137.
Meyer, K., Hammond, K., Parnell, P.F., Mackinnon, M.J. & Sivarajasingam, S., 1990. Estimates of heritability and repeatability for reproductive traits in Australian beef cattle. Livest. Prod. Sci. 25, 15-30.
Mulaudzi, J., 2000. An integrated system of growth trait improvement in beef cattle under communal management conditions. MTech (Agric) dissertation, Technikon Free State, South Africa.
Neser, F.W.C., Konstantinov, K.V. & Erasmus, G.J., 1995. Estimated genetic trends for weaning weight in three Dorper lines with different selection criteria. S. Afr. J. Anim. Sci. 25, 65-69.
Otte, M.J., Woods, A.J. & Abuabara, Y., 1992. Live weight estimation of cattle by scale and tape - A method comparison study. Trop. Anim. Health Prod. 24, 109-114.
SAS, 1989. Statistical Analysis System user's guide. (6th ed.). SAS Institute Inc., Raleigh, North Carolina.
Schoeman, S.J. & De Wet, R., 1993. A comparison between female lambs of the Dorper and two synthetic composites with respect to feed intake, growth and efficiency. S. Afr. J. Anim. Sci. 23, 4-12.
Snyman, M.A. & Olivier, W.J., 2002. Productive performance of hair and wool type Dorper sheep under extensive conditions. Small. Rum. Res. 45, 17-23.
Swanepoel, F.C.J., 1984. Die verwantskap tussen liggaamsmate en prestasie van Simentalerbulle. MSc (Agric) dissertation, University of the Orange Free Sate, South Africa.
Swanepoel, F.J.C. & Heyns, H., 1986. Relationship between growth parameters and scrotal circumference in Simmentaler bulls. S. Afr. J. Anim. Sci. 16, 218-219.
Vargas, C.A., Elzo, M.A., Chase, C.C., Chenoweth, P.J. & Olson, T.A., 1998. Estimation of genetic parameters for scrotal circumference at puberty in heifers and hip height in Brahman cattle. J. Anim. Sci. 76, 2536-2541.
Venter, F.J., 1987. Die verwantskap tussen liggaamsmates en prestasie van *Bos indicus* en *Bos taurus* bulle. MSc (Agric) dissertation, University of the Orange Free Sate, South Africa.
Vermeulen, S.W., 2001. 'n Kritiese evaluasie van voeromset by Bonsmaraverse. MTech (Agric) dissertation, Technikon Free State, South Africa.