Effect of winter nutritional levels on subsequent growth of beef heifers in the Highland Sourveld of Natal

A. van Niekerk* and R. Kernick
Department of Agriculture and Water Supply, Private Bag X9059, Pietermaritzburg 3200, Republic of South Africa
A.W. Lishman
Department of Animal Science, University of Natal, P.O. Box 375, Pietermaritzburg 3200, Republic of South Africa

Received 11 October 1988; accepted 1 December 1989

The effect of different levels of winter nutrition on the subsequent performance of Simmentaler weaner (seven-month-old) heifers on summer veld at different stocking rates was evaluated in the Highland Sourveld of Natal. The data from 300 heifers over a three-year period were analysed. During their second winter, the heifers were fed to achieve a target mating mass of 330 kg at 26 months of age. The feed cost to achieve a growth rate of 0,5 kg/d during the first winter following weaning was 93% higher than the cost to achieve a growth rate of 0,25 kg/d. On summer veld, heifers run at a low stocking rate of 0,75 LSU/ha (for the grazing period) gained significantly ($P < 0,01$) more mass than heifers subjected to a high stocking rate of 1,25 LSU/ha, irrespective of the previous winter nutritional level. Within each stocking rate, the heifers at a low winter nutritional level gained significantly ($P < 0,01$) more mass on veld than those on the high winter plane of nutrition. Significantly ($P < 0,01$) more compensatory growth occurred during the first half (94 days) of the grazing season. The data suggest that the ability of a beef heifer to achieve compensatory growth on summer sourveld in Natal should be exploited, but that the degree of compensatory growth might be significantly modified by stocking rate. The difference of R73 (at current money value) per head between the lowest and highest feed costs up to the mating stage underlines the importance of selecting the correct rearing strategy for heifers in the sourveld.

Die invloed van verskillende wintervoedingspeile op die prestasie van 300 Simmentalerspeenverse (sewe maande oud) op somerveld, is oor 'n periode van drie jaar ondersoek. Gedurende die tweede winter na speen (as 18-maande-oud diere) is die verse gevoer om 'n dekmassa van 330 kg (op 26 maande) te bereik. Die voerkoste om 'n daaglikse toename van 0,5 kg gedurende die eerste winter na speen te handhaaf, was 93% hoër vergeleke met koste vir 'n toename van 0,25 kg/d. Teen 'n lae veebelading van 0,75 GVE/ha (vir die weiperiode) op somerveld, het verse betekenisvol ($P < 0,01$) meer in massa toegeneem vergeleke met 'n hoë veebelading (1,25 GVE/ha). Binne elk van die veebeladings het die verse op die lae voedingspeil gedurende die eerste winter betekenisvol ($P < 0,01$) meer in massa toegeneem op veld as verse wat teen 'n hoë voedingspeil oorwinter het. Betekenisvol ($P < 0,01$) meer kompensatoriese groei is gedurende die eerste helfte (94 dae) van die weiperiode behaal. Kompensatoriese groei op somerveld is 'n belangrike faktor, maar kan deur hoë veebeladings beperk word. Die verskil van R73 (teen huidige geldwaarde) per vers tussen die hoogste en laagste voerkoste tot en met dekking is 'n bewys van die belangrikheid om die regte grootmaakstrategie vir verse in die suurveld te kies.

Keywords: Compensatory growth, economics, heifers, winter nutrition.

* To whom correspondence should be addressed.

Introduction

Replacement heifers are not generally mated before the age of 24 months because of the extensive nature of the majority of beef enterprises in the Republic of South Africa. Age and mass at which puberty is attained are the most important factors affecting cyclic activity and conception when heifers are bred to calve down at two years of age (Ferrell, 1982). According to Meaker, Coetsee & Lishman (1980), mass at puberty is mainly a function of pre- and post-weaning nutrition. However, because of the time factor and quantity of feed required in the Highland Sourveld of Natal, when heifers are mated to calve down as three-year-olds, the economic implications of the enterprise become vitally important.

Irrespective of whether heifers are mated at 12—14 months or at two years of age, an adequate level of feed is necessary for good performance in their first and subsequent production cycles as cows (Bond & Wiltbank, 1970; Kropp, Stephens, Holloway, Whiteman, Knori & Totusek, 1973; Corah, Dunn & Kaltenbach, 1975). However, whilst winter sweetveld might support young cows during the first and second lactation with little or no supplementary feeding, this is not true for the sourveld areas of Natal. The most efficient and economical feeding levels for heifers and mature cows under different management systems in the Highland Sourveld, remain obscure (Harwin, Lamb & Bisschop, 1967). The solution to these problems becomes increasingly important when viewed in the light of existing information. Undernutrition may result in increased age at puberty (Joubert, 1954; Wiltbank, Kasson & Ingalls, 1969), impaired fertility (Hill, Lamond, Hendricks, Dickey & Niswender, 1970) and reduced milk production during the first lactation (Bond & Wiltbank, 1970). In contrast, overfeeding may result in a decline in breeding efficiency (Arnett, Holland & Totusek, 1971), high calf mortality (Bond & Wiltbank, 1970), decreased mammary gland development (Swanson, 1957) and reduced milk production (Swanson, 1957; 1960).

Some preliminary research has been conducted by Meaker (1976). However, the identification of the most efficient feeding regime to rear replacement heifers, in terms of the livemass gains necessary to achieve acceptable conception rates at the lowest possible cost, is therefore essential to the beef industry in the Sourveld of Natal, and therefore the objective of this study was to investigate means of achieving this goal.

Procedure

The experiment was conducted over three seasons at the Thabamhlope Research Station (near Estcourt in Natal) situated at an altitude of 1 450 m above sea level, within

Bioclimate Area 4e (Phillips, 1973). The mean annual rainfall at the station is 900 mm per annum with about 70% of the rainfall being recorded between November and March. Mean maximum temperatures are 22 °C and the mean minimum temperatures 6 °C.

300 Simmentaler weaner heifers (*ca.* seven months of age) with a mean initial mass of 190,1 kg were used in the experiment. The relatively low post-weaning mass can be ascribed to two factors. Firstly, the size of the dams (mean mass 460 kg), and the mean maximum mass of the calves which was *ca.* 210 kg (45% of the mature cow mass). Secondly, because of the relatively high stocking rates, the calves lost mass towards the end of the grazing season. The 190 kg initial mass is comparable with heifer weaners in the area. The experimental design is diagrammatically illustrated in Figure 1.

The first winter feeding phase (following weaning) was conducted in feed-pens and extended for 104—120 days. No grazing was available in the winter pens. At the end of the winter feeding period the animals were allocated to the summer grazing treatments at three stocking rates, namely, 1,25, 1,0 and 0,75 LSU/ha. These stocking rates were based on an expected grazing period of 210—240 days. On the basis of the initial and expected final summer livemass, a heifer was regarded as 0,7 of a LSU. The target mating mass was 330 kg by mid-October of the second season, when the heifers were 24—25 months of age. By varying the nutritional level during the second winter, the heifers were only allowed to gain the remaining difference between the mass reached at the end of the first summer grazing period and the target mating mass.

The rations fed to the heifers in the winter feed-pens during both winter periods consisted of maize silage and *Eragrostis curvula* hay. During the last of the three seasons, in addition to the silage and hay, the heifers in Treatment 1 received a concentrate consisting of 80% maize meal plus 20% of a commercial protein supplement (69% of protein derived from urea) to achieve the required growth rate. The heifers were weighed fortnightly, following an 18-h starvation period. The quantity of feed was adjusted every two weeks, depending on the animals' performance.

A mineral lick consisting of 50% salt and 50% dicalcium phosphate was available from the beginning of the grazing period (end October) until the 15th of February. A lick consisting of 30% salt, 30% dicalcium phosphate, 25% maize meal and 15% urea was freely available to all the animals between the 15th of February and the end of the summer grazing period.

Animals below 240 kg at the beginning of the second winter feeding period were culled. Such heifers would have had to gain at least 100 kg during the second winter feeding period. Previous research at the Station showed that this level of growth is uneconomical under sourveld conditions.

Summer grazing management was based on a six-camp system. Each camp was grazed for seven days and rested for 35 days.

Analysis of variance was used to test the effect of treatment on mass changes with seasons being used as replicates. The interactions between winter and summer nutritional levels were analysed by multiple regression analyses.

Results

The mean average daily gains (ADGs) of 0,46 (Treatment 1), 0,18 (Treatment 2) and −0,10 (Treatment 3) kg, varied from the projected gains of 0,5, 0,25 and −0,12 kg (Table 1). However, differences in live mass gain

Table 1 Mean mass changes of the heifers fed at three nutritional levels during the first winter post-weaning

	Winter nutritional level		
Projected growth rate (kg/d)	High 0,5 kg ± *SE*	Medium 0,25 kg ± *SE*	Low −0,12 kg ± *SE*
Initial mass (kg)	189,92 ± 15,92	189,80 ± 14,03	190,41 ± 11,56
Final mass (kg)	241,33 ± 19,86	209,77 ± 20,86	179,87 ± 7,61
Mass gain (kg)	51,41	19,97	−10,54
ADG[a] (kg)	0,46	0,18	− 0,10

[a] 113,67 ± 8,51 days.

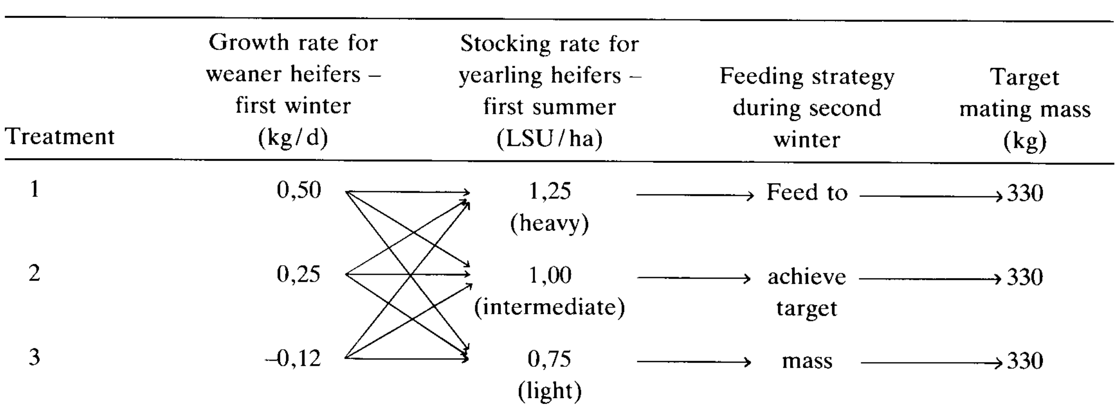

Figure 1 Experimental methodology employed to investigate heifer rearing strategies in the Sourveld.

between the animals over the winter period were sufficient to promote varying degrees of compensatory growth on summer grazing.

The quantities of each ration component fed during the first winter and related costs are summarized in Table 2. The relatively high cost of the rations fed to the heifers gaining 0,5 kg/d (Treatment 1) can partly be ascribed to the cost of the concentrate. However, the inclusion of this component into the ration was necessary to achieve the desired growth rate of *ca.* 0,5 kg/d.

Table 2 Ration components and related costs, per heifer, during the first winter feeding period

Predicted daily gain (kg)	Treatment 1	Treatment 2	Treatment 3
	0,5	0,25	−0,12
Feed consumed (kg DM/d)			
E. curvula hay	1,93 ± 0,11	2,29 ± 0,30	2,62 ± 0,19
Maize silage	2,57 ± 0,21	1,52 ± 0,12	nil
Concentrate	0,95	nil	nil
Urea lick (g/d)	103,00	111,50	122,00
Feed costs[a]			
E. curvula hay	R25,70	R30,50	R34,90
Maize silage	R34,23	R20,25	nil
Concentrate	R36,91	nil	nil
Urea lick	R 2,82	R 3,12	R 3,41
Total	R99,66	R53,87	R38,31

[a] Feed costs based on Agric. Prod. Economics figures – 1989: *E. curvula* hay – R120/t DM; maize silage – R120/t DM; concentrate – R350/t; lick – R250/t.

The mass gains of the heifers on summer veld and final summer live mass at the three stocking rates, are summarized in Table 3. Irrespective of the winter nutritional level, the animals stocked at the low stocking rate (0,75 LSU/ha) gained significantly ($P < 0{,}01$) more mass on summer veld than the heifers subjected to the high stocking rate treatment (1,25 LSU/ha). The differences in mass gain between the low and medium, and medium and high stocking rate treatments were, in most instances, not statistically significant (Table 3).

Within each stocking rate, the heifers at a low winter nutritional level gained significantly ($P < 0{,}01$) more mass on veld than those on the high plane of winter nutrition. However, in an attempt to determine at what stage the compensatory growth occurred during the summer grazing season, the data collected during the last two seasons were further analysed within two specific grazing periods (Table 4).

Within each stocking rate, heifers on the low plane of winter nutrition achieved significantly ($P < 0{,}01$) larger mass gains on veld than those on the high plane of winter nutrition during the first half (94 days) of the grazing season. These data suggest that compensatory growth occurred during the first 94 days of grazing and not over the entire grazing season.

The significance of the compensatory growth is evident from the relationships between winter nutritional level and summer stocking rate as presented in Table 5. The largest correlations were obtained at the low and medium stocking rates, where compensatory growth was possible. The r value of −0,346 (low winter/low stocking rate) and −0,342 (low winter/medium stocking rate) just failed to achieve significance at the 5% level.

Mass gains required during the second winter in order to achieve a mating mass of 330 kg by mid-October are presented in Table 6. These mass gains represent the deficit between the final summer mass (Table 3) and the target mating mass. During the second winter feeding period the heifers were grouped in pens and fed so as to achieve the necessary mating mass. As expected, the heifers wintered on the low plane of nutrition and subsequently stocked at the medium to high stocking rate on summer veld, had to gain the most mass and consequently had the highest feed requirements.

The total feed costs incurred during the first and second winter feed periods are presented in Table 7. Because of a change in feed costs between the different seasons, a cost of R2/kg livemass gain has been used in the analyses for the second winter feeding period (Table 7). This figure is based on the actual feed intakes and calculated on the basis of the costs shown in Table 2. The lowest total feed costs (both winters) were realized by the heifers stocked at the low stocking rate and subjected to a medium plane of nutrition during the first winter. The highest feed costs were incurred by the

Table 3 Mean mass gain and final summer live mass of the heifers at three stocking rates as affected by winter plane of nutrition

	Stocking rate (LSU/ha)					
	0,75		1,0		1,25	
Winter level of nutrition	gain (kg ± *SE*)	final mass (kg)	gain (kg ± *SE*)	final mass (kg)	gain (kg ± *SE*)	final mass (kg)
High (0,5 kg/d)	$78{,}91^{a}$ ± 9,11	319,20	$70{,}94^{ac}$ ± 4,36	305,13	$68{,}60^{bc}$ ± 12,80	298,00
Medium (0,25 kg/d)	$90{,}79^{b}$ ± 10,87	304,71	$79{,}56^{a}$ ± 10,19	291,93	$76{,}16^{ac}$ ± 9,24	279,05
Low (−0,12 kg/d)	$104{,}61^{c}$ ± 14,70	292,36	$91{,}70^{bd}$ ± 12,03	270,14	$83{,}98^{d}$ ± 7,15	260,49

[a—d] Means within rows and columns having one superscript in common do not differ significantly ($P < 0{,}01$).

Table 4 Effect of winter nutritional level on mass gains in heifers on summer veld at three stocking rates

Winter nutrition level	Summer stocking rate (LSU/ha)	Grazing days: Day 1 — 94 mass gain kg ± *SE*	Day 1 — 94 ADG kg ± *SE*	Day 95 — 188 mass gain kg ± *SE*	Day 95 — 188 ADG kg ± *SE*
High	0,75	42,30[a] ± 5,31	0,45 ± 0,05	36,19[a] ± 17,94	0,39 ± 0,19
Medium	0,75	52,17[b] ± 3,32	0,55 ± 0,04	44,15[a] ± 10,68	0,45 ± 0,14
Low	0,75	62,67[c] ± 3,54	0,71 ± 0,09	48,76[a] ± 16,80	0,47 ± 0,18
High	1,0	36,66[a] ± 6,64	0,39 ± 0,07	35,25[a] ± 9,97	0,38 ± 10,11
Medium	1,0	30,48[a] ± 11,96	0,42 ± 0,13	39,95[a] ± 3,32	0,43 ± 0,04
Low	1,0	62,04[b] ± 11,96	0,66 ± 0,13	40,89[a] ± 5,98	0,44 ± 0,06
High	1,25	23,50[a] ± 10,63	0,25 ± 0,11	32,43[a] ± 12,63	0,35 ± 0,13
Medium	1,25	27,26[a] ± 00,00	0,29 ± 0,00	38,55[a] ± 3,98	0,41 ± 0,04
Low	1,25	48,88[b] ± 3,99	0,52 ± 0,04	40,42[a] ± 6,64	0,43 ± 0,07

[a—c] For each stocking rate treatment and within columns, means with different superscripts differ significantly ($P < 0{,}01$).

Table 5 Correlations describing animal performance on different winter nutritional levels and summer stocking rates (pooled data – last two seasons)

Winter nutrition level	Summer stocking rate (LSU/ha)	n	Correlation coefficient	Level of significance	Regression equation[a]
High	1,25	24	r = –0,130	NS[b]	Y = 59,89 – 0,01X
High	1,00	23	r = –0,318	NS	Y = 79,62 – 0,14X
High	0,75	20	r = –0,485	*	Y = 104,12 – 0,60X
Medium	1,25	23	r = –0,208	NS	Y = 71,16 – 0,14X
Medium	1,00	23	r = –0,726	**	Y = 96,24 – 0,64X
Medium	0,75	17	r = –0,611	**	Y = 115,28 – 0,84X
Low	1,25	23	r = –0,071	NS	Y = 85,08 – 0,16X
Low	1,00	24	r = –0,342	NS	Y = 97,91 – 0,42X
Low	0,75	20	r = –0,346	NS	Y = 101,55 – 0,97X

[a] Y = summer gain; X = winter gain.
[b] Non-significant.
* Significant 5% level.
** Significant 1% level.

Table 6 Mass gains required during the second winter feeding period to achieve 330 kg mating mass

Winter nutrition level	Stocking rate on summer veld (LSU/ha): 0,75 kg	1,00 kg	1,25 kg
High	10,80	24,87	32,00
Medium	25,29	38,07	50,95
Low	37,64	59,86	69,51

heifers at the low nutritional level and subsequently subjected to the high stocking rate. The latter heifers were not able to realize any significant compensatory growth because of the high stocking rate. Consequently, a considerable amount of feeding was required during the second winter to reach the target mating mass. The culling rate (< 240 kg by the end of the summer grazing) was generally high in this treatment, with 56% of heifers being culled during the first season.

Discussion

The difference of R72,88 per head between the lowest and highest feed costs up to the mating stage underlines the importance of selecting the correct rearing strategy for heifers in the sourveld of Natal. In a moderately sized beef herd of 200 cows with a replacement rate of 20%, the R73 per head would represent either a saving, or an additional expense of R2 920 in terms of feed costs, depending on the selection of the rearing procedure.

The cost of feeding the heifers on the high plane during the first winter accounted for 82,2% (low SR) —

Table 7 Total feed costs incurred during the first and second winter feeding phases

Winter feed level	1st Winter feed costs	2nd Winter costs SR (LSU/ha) 0,75	1,00	1,25	Total costs SR (LSU/ha) 0,75	1,00	1,25
High	R99,66	R21,60	R 49,74	R 64,00	R121,26	R149,40	R163,66
Medium	R53,87	R50,58	R 76,14	R101,90	R104,45	R130,01	R155,77
Low	R38,31	R75,28	R119,72	R139,02	R113,59	R158,03	R177,33

60,9% (high SR) of the total feed costs (Table 2). In comparison, the first winter feed costs of the heifers fed on the low nutritional plane accounted for 33,7% (low SR) — 21,6% (high SR) of the total feed costs (Table 2). Whilst the inclusion of the concentrate in the ration was necessary to increase the protein intake to a level necessary for a growth rate of 0,5 kg/d (NRC, 1976), it also increased the cost of the ration considerably. The concentrate was in fact the most expensive component of the ration fed to the heifers required to gain 0,5 kg/d and, consequently, the total feed cost of this ration was considerably greater (85%) than the cost of the ration fed to the heifers required to gain 0,25 kg/d.

Although a large proportion of the mass gains obtained during the first few weeks of grazing by the heifers on the low plane of winter nutrition can probably be ascribed to 'gut-fill', compensatory growth over the rest of the season was evident. The inverse relationships between level of winter feeding and subsequent performance on summer veld (Table 5) indicate the ability of the heifers to exhibit compensatory growth. These results are in general agreement with those of Meaker (1976). The precise mechanisms contributing to compensatory growth are still not fully understood. The subject has, however, been comprehensively reviewed by Wilson & Osbourn (1960), Allden (1970) and O'Donovan (1984). In the present study, the degree of under-nutrition could not be described as severe and by the end of the second winter feeding period, where feed was freely available, complete compensation had taken place. Most of the compensation, however, took place during the first 12 weeks of grazing (Table 4). Results from this study are in general agreement with those of Gleeson (1972), Wanyoike & Holmes (1981) and O'Donovan (1984). The significant inverse correlations shown in Table 5 are somewhat lower than the $-0,78$ obtained by Lawrence & Pearce (1964), $-0,75$ to $-0,80$ by McCarrick, Harrington & Conway (1963) and $-0,81$ measured by Wanyoike & Holmes (1981). The non-significance of the correlations for the heifers wintered on the low planes is surprising. It is, however, possible that there may be fundamental differences in response to realimentation between animals fed to maintain mass and those fed to gain mass during the winter (Wilson & Osbourn, 1960). The most significant correlations were obtained at the light, and in one case, intermediate stocking rate. Several researchers (Meyer, Hull, Weitkamp & Bonilla, 1965; O'Donovan, 1972; Horton & Holmes, 1978; Baker, Young & Laws, 1985) have recorded higher feed intakes in cattle during periods of realimentation than would normally be expected. It is therefore axiomatic that if the stocking rate is too high, or the grass is of poor quality and in short supply during the realimentation phase, then complete compensation is not possible. The data do, however, provide sufficient evidence to support the strategy of exploiting compensatory growth on Highland Sourveld as part of a management decision aimed at reducing the cost of rearing replacement heifers. The importance of a sound knowledge of a growing heifer's nutritional requirements and the production characteristics of the natural pasture, cannot be overemphasized.

The combined production and economic data suggest that the optimum strategy for raising heifers in the sourveld would be a low to medium growth rate during the first winter (*ca.* 0,25 kg/d) followed by a stocking rate of about 0,75 LSU/ha on summer veld. The deficit between the final summer live mass and the target mating mass could be corrected during the second winter at a relatively low cost. It should be stressed, however, that the results obtained in this study have been gained by using a six-camp grazing system. Whether similar results could be obtained from a less sophisticated system, and in particular, a continuously grazed system, is open to speculation.

References

ALLDEN, W.G., 1970. The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. *Nutr. Abstr. Rev.* 40, 1167.

ARNETT, D.W., HOLLAND, G.L. & TOTUSEK, R., 1971. Some effects of obesity in beef females. *J. Anim. Sci.* 33, 1129.

BAKER, R.D., YOUNG, N.E. & LAWS, J.A., 1985. Changes in the body composition of cattle exhibiting compensatory growth and the modifying effects of grazing management. *Anim. Prod.* 41, 309.

BOND, J. & WILTBANK, J.H., 1970. Effect of energy and protein on estrus, conception rate, growth and milk production of beef females. *J. Anim. Sci.* 30, 438.

CORAH, L.R., DUNN, T.G. & KALTENBACH, C.C., 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. *J. Anim. Sci.* 41, 819.

FERRELL, C.L., 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. *J. Anim. Sci.* 55, 1272.

GLEESON, P.A., 1972. Effect of plane of nutrition on spring-born calves during their first winter and on their subsequent growth and reproductive performance. *Ir. J. agric. Res.* 11, 31.

HARWIN, G.O., LAMB, R.D. & BISSCHOP, J.H.R., 1967. Some factors affecting reproductive performance in beef females. *Proc. S. Afr. Soc. Anim. Prod.* 6, 171.

HILL, J.R. (jun.), LAMOND, D.R., HENDRICKS, D.M., DICKEY, J.F. & NISWENDER, G.D., 1970. The effects of undernutrition on ovarian function and fertility in beef heifers. *Biol. Reprod.* 2, 78.

HORTON, G.M.J. & HOLMES, W., 1978. Compensatory growth by beef cattle at grassland or on an alfalfa-based diet. *J. Anim. Sci.* 46, 297.

JOUBERT, D.M., 1954. The influence of high and low nutritional planes on the oestrus cycle and conception rate of heifers. *J. Agric. Sci.* 45, 164.

KROPP, J.R., STEPHENS, D.F., HOLLOWAY, J.W., WHITEMAN, J.V., KNORI, L. & TOTUSEK, R., 1973. Performance on range and in drylot of two-year-old Hereford, Hereford × Holstein and Holstein females as influenced by level of winter supplementation. *J. Anim. Sci.* 37, 1222.

LAWRENCE, T.L.J. & PEARCE, J., 1964. Some effects of wintering yearling beef cattle on different planes of nutrition. II. Slaughter data and evaluation. *J. Agric. Sci. (Camb.)* 63, 23.

McCARRICK, R.B., HARRINGTON, D. & CONWAY, A., 1963. The effects of energy restriction between 20—24 months of age on subsequent growth and carcass development of beef cattle. *Ir. J. agric. Res.* 2, 131.

MEAKER, H.J., 1976. The influence of different planes of nutrition during winter on the conception rate of heifers. *S. Afr. J. Anim. Sci.* 6, 21.

MEAKER, H.J., COETSEE, T.P.N. & LISHMAN, A.W., 1980. The effects of age at first calving on the productive and reproductive performance of beef cows. *S. Afr. J. Anim. Sci.* 10, 105.

MEYER, J.H., HULL, J.L., WEITKAMP, W.H. & BONILLA, S., 1965. Compensatory growth responses of fattening steers following various low energy intake regimes on hay or irrigated pasture. *J. Anim. Sci.* 24, 29.

NRC, 1976. Nurient requirements of domestic animals, No. 4. Nutrient requirements of beef cattle. National Academy of Sciences, Washington, DC.

O'DONOVAN, P.B., 1972. Errors associated with expressing pasture intake as dry matter rather than organic matter at high stocking intensities. *J. Agric. Sci. (Camb.)* 78, 97.

O'DONOVAN, P.B., 1984. Compensatory gain in cattle and sheep. *Nutr. Abstr. Rev.*, Series B. 54, 389.

PHILLIPS, J.F.V., 1973. The agricultural and related development of the Tugela Basin and its influent surrounds. *Natal Town and Regional Planning Dept.* No. 19.

SWANSON, E.W., 1957. The effect of fattening dairy heifers upon their growth and lactation. *J. Dairy Sci.* 40, 611 (Abstr.).

SWANSON, E.W., 1960. Effect of rapid growth with fattening of dairy heifers on their lactational ability. *J. Dairy Sci.* 43, 377.

WANYOIKE, MARGARET, M. & HOLMES, W., 1981. The effect of winter nutrition on the subsequent live-weight performance and intake of herbage by beef cattle. *J. Agric. Sci. (Camb.)* 97, 221.

WILSON, P.N. & OSBOURN, D.F., 1960. Compensatory growth after undernutrition in mammals and birds. *Biol. Rev.* 35, 324.

WILTBANK, J.H., KASSON, C.W. & INGALLS, J.E., 1969. Puberty in crossbred and straightbred heifers on two levels of feed. *J. Anim. Sci.* 29, 602.