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INTENSIVE BEEF PRODUCTION ON CULTIVATED
PASTURES IN A SUB-TROPICAL ENVIRONMENT

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ABSTRACT

INTENSIVE BEEF PRODUCTION ON CULTIVATED PASTURES IN A
SUB-TROPICAL ENVIRONMENT

The comparitive performance of spring-calving beef
cowherds comprising either Dual Purpose (Simmentaler) or
British-cross (Hereford x Africaner) cows and calves was
investigated at stocking rates of 3,0, 4,12, 5,34 and 6,74
cows and calves/ha on kikuyu pasture over three seasons. An
increase in stocking rate was associated with a decrease in
the length of the grazing period, an increase in the mass and
condition loss of cows, a decrease in calf livemass gains, a
decrease in milk production, an increase in the production of
beef per hectare and a decrease in margins over feed costs
per cow. Stocking rate did not influence reconception rates,
which averaged 65% over the three seasons. Simmentaler cows
produced calves approximately 2 kg heavier at birth and 24 kg
heavier at weaning, approximately 1,4 litres of milk more per
day, lost more condition and attained higher margins over
feed costs per cow and per hectare than Hereford-cross cows.
Season influenced the length of the grazing season, birth
mass, livemass gains in calves and mass changes in cows. Milk
production accounted for 40% of the variation in calf gains

on pasture. The conversion of milk to calf gain was influenced by milk yield, stocking rate, breed and calf sex.

Ovarian and endocrinological responses associated with normal and restricted suckling for a 15-day period at two postpartum stages (Days 35 to 50 and 60 to 75) were examined in Bos taurus and Bos indicus cows. All cows received progestagen therapy , followed by GnRh administration during the periods of variable suckling intensity. Restricted suckling exerted little influence in Bos taurus cows, but tended to improve the ovulatory response, to decrease the incidence of "short" cycles and to increase reconception rates in Bos indicus cows. Treatment exerted no influence on calf growth and on tonic LH and oestrogen secretion. Bos indicus cows suckled normally released more LH in response to GnRh than Bos taurus cows. Bos indicus cows suckled once daily secreted less LH in response to GnRh than those suckled normally.

Seasonal effects on tonic LH, and progesterone secretion were studied in cycling Friesland cows. Mean tonic LH levels during autumn were significantly higher than those during summer and spring. Season exerted no influence on progesterone secretion.

DECLARATION

I hereby declare that the results contained
in this thesis are from my own origonal work
and have not been previously submitted by me
in respect of a degree at any other university

B. P. Louw

Pietermaritzburg

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ABBREVIATIONS

DH   density hydrometer

FCM   fat-corrected milk

FSH   follicle stimulating hormone

GnRh   gonadotropin releasing hormone

HCG   human chorionic gonadotropin

HPC   high protein concentrate

LH   luteinizing hormone

NPN   non-proteinic-nitrogen

PMSG   pregnant mare serum gonadotropin

RVI   radical veld improvement

SNF   solids-non-fat

CONTENTS

GENERAL INTRODUCTION

An evaluation of future demands for beef in South Africa indicates continued seasonal surplusses over the short term, but an ever-increasing demand with time (Jacobs, 1983). Bold new production strategies will be essential to prevent serious deficits by the turn of the century (Griessel, 1979). There is little doubt that the total demand for beef will increase in future, despite a decrease in per capita consumption over recent years (Lombard, 1977). By the year 2000 the human population is expected to exceed 49 million, of which 70% will be Black (van Marle, 1982) with an anticipated purchasing power considerably greater than at present (Nel, 1981). Lombard (1979) is of the opinion that an annual growth in beef supplies of between four and six percent will be necessary over the long term, in order to meet future demands. Approximately 37 % more beef will be required each year by the end of the century than during the early 1980's (Meissner & Naude, 1982). This increased demand can be met in part by improving the rate of turnover through measures such as feedlotting (Steenkamp, 1979). However, the basic problem facing the South African beef industry over the long term is the supply of an adequate number of weaner calves (Harwin, 1974; Luitingh, 1974; Luitingh & Rudert, 1981). Two important factors, operating at present, seriously impede the possibility of increased weaner production in future. Firstly, the natural veld grazing in the Republic is stocked to capacity, and in many areas overstocking has reduced the

carrying capacity (Tainton, 1981). In the second place, the annual calving percentage in the national beef herd varies between 55 and 60 % (Anonymous, 1981), and this places a severe limitation on potential slaughter material. The application by the industry of improved managerial and technological inputs can contribute substantially to the solution of the problem of inadequate weaner supplies (Edwards, 1966; Venter & Luitingh, 1980). However, as emphasized by Harwin & Lombard (1974), Theron (1975) and Luitingh & Rudert (1981), intensification via the use of radical veld improvement (RVI) techniques in the eastern, high-rainfall areas of the Republic holds the greatest promise as a means of increasing animal numbers. Potential increases in carrying capacity of 400% are possible when natural veld is replaced by established pastures in the Highland Sourveld of Natal (Theron, 1975).

Intensification programmes may be directed at several components of the production process in beef herds. One such component is the raising of young stock after weaning, and its intensification through the use of cultivated pastures has enjoyed considerable attention (Edwards, 1982). In contrast, the use of cultivated pastures for the beef cowherd has received little prominence. This is understandable, in view of the relatively small monetary returns associated with this practice at present (Theron & Harwin, 1983). However, the production of weaner calves off intensive pastures is likely to become essential in order to meet future long-term demands. At present cultivated pastures are extensively used as a roughage source for beef cowherds in various parts of the world, including Europe (Kilkenny & Dench, 1981). The

objective of the investigation to be described was to answer certain pertinent questions associated with intensification programmes in beef suckler herds. These questions related to the type or breed of cow most productive on, and the stocking rate at which maximal monetary returns are obtained on intensively managed pastures. Emphasis was placed on the importance of milk production, since doubt has been expressed concerning its importance as a determinant of calf growth under intensive conditions (van Marle, 1974). The suckling stimulus was studied in detail, since it is known to suppress ovarian function (Wettemann, Turman, Wyatt & Totusek, 1978; Randel, 1981) and it was anticipated that cows grazing intensive pastures would be subject to more suckling activity than those which are less confined, and subjected to more extensive conditions. Finally, seasonal effects on reproductive function were examined, since it has been suggested that all-year mating may be preferable to the use of conventional breeding seasons in highly intensive beef production (Harwin & Lombard, 1974).

CHAPTER 1

THE INFLUENCE OF STOCKING RATE AND BREED ON COW AND CALF PERFORMANCE ON KIKUYU PASTURE

INTRODUCTION

A relatively large area of Natal, and particularly Bioclimatic Group 3 as defined by Philips (1973), is well suited to the cultivation of kikuyu (Pennisetum clandestinum) pasture, and the utilization thereof by the beef herd. The area receives in excess of 800 mm of rain which is favourably distributed throughout the summer months. Mean daily temperatures in excess of 10 °C between October and March further promote pasture growth, providing that soil nutrient deficiencies are corrected (Cross, 1979). Slopes greater than 15% prevent the cultivation of cash crops on a large proportion of the available land. The natural veld grazing is extremely sour, which favours its total replacement by a cultivated dryland pasture such as kikuyu (Edwards,1966). Many farms in the area are too small to provide viable incomes from beef herds maintained on veld grazing alone. The introduction of intensification progammes incorporating the use of kikuyu offers a means of overcoming this problem (Harwin & Theron, 1975).

Well managed kikuyu provides relatively large yields of nutritious grazing from approximately Mid-October until the end of April (Taylor, 1949). Total yields of pasture are largely a function of the amount of nitrogenous fertilizer

applied (Theron & Cross, 1964), and maximum rates of herbage production are normally attained during late December (Cross, 1979). The quality of kikuyu declines during the latter half of the grazing season (Warren, 1972). It is thus well suited to beef cow/calf enterprises in which calving is planned to occur during the spring months. Peak nutritional requirements of the cow during lactation can then be matched with peak yields of pasture during mid-summer. Synchronizing the nutritional requirements of the herd with the available forage flow is a prerequisite for an efficient cow/calf programme (Harwin & Lombard, 1974). However, Theron (1975) has mentioned the possibility of certain pastures providing nutrients in excess of those required by relatively low-producing stock. Experience gained by farmers has also shown that lactating beef cows become overfat when grazing cultivated pastures at relatively light stocking rates, indicating the need for a degree of intake restriction. Consequently, the current study examined the relative performance of cow/calf herds at four stocking rates on kikuyu. An attempt was made to establish the stocking rate at which economical efficiency is maximised.

The utilization of kikuyu by the beef suckler herd represents a major digression from the more traditional use of veld grazing. It is not clear which breed-type is most productive in this relatively intensive environment. Anderson (1978) proposed that the large European beef breeds are best suited to productive grassland, whereas the smaller British breeds are preferable in extensive systems characterized by relatively poor husbandry conditions. Paterson, Venter & Harwin (1980b) suggested that relatively late maturing types may be most productive when kept on pasture and high levels of

nutrition. Harwin & Lombard (1974) reached the same conclusion, but van Marle (1974) proposed that Dual Purpose breeds are less suited to intensive conditions than earlier-maturing, smaller breeds. It may be postulated that Dual Purpose cattle which produce relatively large quantities of milk and "growthy" calves will best express the improved production potential created by established pastures than their British Beef counterparts. However, Dual Purpose breeds might be less efficient than other types, since there are indications of an antagonistic relationship between milk production above a certain level and overall efficiency. Thus, high-yielding Dual Purpose and dairy-type cows may reproduce less efficiently than the lower-yielding British Beef cows (Totusek, Lusby & Stephens, 1974; Holloway, Stephens, Whiteman & Totusek, 1975). Furthermore, data povided by a number of researchers including Johnsson & Morant (1984) indicate that the pre-weaning environment provided by the high-yielding cow can negatively influence the milk production potential of her female offspring. Although calf growth rates are largely dependant on the milk yield of their dams (Gleddie & Berg, 1968; Totusek, Arnett, Holland & Whiteman, 1973), the conversion of milk to calf gain becomes less efficient as milk yields increase above a certain level (Deutsher & Whiteman, 1971; Wyatt, Gould, Whiteman & Totusek, 1977).

The study to be described aimed at resolving the problem of which cattle type will most productively utilize established pasture . The investigation involved a comparison of the performance in general, and milk production in particular, of Dual Purpose and British Beef-type cattle on kikuyu . Emphasis was placed on the relationship between milk

yield and calf gain on pasture, since forage quality might
influence the extent to which calves are dependant on the milk
production of their dams (Holloway, Butts & Worley, 1982).

Two different techniques are commonly used to measure milk
production in beef cows. The calf nursing method involves an
estimation of yield by weighing calves prior to and after
suckling (Mondragon, Wilton, Allen & Song, 1983).
Alternatively, cows are milked following calf separation and
oxytocin administration (Belcher, Frahm, Belcher & Bennet,
1980). The latter method was used in the present study, since
it was considered preferable to obtain an estimate of milk
quality.

PROCEDURE

The performance of spring-calving beef cowherds on kikuyu
was examined during three consecutive summer seasons. The
trial commenced during 1980 and ended during 1983.

Experimental location

The investigation was conducted at the Cedara Research
Station, which is situated approximately 1060 m above sea
level, and latitude $29^{\circ} 32'$ and longitude $30^{\circ}17'$. The area
receives on average 871 mm of rain each year , mainly during
the summer (October to March) months. Summers are hot and
winters cold with frequent frost. The Research Station falls
within Bioclimatic Group 3, as defined by Phillips (1973).

Experimental animals

Two cattle types, namely Dual Purpose and British-cross, were studied. The Dual Purpose type was represented by purebred Simmentalers, and the British-crosses by Hereford x Africaner crossbreds. The proportion of Hereford breeding in the crossbred cows varied from 75 to 87,5%. Simmentaler cows were inseminated with semen of the same breed , and Hereford-cross cows with Hereford semen throughout the course of the trial.

Replacement heifers were mated at approximately 26 months to calve as three-year olds. Cows varied in age from three to 12 years. Cows which failed to conceive during two consecutive breeding seasons were omitted from the trial, as were those which in any one season produced weaners which were 12 % lighter than their group average.

Experimental treatments

Various production parameters were measured in cows and calves subjected to four stocking rates on kikuyu. Groups allocated to each of the stocking rates consisted of a combination of Simmentalers and Hereford-crosses, in order to achieve a breed comparison. A summary of the stocking rates employed over the three seasons is presented in Table 1. Stocking rates were not designed in terms of the number of Livestock Units per hectare, as is common practice in experiments dealing with growing animals on pasture. They were implemented, and are described in terms of cows and calves per

Table 1.   Stocking rates imposed on the cows and calves during the 1980/1981, 1981/1982 and 1982/1983 grazing season.

Stocking rate applied (cows & calves/ha)	Number of cow/calf pairs per treatment		Area of kikuyu allocated per treatment (ha)	
	1980/1981	1981/1982 & 1982/1983	1980/1981	1981/1982 & 1982/1983
3,0	8	16	2,67	5,33
4,12	11	22	2,67	5,34
5,34	10	19	1,87	3,56
6,74	13	24	1,93	3,56
TOTAL	42	81	9,14	17,79

hectare (cows and calves/ha). As far as was possible, and depending on the animals available each season, the proportion of mature cows to first-calvers, and Simmentalers to Hereford-crosses was similar for each of the four stocking rates. The groups were further balanced for initial cow and calf mass, condition score (in cows), calving date and calf sex. Tables 2 and 3 summarize the structures of the different herds used during the study.

Cows and heifers were mated over a 75-day period between 1 November and 15 January. Consequently, calving occurred between 10 August and 31 October each season. The cattle were placed on pasture when, on the advice of Pasture Management Specialists, sufficient material was available to ensure the completion of at least two grazing cycles (56 days) in animals allocated to the heaviest stocking rate, even in the event of no rain falling within this period. The calves were weaned (on a group basis) after having maintained or lost mass over two consecutive weeks. At weaning the calves were removed from, and the cows returned to pasture. Cows remained on grass until the mean pasture height in the series of allocated grazing camps decreased to 2,5 cm or less. Grass height (a measure of pasture availability) was determined by a pasture disc meter (Bransby & Tainton, 1977).

Following the removal of the cows from pasture they were pooled and overwintered to obtain a "target" body condition score of 3,0 at calving. Condition scores were based on a five-point scale (fat = 5, thin = 1; van Niekerk & Louw, 1982). Subsequent to calving all available cows (including those which were dry the previous season) were re-allocated to the different stocking rates for the ensuing grazing season.

Table 2. The number of Simmentaler and Hereford-cross
          cow/calf pairs allocated to the different
          stocking rates each season.

Stocking rate applied (cows & calves/ha)	3,0	4,12	5,34	6,74
Number of cow/calf pairs (both breeds):				
1980/81	8	11	10	13
1981/82	16	22	19	24
1982/83	16	22	19	24
Number of Simmentaler cow/calf pairs :				
1980/81	3	3	3	5
1981/82	9	13	10	10
1982/83	11	6	6	14
Number of Hereford-cross cow/calf pairs :				
1980/81	5	8	7	8
1981/82	7	9	9	14
1982/83	5	16	13	10

Table 3.   Herd structures of groups allocated to the
           different stocking rates each season.

Stocking rate applied (cows & calves/ha)	3,0	4,12	5,34	6,74
Number of cow/calf pairs (both breeds):				
1980/81	8	11	10	13
1981/82	16	22	19	24
1982/83	16	22	19	24
Number of mature cows:				
1980/81	8	11	10	13
1981/82	11	15	13	18
1982/83	13	16	15	19
Number of first-calvers:				
1980/81	0	0	0	0
1981/82	5	7	6	6
1982/83	3	6	4	5
Number of male calves:				
1980/81	4	4	4	7
1981/82	10	14	6	17
1982/83	12	11	9	12
Number of female calves:				
1980/81	4	7	6	6
1981/82	6	8	13	7
1982/83	4	11	10	12

This re-allocation was performed without regard for the treatments imposed on the cows during the previous grazing season.

Two calves died from redwater during the 1982 / 1983 season. Their dams were removed from pasture, and replaced by a reserve cow/calf pair. Measurements obtained in these animals were not included in the analysis of data.

Pasture management

Soil samples were obtained from all camps approximately eight weeks prior to the commencement of the grazing season. Soil phosphorous and potash levels were raised to 20 and 150 parts per million by applying (when necessary) superphosphate and muriate of potash, respectively. These nutrients were applied approximately seven days prior to first grazing. A total of 250 kg of nitrogen (N), split over three dressings of 83 kg each, was applied to each hectare of pasture in the form of limestone ammonium nitrate (LAN). In the event of no superphosphate application prior to the grazing season the first dressing of LAN (during early September) was replaced by an application of ammonium sulphate. The second and third dressings of LAN were applied during early December and mid-February, respectively.

The cattle allocated to each stocking rate were rotated through eight grazing camps. The period of stay was 3,5 and the period of absence 24,5 days. A fixed rotational grazing system, whereby all groups were moved from one camp to another on Monday afternoons (14h00) and Friday mornings (08h00) was

adhered to throughout the grazing season.

The only supplement provided on pasture was a mineral lick. It was fed on an ad lib. basis and consisted of:

> 40 % salt
>
> 40 % dicalciumphosphate
>
> 15 % feedlime
>
> 5 % molasses powder

Animal management

All calves were castrated with a Burdizzo castrator and dehorned with a hot-iron at approximately two months of age. Calves were treated against tapeworms at six weeks of age and at two-monthly intervals thereafter until weaning. Treatment against roundworms was first administered at three months of age, and thereafter at two-monthly intervals until weaning. Cows were treated against roundworms on being removed from pasture each season. The herd was dipped at two-weekly intervals during the summer months (October to April) and at monthly intervals during the remaining months of the year. A series of vaccinations, prescribed by local veterinarians and designed to ensure good herd health, was administered throughout the investigation.

During the breeding season cows and heifers were observed for oestrus in the early morning (05h00 to 07h00) and late afternoon (17h00 to 19h00). Cows in oestrus during the morning were inseminated between 15h00 and 16h30 on the same day, and those on heat during the afternoon were served between 07h00 and 08h00 the following day. Semen was obtained from a local

artificial insemination (AI) co-operative. The allocation of
bulls to the cows and heifers was performed on a random basis.

Winter feeding

During the periods between consecutive grazing seasons the
cowherd initially grazed either maize stover or spared fescue
and kikuyu pastures. Thereafter, they were placed in feeding
pens and fed Eragrostis curvula hay and maize silage,
supplemented with non-proteinic-nitrogen (NPN) licks. Cows
were grouped and fed different quantities of these roughages
in order to obtain the "target" condition score of 3,0 at
calving. After parturition the cows had free access to maize
silage, and in addition each cow received 0,4 kg of High
Protein Concentrate (HPC, 33% protein) every day. A
NPN-mineral lick was also provided on an ad lib. basis.

Feeding of weaner calves

The influence of pre-weaning stocking rate on the
subsequent growth performance of weaner calves over a 88-day
period was examined after the conclusion of the 1981/82
grazing season. The four groups of calves previously subjected
to the different stocking rates were separately fed a ration
consisting of maize silage and a lick concentrate, both fed on
an ad lib. basis. The silage had a dry matter content of
28,7%, and a total digestible nutrients and crude protein
content (as is basis) of 19,2 and 2,3%, respectively. The lick
concentrate was fed separately from the silage, and consisted
of 35% maize meal, 15% urea-free HPC (40% protein), 10% urea,

20% bonemeal and 20% salt. Feeding commenced one week after weaning.

Measurements obtained

Bodymass and body condition

Calves were weighed within 24 hours of birth. Cows and calves were weighed at fortnightly intervals. Between mid-March and weaning the calves were weighed at weekly intervals, in order to accurately establish when the calves ceased gaining mass, and therefore the date of weaning. Food and water was not withheld prior to weighing, which always commenced at the same time of the day (08h00). Body condition scores were obtained at intervals of 30 days.

Milk production

An estimate was obtained of the quantity and quality of milk produced by 79 of the 81 cows during the 1981/82 season. Cows were first milked approximately 30 days after calving, and thereafter at monthly intervals until weaning. The following procedure (Eden, 1970) was used to measure daily yields:

Cattle were removed from pasture at 15h00 on Day 1, that is, the day prior to the one on which yields were measured. Cows and calves were immediately separated, and remained so until the completion of the test. Each cow was restrained in a neck-clamp and injected (iv) with 15 international units of synthetic oxytocin (Ciba Geigy). The udder was immediately

washed with luke-warm water for 30 seconds. The cluster unit of a portable milking machine was then attached until all residual milk was removed. This procedure was performed to "empty out" the udder; immediately thereafter the actual test period of 24 hours commenced. The cows were placed in feeding pens overnight with free access to good quality Eragrostis curvula hay, maize silage and water. At approximately 05h00 and 15h00 on Day 2 the milking procedure described above was repeated. Care was taken to ensure that the cows were milked in the same order at each milking. The number of cows milked at each test did not exceed 13. The milk obtained at each of the two milkings was weighed, and the total mass assumed to represent the daily milk production.

The overnight penning of the cows was performed in preference to allowing the cows to graze in the pasture camps. The latter procedure, which was initially attempted, led to cows frequently breaking out of their grazing camps in an attempt to rejoin their calves. Satter & Bringe (1969) found that milk and fat yields change significantly only five days after an abrupt ration change.

A composite milk sample (approximately 150 ml) was obtained by mixing samples drawn at the morning and afternoon milkings. The volumes of the samples were proportionate to the total quantity of milk produced at each of the milkings . An auto-analyser (N. Foss Electric) was used to measure butterfat, protein and lactose concentrations, and a density hydrometer (DH; BSS 794) was utilized to determine the density of the milk. The solids-non-fat (SNF) content of the milk was calculated by using the following formula (Vanstone & Bristow,1960):

$$SNF(\%) = 0,25(DH\ degrees) + 0,22(Fat\%) + 0,72$$

Milk yields were corrected to a four percent fat basis by using the following formula:

Fat-corrected milk (FCM) yield =

$$(0,4 + 15 \times \frac{Butterfat\ \%)\ Milk\ yield}{100}$$

Lactation curves (from 30 days after calving onwards) were obtained for milk and milk constituent yields of each cow by fitting regression equations to the yields of FCM, protein, lactose and SNF measured at monthly intervals. Quadratic functions provided the best fit to the yields obtained over time in all cows. Cummulative yields over varying periods of time were calculated from the regression equations.

Feed intakes

The quantity of maize silage consumed by the weaner calves subsequent to the 1981/82 grazing season was measured. On each day of the feeding period each group of calves was fed 20% more silage than was consumed the previous day. The unconsumed silage was weighed back on a daily basis. A similar procedure was followed to obtain lick concentrate intakes, although this was performed on a weekly basis.

Meteorological data

Data pertaining to daily maximum and minimum temperatures and
rainfall were supplied by the Meteorological Data Section at
Cedara College.

Statistical analyses

Factors responsible for variation in masses of cows and
calves, condition scores in cows and milk and milk constituent
yields were examined by stepwise multiple regression analyses.
Least squares procedures were used to examine the growth rates
of calves subsequent to weaning during the 1981/82 season. A
chi-squared test was used to examine the effect of stocking on
reconception rates.

RESULTS

Meteorological conditions

The amount and distribution of rain, together with maximum
and minimum temperatures recorded during the study, and the
respective long-term (30-year) averages are diagrammatically
illustrated in Fig. 1. A feature of the climatic conditions
was that annual rainfall was what could be considered below
average during each of the seasons in question. The 1980/81,
1981/82 and 1982/83 seasons received 83,7, 81,3 and 73,7%,
respectively, of the long-term mean seasonal rainfall.
Rainfall was relatively well distributed over the summer
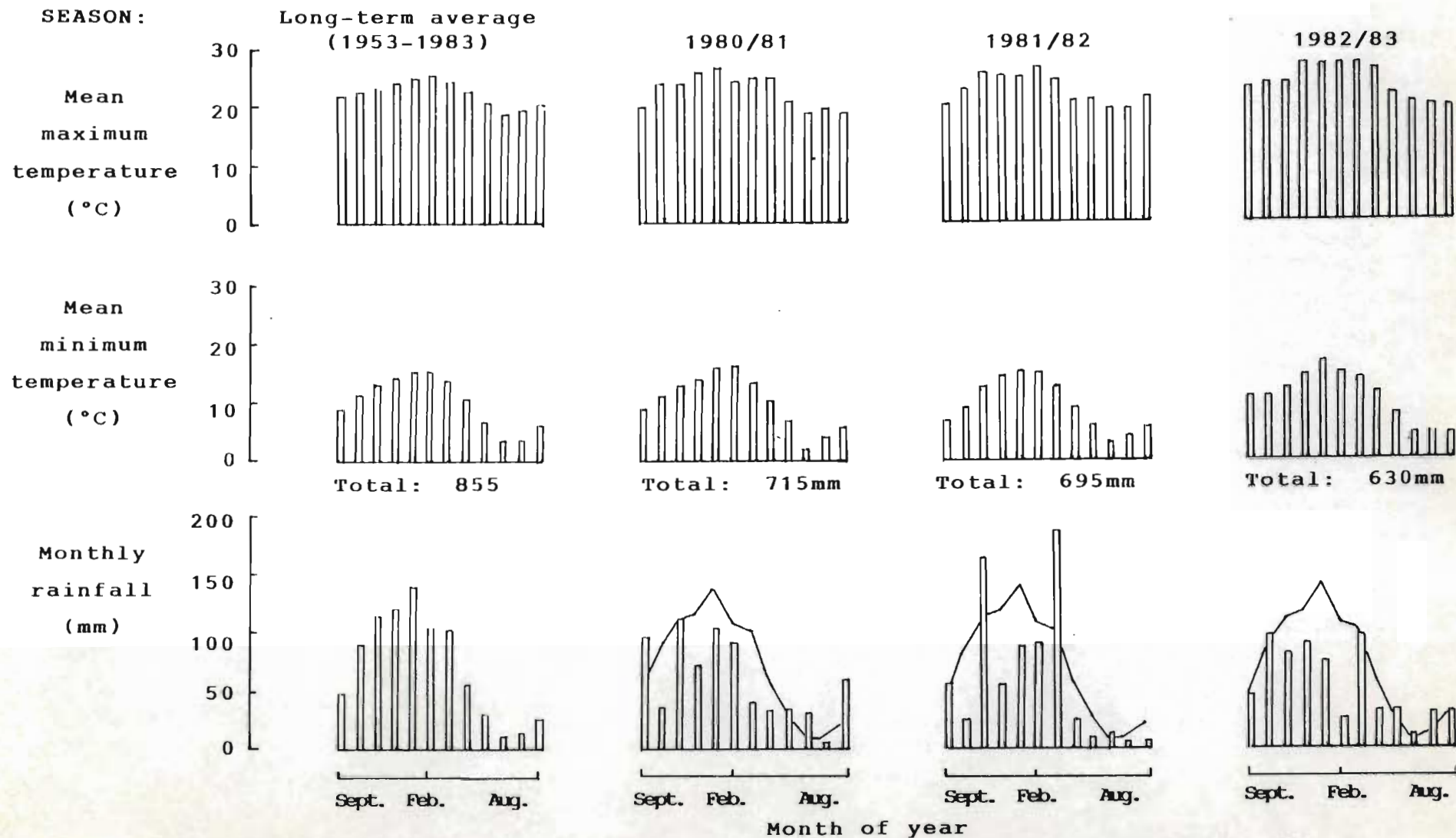
Fig. 1.   Mean monthly meteorological data and the respective long-term averages.   The long-term mean
is superimposed on monthly rainfall totals for the three seasons studied.

(September to April) months during the last 30 years, and historically January received the highest monthly rainfall. Total monthly rainfall figures were below the long-term averages during virtually all the months which comprised this study. The months of November and March of the 1981/82 season were exceptions, since 47 and 76%, respectively, more rain was recorded than the historic averages. The amount of rain which fell during the active growing season of kikuyu (September to April) was 73,6, 88,0 and 68,6% of the long-term average during the 1980/81, 1981/82 and 1982/83 seasons, respectively.

Maximum and minimum temperatures were not significantly influenced by season, and they did not differ significantly from the respective long-term averages (Fig. 1).

Stocking rates in terms of metabolic masses per hectare

Cow and calf livemasses measured on pasture were converted to metabolic mass $(W^{0,75})$ in order to obtain a more accurate indication of effective stocking rates. Fig. 2 illustrates the total metabolic masses per hectare for the different stocking rates.

Total metabolic mass per hectare and stocking rate were linearly correlated at the start of the grazing season (r=0,99 for each of the seasons). Thus, the difference in metabolic mass per hectare between the stocking rates of 3,0 and 4,12 was virtually identical to that between the rates of 4,12 and 5,34, and between the rates of 5,34 and 6,74 cows and calves/ha.

On a hectare basis, and over the three seasons, total calf metabolic mass constituted between 15 and 21,1% of total cow

Total calf metabolic mass/ha

Total cow metabolic mass/ha

SEASON:

1980/81

1981/82

1982/83

Total cow and calf metabolic mass per ha (kg)

1200 800 400

3,0 4,12 5,34 6,74

Stocking rate (cows and calves/ha)
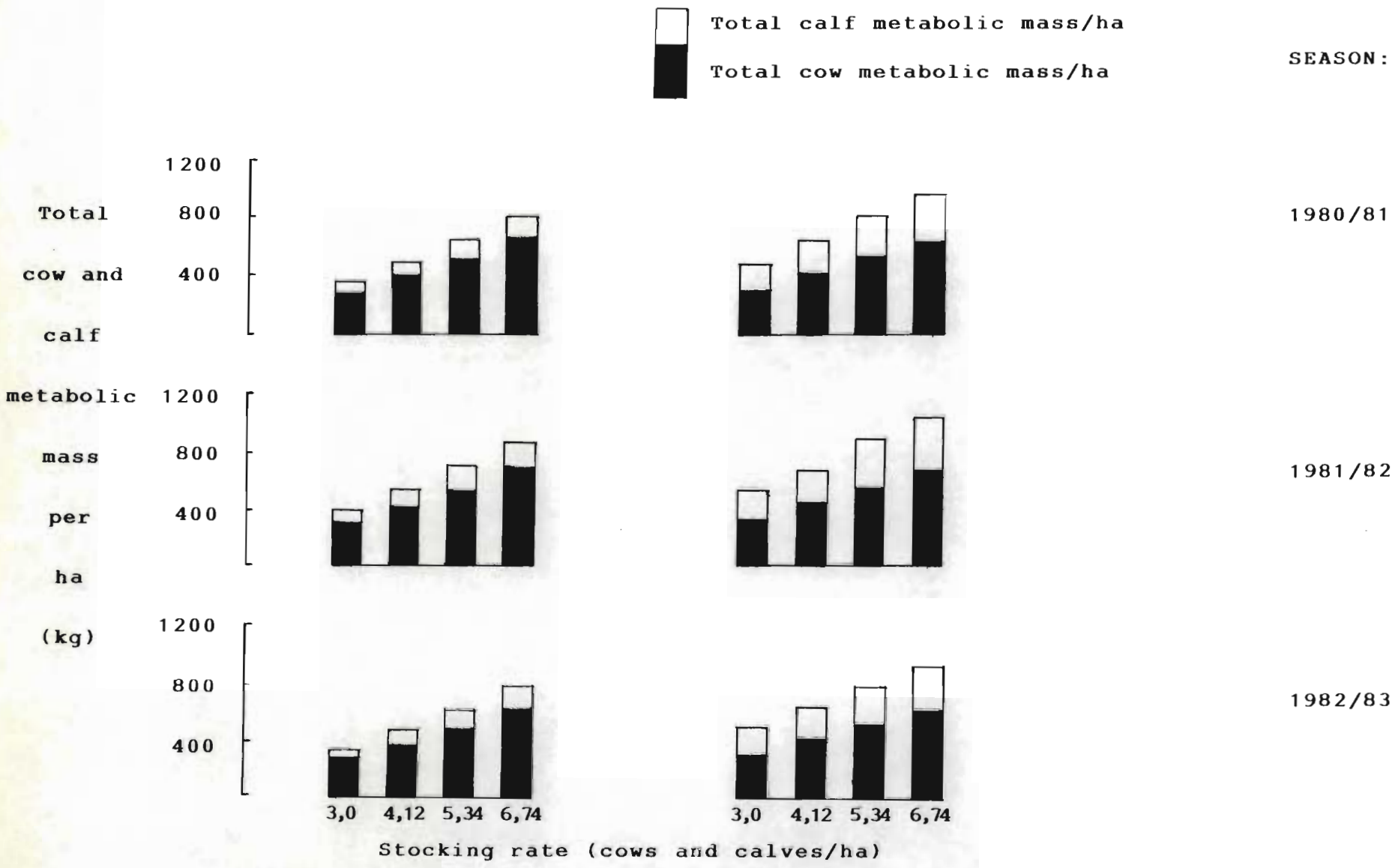
Fig. 2. Total metabolic mass per ha at the start of the grazing season and at weaning during each season.

and calf metabolic mass at the start of the grazing season.
Within any one season this percentage varied by less than one
over the four stocking rates.

It is evident from Fig. 2 that the total metabolic mass
per hectare increased between the start of the grazing season
and weaning at all stocking rates, largely as a result of
increases in calf size. Over the three seasons these increases
averaged 36,3, 28,9, 25,0 and 17,8% for the stocking rates of
3,0, 4,12, 5,34 and 6,74 cows and calves/ha, respectively.
Therefore, the increases per hectare were largest at the
lightest , and smallest at the heaviest stocking rate.

At weaning the calves constituted approximately one third
of total metabolic mass per hectare (Fig. 2). Within any
season the total calf metabolic mass as a percentage of cow
and calf metabolic mass varied by less than four percent over
the four stocking rates.

Length of the grazing periods

Table 4 summarizes the dates om which the grazing season
commenced, weaning was performed and the cows were removed
from pasture each season. A feature of these dates was that
they varied considerably from season to season. The date on
which grazing commenced varied by more than a month, from 17
October during 1980 to 20 November during 1981. Increases in
stocking rate were associated with decreases in the length of
the grazing period. However, at certain stocking rates the
length of the grazing period varied by 90 days between seasons
(Table 4).

Table 5 depicts the mean duration of the grazing period

Table 4.   The influence of stocking rate on the length of the grazing season and winter feeding period during each season.

SEASON	1980/1981				1981/1982				1982/1983			
Stocking rate (cows & calves/ha)	3,0	4,12	5,34	6,74	3,0	4,12	5,34	6,74	3,0	4,12	5,34	6,74
Date animals placed on pasture	17 October 1980				20 November 1981				1 November 1982			
Date calves weaned	2 July '81	18 June '81	30 April '81	22 April '81	21 June '82	14 June '82	17 May '82	17 May '82	6 June '83	16 May '83	14 March '83	14 March '83
Length of period between start of grazing and weaning (days)	258	244	195	188	213	206	178	178	217	196	133	133
Date when cows were removed from pasture	2 July '81	2 July '81	4 June '81	30 April '81	19 July '82	24 June '82	27 May '82	17 May '82	6 June '83	16 May '83	21 March '83	21 March '83
Length of period that cows remained on pasture(days) +	258 (8,5)	258 (8,5)	230 (7,5)	195 (6,4)	241 (7,9)	216 (7,1)	188 (6,2)	178 (5,8)	217 (7,1)	196 (6,4)	140 (4,6)	140 (4,6)
Length of winter feeding period (days)*	123	123	151	186	106	131	159	169	149	170	226	226

+ The number of months is indicated in brackets
* Assuming that grazing was to commence on 2 November each season

until weaning and until cows were removed from pasture. On average grazing commenced on 2 November. Grazing periods tended to become shorter as the stocking rate increased, but this relationship was not linear. On average weaning was performed within seven days (during late April) at the two heaviest stocking rates (5,34 and 6,74 cows and calves/ha). A fortnight separated mean weaning dates of 5 and 19 June at the two lightest stocking rates (3,0 and 4,12 cows and calves/ha, respectively). However, a relatively large difference of on average 45 days occurred between the dates of weaning in cows subjected to the intermediate stocking rates of 4,12 and 5,34 cows and calves/ha. Cows subjected to the stocking rates of 3,0, 4,12, 5,34 and 6,74 cows and calves/ha remained on grass for on average 10, 9, 17 and 5 days after weaning, respectively. The relationship between stocking rate and the length of the period on pasture is diagrammatically illustrated in Fig. 3.

In examining the relationship between stocking rate and the duration of the summer grazing period in cows (Fig. 3), an increase in stocking rate was associated with an increase in the length of the winter feeding period. Thus, cows stocked at rates of 3,0, 4,12, 5,34 and 6,74 cows and calves/ha were wintered for on average 4,2, 4,7, 5,9 and 6,4 months, respectively (Table 5).

During the 1982/83 season the experimental procedure was modified slightly as a result of the exceptionally dry conditions experienced over, but especially during the latter half of the grazing period (Fig. 1). Cows subjected to the two heaviest stocking rates (5,34 and 6,74 cows and calves/ha) were removed from pasture on 21 March, and only one week after

Table 5.   Mean lengths of different periods on pasture and winter feeding periods over three seasons.

Mean date on which cattle were placed on pasture	Stocking rate (cows & calves/ha)	Mean date of weaning	Mean date on which cows were removed from pasture	Mean No. of months between the start of the grazing and:		Mean length of winter feeding period (months)
				Weaning	The date on which cows were removed from pasture	
2 November ± 17 days	3,0	19 June ± 13 days	29 June ± 22 days	7,5 ± 0,8	7,8 ± 0,7	4,2 ± 0,7
	4,12	5 June ± 18 days	14 June ± 25 days	7,1 ± 0,8	7,3 ± 1,0	4,7 ± 1,0
	5,34	20 April ± 33 days	7 May ± 41 days	5,5 ± 1,0	6,1 ± 1,5	5,9 ± 1,5
	6,74	17 April ± 32 days	22 April ± 29 days	5,5 ± 1,0	5,6 ± 0,9	6,4 ± 0,9
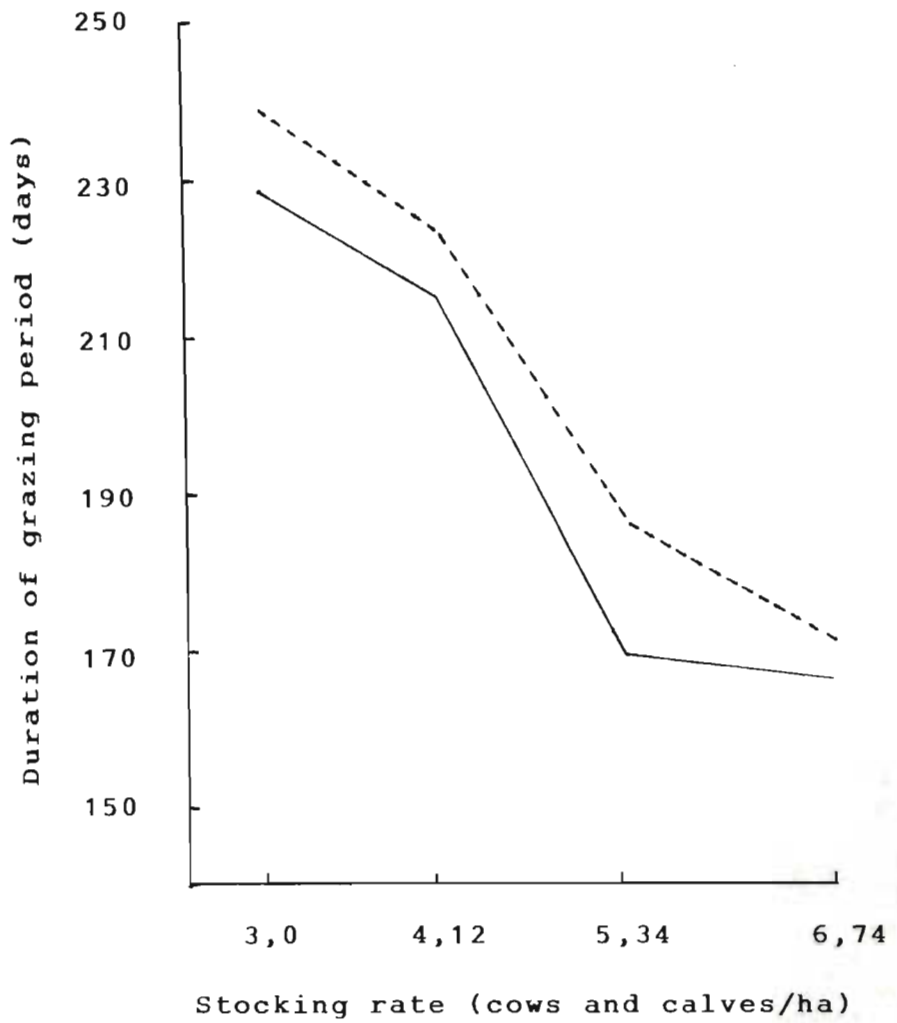
Fig. 3.   The relationship between stocking rate and
the length of the grazing periods on pasture.

weaning. Insufficient grass (or a pasture disc height of less than 2,5 cm on average) was available to further sustain the cows. The calves were then placed on pasture again, on the same day that the cows were removed from grass. The kikuyu was thus allowed to recover as a result of the drastic reduction in stocking rate. The calves remained on pasture for another 88 days, or until 10 June, 1983, before a mean pasture disc height of 2,5 cm was recorded.

Cow production parameters

Mass Changes

The mass of cows recorded within 14 days of calving was used as a measure of size. There was a relatively small difference between the sizes of the two breeds, since Simmentaler cows weighed 480,2 ± 60,9, and Hereford-crosses 465,6 ± 57,4 kg within 14 days of calving. Mass changes in cows over the course of each of the grazing periods are diagrammatically illustrated in Fig. 4. Data obtained for first-calvers and mature cows were pooled, since a regression analysis (to be described) indicated that mass changes were not affected by parity status. Cows stocked at rates of 3,0 and 4,12 cows and calves/ha gained mass consistently between the commencement of the grazing period and mid-April during the 1980/81 and 1981/82 seasons, and between the onset of grazing and mid-February during the 1982/83 season. Over these periods the cows stocked at the rate of 5,34 cows and calves/ha tended to maintain, and those stocked at the heaviest rate to lose mass. A feature of changes in cows
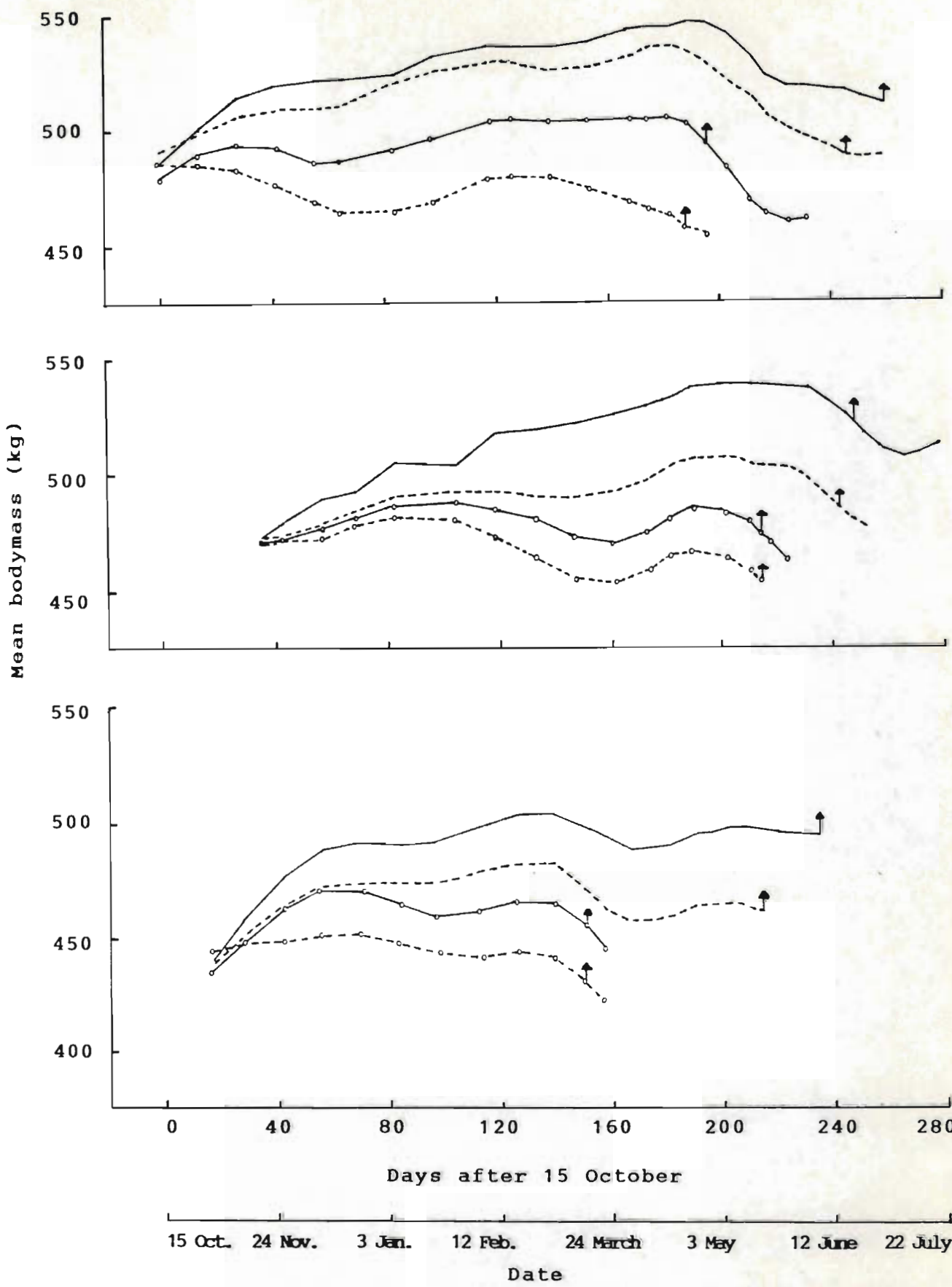
Fig. 4. Mean mass changes in cows stocked at rates of
3,0(———), 4,12(— — —), 5,34(∘———∘) and 6,74 cow
and calves/ha(∘— — —∘) between the commencement a
end of the grazing season.
↑ Signifies weaning.

subjected to the two heaviest stocking rates was that they temporarily regained mass which was lost during the first half of the grazing period. These initial losses which were followed by temporary gains did not occur at the same time of the year each season. They occurred in December, February/March and December/January during the 1980/81, 1981/82 and 1982/83 seasons, respectively (Fig. 4).

A stepwise multiple regression analysis was used to study the relationship between cow mass changes on pasture and a number of selected variates considered likely to affect these. Two dependant variables were considered, viz. the mass change between the commencement of the grazing period and weaning (Y1) and the change between the commencement of the grazing period and the removal of cows from pasture (Y2). The independant variates regressed against Y1 and Y2 were:

X1: Stocking rate

X2: Initial mass (at the start of the grazing
                    period)

X3: Season (or Year)

X4: Days postpartum (at the start of the grazing
                    period)

X5: Breed

X6: Condition score (at the start of the grazing
                    period)

X7: Cow age (in years)

X8: Calf gain (between the start of the grazing
                    period and weaning)

Independant variables which contributed significantly to

the variation in Y1 and Y2 are summarized in Table 6. Stocking rate and initial mass accounted for approximately 40 and 15%, respectively, of the total variation. For every 10 kg increase in initial mass, cows lost on average 2,1 kg more during their stay on pasture. Season and days postpartum significantly (P < 0,05) influenced mass changes until weaning, but each accounted for less than two percent of total variation (Table 6). It was noteworthy that neither breed, initial condition score nor cow age significantly influenced mass changes on pasture.

Season was omitted from the regression equations presented in Table 6, for the purpose of predicting mass changes in the absence of knowledge relating to future seasonal effects. The equations then change to:

$$Y1 = 171,7 - 15,8(X1) - 0,2(X2) + 0,21(X4)$$
$$(R = 0,75; P < 0,05)$$
$$Y2 = 185,4 - 17,2(X1) - 0,2(X2) + 0,2(X4)$$
$$(R = 0,77; P < 0,05)$$

Table 7 summarizes predicted cow masses based on the equations provided above. The data presented in Table 7 effectively summarize overall mean mass changes in cows over three seasons. For the purpose of obtaining predicted masses the actual mean initial masses in the two breeds, and the actual mean days postpartum at the start of the grazing period in all cows were used as independant variables in the regression equation.

The relationship between stocking rate and cow mass changes on pasture, as described by the regression equations,

Table 6.   Factors which influenced cow mass changes on pasture, as determined by a stepwise multiple regression analysis.*

Dependant Variables	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in:		Significance of added independant variable
		Y1(R^2 X100)	Y2(R^2 X100)	
Y1(mass change between start of grazing and weaning)	Stocking rate(X1)	40,3	42,0	P < 0,001
	Stocking rate(X1)+Initial mass(X2)	54,8	58,2	P < 0,001
Y2(mass change between start of grazing and removal of cows from pasture)	Stocking rate(X1)+Initial mass(X2)+Season(X3)	56,3	59,6	P < 0,05
	Stocking rate(X1)+Initial mass(X2)+Season(X3)+ Days postpartum(X4)	57,5	–	P < 0,05

Regression equations:

$Y1 = 152,2-15,8(X1)-0,183(X2)+5,7(X3)+0,18(X4)$ $R = 0,76;$ $P < 0,05$
$Y2 = 173,9-17,3(X1)-0,21(X2)+7,3(X3)$ $R = 0,77;$ $P < 0,05$

* The following values were allocated to the three seasons in the analysis: 1980/1981 = 1, 1981/1982 = 2, 1982/1983 = 3.

Table 7. Overall mass changes in cows on pasture over three seasons, as obtained from multiple regression equations (On average cattle commenced grazing on 2 November $\pm$ 17 days).

Stocking rate (cows & calves/ha)	3,0		4,12		5,34		6,74	
Breed	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X
Mean initial mass (kg)	467,3	451,2	467,3	451,2	467,3	451,2	467,3	451,2
Mean date of weaning	19 June	19 June	5 June	5 June	20 April	20 April	17 April	17 April
Mean mass at weaning (kg)	506,7	493,9	489,0	476,2	469,7	456,9	447,6	434,8
Mean mass change between 2 Nov. and weaning (kg)	+39,4	+42,7	+21,7	+25,0	+2,4	+5,7	-19,7	-16,4
Mean date on which cows were removed from pasture (kg)	29 June	29 June	14 June	14 June	7 May	7 May	22 April	22 April
Mean mass when removed from pasture (kg)	502,2	489,8	482,9	470,5	462,0	449,6	437,9	425,5
Mean mass change between 2 Nov. and the date on which cows were removed from pasture (kg)	+34,9	+38,6	+15,6	+19,3	-5,3	-1,6	-29,4	-25,7

is diagrammatically illustrated in Fig. 5. It should be noted that the different regression lines presented for Simmentaler and Hereford-cross cows in Fig. 5 do not represent a breed difference per se, but are due to the effect of the different initial masses in the two breeds (see Table 7).

Condition scores

Relative condition score changes in cows on pasture are presented in Fig. 6. Relative changes are provided, since initial scores differed between breeds (significantly) and stocking rates (non-significantly). Mean scores at calving in all Simmentalers (2,96 ± 0,17) did not differ from those in the Hereford-crosses (3,02 ± 0,11), but the latter breed gained more condition than the Simmentalers on the silage regime offered between calving and the start of the grazing period. Consequently, the scores in the Hereford-crosses were significantly (P < 0,05) higher than those in the Simmentalers when cattle commenced grazing pasture. It is also evident from Fig. 6 that the Hereford-cross cows also gained more (or lost less) condition on pasture than their Simmentaler counterparts. All cows stocked at the rate of 3,0 cows and calves/ha consistently gained condition between the start of grazing and early April during the 1980/81 and 1981/82 seasons, and mid-January during the 1982/83 season, before they rapidly lost condition. Cows stocked at the heaviest rate lost condition throughout their stay on pasture during each season (Fig. 6). A multiple regression analysis indicated that stocking rate, breed, initial score and stage postpartum significantly (P < 0.05) influenced score changes, but these
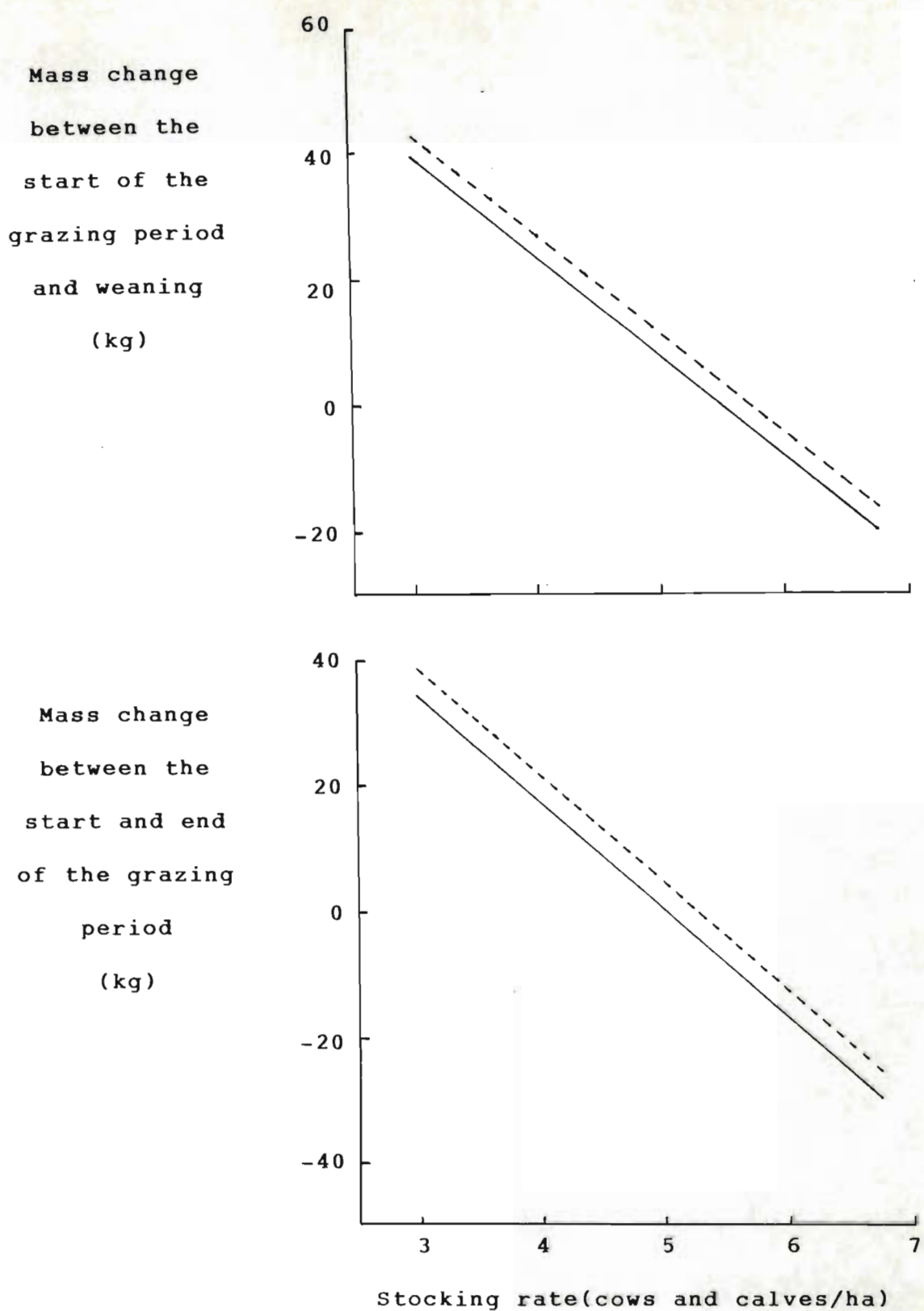
Fig. 5. The relationship between stocking rate and mass chang
in Simmentaler(————) and Hereford-cross(- - - -) cows
pasture.
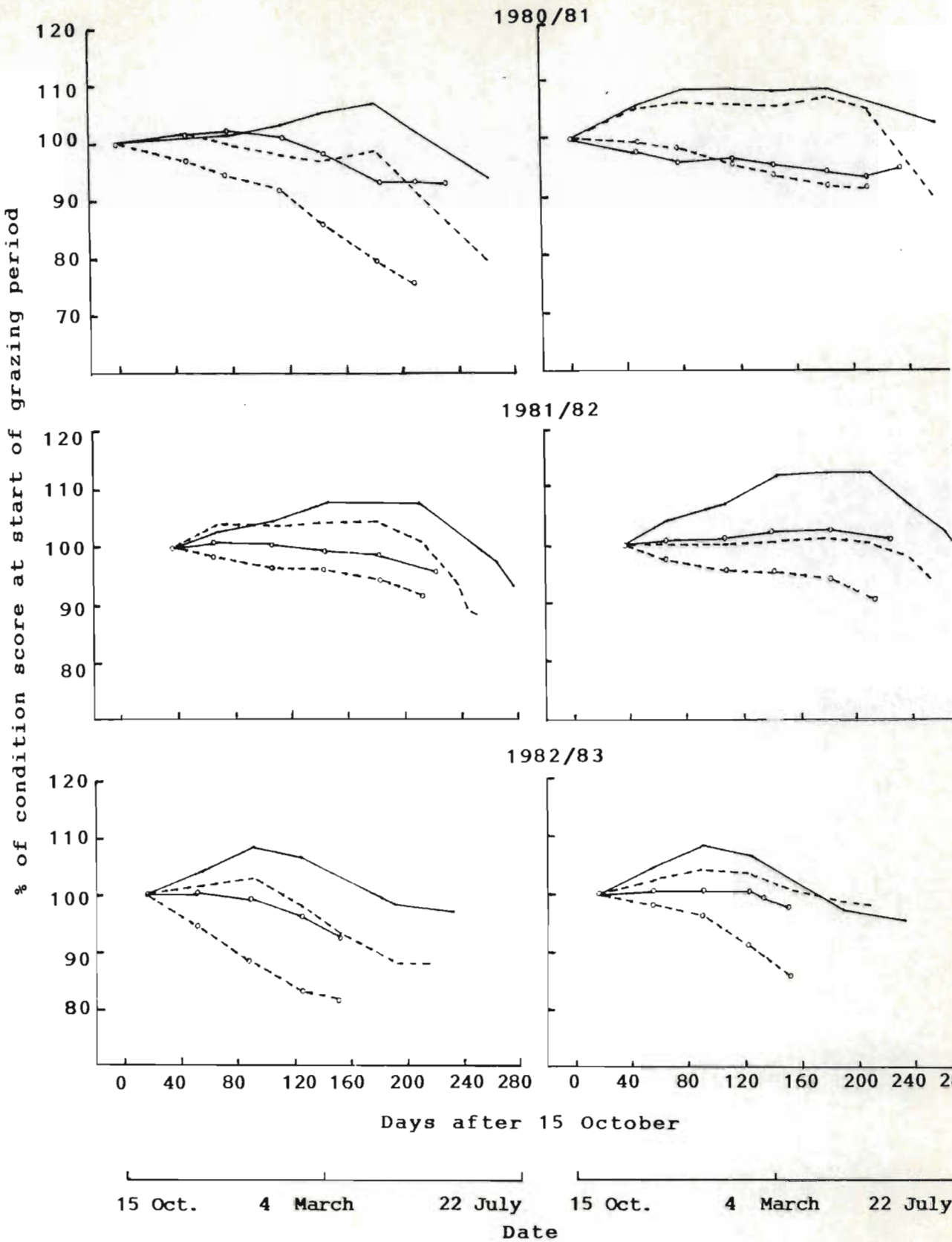
Fig. 6. Relative condition score changes in cows stocked at rates of 3,0 (———), 4,12(- - - -), 5,34 (o———o) and 6,74 cows and calves/ha(o- - -o) on pasture.

variables together accounted for only 20,4% of total variation
(Table 8). The regression equation presented in Table 8 was
therefore not considered suitable for predictive purposes.
Season did not influence score changes, and consequently those
obtained at each of the four stocking rates were pooled over
the three seasons. Table 9 summarizes the resultant overall
means.

Reconception rates

Rebreeding rates and intercalving periods obtained in the
lactating cows following artificial mating are presented in
Table 10. Reconception rates were not affected by season and
parity status. Consequently, those obtained in all
Simmentalers at each of the four stocking rates were pooled
over the three seasons. A similar procedure was adopted for
the Hereford-crosses. Reconception rates tended to be higher
among the Simmentalers than among the Hereford-crosses at each
of the four stocking rates, but these differences were not
significant. It is further evident from Table 10 that stocking
rate did not influence reconception rates (approximately 65%)
and intercalving periods (in cows which reconceived). On
average 7,4% of the cows subjected to each of the stocking
rates failed to exhibit oestrus during the breeding season.

Mean calving dates, post-calving mass changes and
condition scores in cows which reconceived were compared to
those in cows which failed to produce a calf, in an attempt to
explain the relatively poor reproductive performance obtained
during the study.The results of the comparison are summarized
in Table 11. Among the Simmentalers the mean calving date in

Table 8.   Factors which influenced condition score changes in cows on pasture, as determined by a stepwise multiple regression analysis. * +

Dependant variable	Independant variables	Contribution of independant variables or combinations thereof to total variation in Y(R^2 X100)	Significance of added independant variable
Y(Condition score change between start of grazing period and removal of cows from pasture)	Stocking rate (X1)	6,6	P< 0,05
	Stocking rate (X1)+Breed (X2)	11,6	P< 0,05
	Stocking rate (X1)+Breed (X2)+Initial score (X3)	16,8	P< 0,05
	Stocking rate (X1)+Breed (X2)+Initial score (X3)+Days postpartum (X4)	20,4	P< 0,05

Regression equation:

$$Y = 0,75 - 0,06 (X1) + 0,1 (X2) - 0,28 (X3) + 0,0027 (X4)   R = 0,45; P< 0,05$$

* Simmentalers were allocated a value of -1, and Hereford-crosses a value of +1 in the regression analysis.

+ Days postpartum refer to those at the start of the grazing period.

Table 9.   Means of pooled condition scores and score changes in cows over three seasons.

Stocking rate (cows & calves /ha)	Breed	Mean initial score when cows placed on pasture	Mean score when cows removed from pasture	Mean score change on pasture
3,0	Simmentaler	2,89±0,29	2,79±0,29	-0,1±0,30
	Hereford-cross	3,17±0,36	3,13±0,41	-0,04±0,30
4,12	Simmentaler	2,98±0,23	2,62±0,37	-0,36±0,37
	Hereford-cross	3,11±0,24	2,92±0,32	-0,19±0,31
5,34	Simmentaler	3,02±0,22	2,86±0,22	-0,16±0,22
	Hereford-cross	3,12±0,29	3,08±0,27	-0,05±0,19
6,74	Simmentaler	2,88±0,26	2,41±0,41	-0,47±0,33
	Hereford-cross	3,10±0,29	2,78±0,34	-0,33±0,21

Table 10. The influence of stocking rate and breed on pooled reconception rates and inter-calving periods over three seasons.

Stocking rate (cows & calves/ha)	Breed	No. of cows mated	Cows conceived		Cows which failed to exhibit oestrus during the breeding season (%)	Intercalving period in cows which reconceived (days)
			No	%		
3,0	Simmentaler	23	16	69,6	10,0	$367,5\overset{+}{-}25,7$
	Hereford-cross	17	11	64,7	0,0	$368,3\overset{+}{-}20,8$
4,12	Simmentaler	22	15	68,2	4,5	$362,8\overset{+}{-}24,3$
	Hereford-cross	33	21	63,6	3,0	$370,2\overset{+}{-}25,6$
5,34	Simmentaler	19	12	63,2	0,0	$378,3\overset{+}{-}23,3$
	Hereford-cross	29	18	62,1	10,3	$375,9\overset{+}{-}20,5$
6,74	Simmentaler	28	19	67,9	10,3	$370,1\overset{+}{-}20,8$
	Hereford-cross	32	18	56,3	15,6	$368,5\overset{+}{-}24,5$

Table 11. Characteristics of cows which reconceived and failed to become pregnant over three mating seasons.

Breed	Result following mating	Mean calving date	Mean bodymass		Mean bodymass change:		Mean condition score at the onset of the mating season
			Within 14 days of calving (kg)	At the onset of the mating period (kg)	From calving until the onset of mating(kg)	During the mating season (kg)	
Simmen-taler	Calf	10 Sept.$\pm$20 days[a]	479,8$\pm$59,8	482,6$\pm$62,6	+2,8$\pm$24,3	+14,4$\pm$29,0	2,96$\pm$0,25
	No calf	22 Sept.$\pm$25 days[b]	484,3$\pm$56,3	485,6$\pm$52,1	+1,3$\pm$31,9	+15,8$\pm$24,3	2,90$\pm$0,29
Hereford-cross	Calf	14 Sept.$\pm$21 days	467,0$\pm$51,3	471,1$\pm$56,7	+4,3$\pm$21,3	+10,5$\pm$22,1	3,14$\pm$0,31
	No calf	20 Sept.$\pm$23 days	462,3$\pm$56,9	471,1$\pm$57,6	+8,9$\pm$21,6	+7,9$\pm$22,1	3,12$\pm$0,25

thin the same column means with different superscripts differ significantly (P< 0,05) from each other.

cows which reconceived was significantly (P < 0,05) earlier
than in those which failed to become pregnant. The
corresponding dates did not differ significantly for the
Hereford-crosses. Bodymasses within 14 days of calving and at
the onset of the mating season, mass changes during the
breeding season and condition scores did not differ between
cows which reconceived and which failed to become pregnant
(Table 11).

The mean number of inseminations per conception was 1,23
for the Simmentalers, and did not differ significantly from
the 1,18 required for the Hereford-crosses. Twenty percent of
the Simmentaler and 15,6 % of the Hereford-cross cows which
conceived were inseminated more than once during the breeding
season.

Calf production parameters

Birth mass

The data in Table 12 illustrate mean birth masses of
calves over the three-year period of study. Cow age did not
significantly influence birth mass, and consequently masses of
calves born to first-calf cows and mature cows were pooled. In
both breeds the male calves were significantly (P < 0,001),
and approximately three kg or 10% heavier than the females.
Simmentaler calves of both sexes were on average 6,0% heavier
than their Hereford-cross counterparts. This difference due to
breed was significant in both sexes (P < 0,05 for males; P <
0,01 for females), but it represented a mass advantage of the
Simmentalers over the Hereford-crosses of only about two kg

Table 12. The influence of breed and sex on calf birth masses measured
           during the study.

Breed	Calf sex	Mean birth mass (kg)	Birth mass as a percentage of post-calving mass in dam
Simmentaler	Male	$35{,}5\pm0{,}7$ ⎤ ***	$7{,}65\pm0{,}15$ ⎤ *
	Female	$32{,}7\pm0{,}8$ ⎦ ⎤ *	$7{,}13\pm0{,}16$ ⎦ ⎤ *
Hereford-cross	Male	$34{,}0\pm0{,}6$ ⎤ *** ⎦ **	$7{,}51\pm0{,}13$ ⎤ * ⎦
	Female	$30{,}4\pm0{,}5$ ⎦	$6{,}63\pm0{,}12$ ⎦

*   Means joined by vertical bars differ significantly from each other.

* $P < 0{,}05$
** $P < 0{,}01$
*** $P < 0{,}001$

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(Table 12). Calf birth mass was expressed as a percentage of cow mass within 14 days of calving for each cow/calf pair. In both breeds this proportion was significantly (P < 0,05) greater in male than in female calves. Simmentaler females at birth also constituted a significantly (P < 0,05) greater proportion of their dam's mass than the Hereford-cross females. In the male calves this proportion was not affected by breed.

The incidence of dystocia in the experimental cowherd was remarkably low, and less than 1,0% of all calvings which occurred over the three seasons required any degree of assistance. Calf losses between birth and one month of age were relatively large at 3,7%, and a further 0,97% of viable calves died (from redwater) whilst grazing pasture. These losses were unrelated to breed or sex of calf.

A stepwise multiple regression analysis was conducted to further examine factors responsible for variation in birth mass of the 225 calves used in the investigation. The independant variables (X1....X6) regressed against birth mass (Y), and the values assigned to these in the analysis, were:

X1: Cow mass (obtained within 14 days of calving)

X2: Calf sex (males = -1; females = 1)

X3: Breed (Simmentalers = -1, Hereford-crosses = 1)

X4: Season (1980/81 =1, 1981/82 = 2, 1982/83 = 3)

X5: Cow age (in years, or first-calvers = 1,

mature cows = 2)

X6: Pre-calving mass change (the mass change

during the final 90 days of gestation)

Cow mass, calf sex, breed and season significantly (P <

0,05) influenced birth mass, although only 17,4, 14,6, 1,9 and

1,8% respectively, of the total variation in birth mass could

be accounted for by these variables (Table 13). On average

birth mass increased by 0,38 kg for every 10 kg increase in

cow mass. The influence of season on birth mass was only just

significant (P < 0,05). On average birth mass decreased by

0,99 kg per season over the investigation. It was noteworthy

that birth mass was not affected by mass changes in the dam

during the final 90 days of pregnancy. The mean mass change

over this period was a gain of 17,0 kg, and actual changes

ranged from a loss of 66,0 to a gain of 84,9 kg.

Calf growth rates

Mass changes in suckling calves were corrected to a steer

basis. The regression analysis summarized in Table 14

indicated that male calves grew significantly (P < 0,01) and

6,7% faster than females, and the ratio of males to females in

the different experimental groups was not identical. The

sex-corrected mass changes each season are diagrammatically

illustrated in Fig. 7. Differences between calf gain due to

stocking rate were relatively small during the first half, and

were manifested mainly during the latter half of the different

periods on pasture. Furthermore, mass increases occurred in a

near linear fashion for the major portion of the different

suckling periods, prior to plateauing off shortly before

weaning (Fig. 7).

Stepwise multiple regression procedures were used to study

factors responsible for variation in calf mass gain. Two

Table 13. Factors which influenced calf birth mass, as determined by a multiple regression analysis.

Dependant variable	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in Y(R^2 X100)	Significance of added independant variable
Birth mass (Y)	Cow mass (X1)	17,4	P < 0,001
	Cow mass (X1) + Sex (X2)	32,0	P < 0,001
	Cow mass (X1) + Sex (X2) + Breed (X3)	33,9	P < 0,05
	Cow mass (X1) + Sex (X2) + Breed (X3) + Season (X4)	35,7	P < 0,05

Regression equation:

$Y = 12,1 + 0,038 (X1) - 2,1 (X2) - 0,81 (X3) + 0,99 (X4)$ $R = 0,6; P < 0,05$
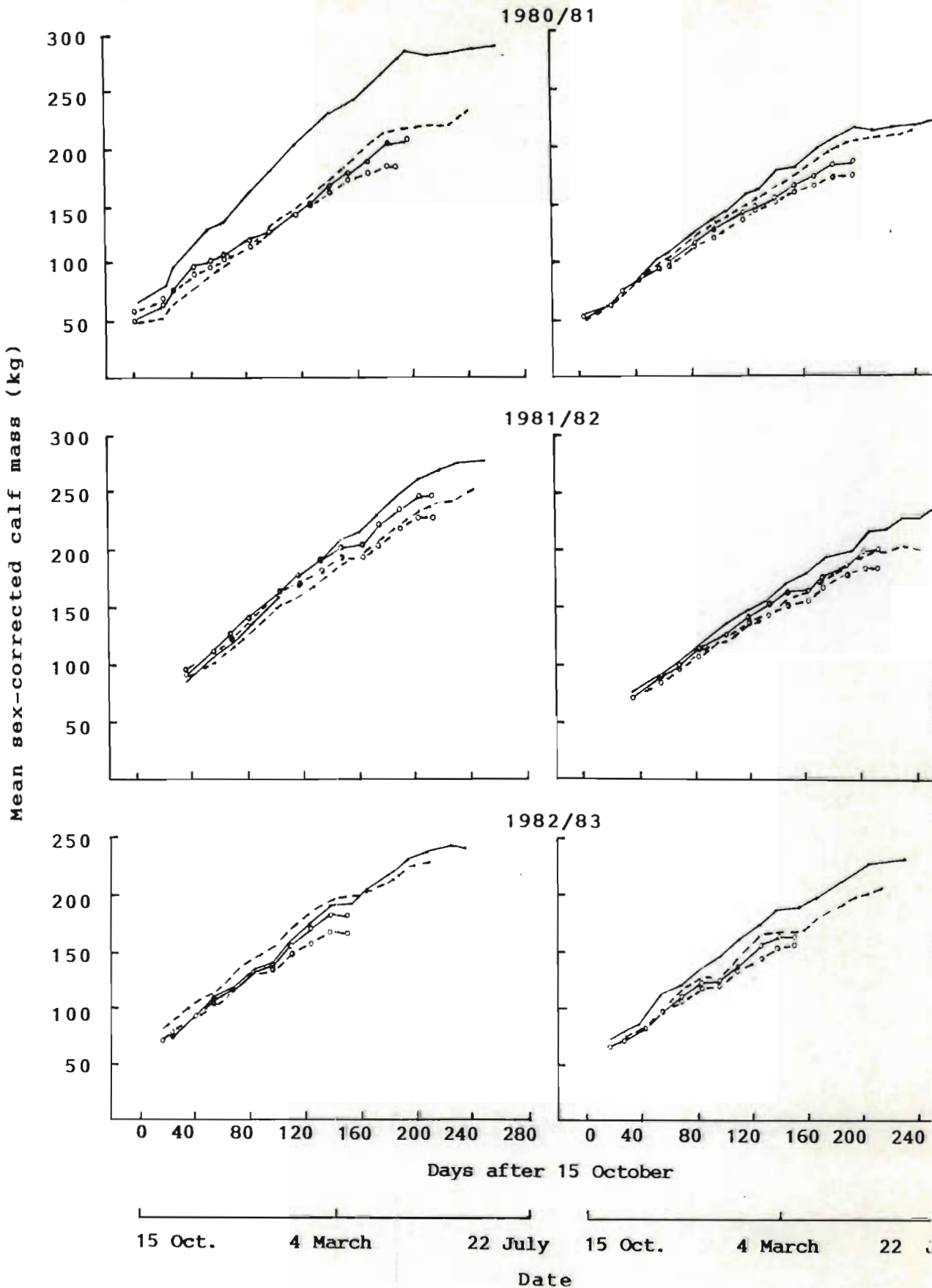
Fig. 7. Mean sex-corrected mass changes in calves stocked
         at rates of 3,0 (———), 4,12 (- - -) , 5,34 (o——o) and
         6,74 cows and calves/ha (o- -o) during each of three
         seasons.

dependant variables were considered. The first (Y1) was calf

gain over a period common to the four stocking rates each

season, that is, the gain between the start of the grazing

period and the date on which weaning was performed in the

animals subjected to the stocking rate of 6,74 cows and

calves/ha. The second dependant variable (Y2) was calf gain

between the commencement of the grazing period and weaning.

Independant variables included in the model, together with the

values assigned to those ultimately included in the regression

equation, were:

X1: Stocking rate

X2: Season (1980/81 = 1; 1981/82 =2; 1982/83 = 3)

X3: Breed (Simmentaler = -1, Hereford-cross = 1)

X4: Sex (male = -1, female = 1)

X5: Initial calf mass (at the start of the grazing

period)

X6: Calf birth mass

X7: Cow mass (measured within 14 days of calving)

X8: Cow age (in years, or first-calvers vs mature

cows)

X9: Calving date

X10: Cow mass change between parturition and Day

120 postpartum)

X11: Cow condition score (at the start of the

grazing period)

X12: Pre-calving mass change (during the final 90

days of pregnancy)

The independant variables which contributed significantly

to the variation in calf gain are presented in Table 14. Stocking rate accounted for 20,0 and 48,1% of the variation over the common period, and until weaning, respectively. Season was responsible for 30,4% of the variation over the common period, and only 9,9% of the variation between the start of the grazing period and weaning. Simmentaler calves gained on average 18,2 kg or 14,3% more than the Hereford-crosses between the start of the grazing period and weaning, and males gained on average 8,8 kg or 6,7% more than females over the same period. Calving date and initial mass contributed significantly (P < 0,05) to variation in calf gain, but these variates were correlated, and only initial mass was chosen for inclusion in the regression equation presented in Table 14. For every 10 kg increase in initial mass the calves gained on average 2,4 kg more between the start of the grazing period and weaning.

In order to obtain a prediction equation for future purposes (in which seasonal effects are unknown) the regression equation which describes calf gain until weaning (Table 14) was modified by omitting Season (X2) as an independant variable. The revised equation, which in effect predicts overall calf performance, based on the results obtained over three seasons, is:

$$Y2 = 207,7 - 17,1(X1) - 8,8(X3) - 4,5(X4) + 0,15(X5)$$

$$(R = 0,77; P < 0,01)$$

The modified regression equation was used to compute weaning masses for subsequent inclusion in an economic analysis. The following criteria were applied for this purpose:

Table 14. Factors which influenced calf gains on pasture over three seasons, as determined by a multiple regression analysis.

Dependant variable	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in:		Significance of added independant variable
		Y1(R^2 X100)	Y2(R^2 X100)	
Y1(calf gain	Stocking rate(X1)	20,0	48,1	P < 0,001
over a common	Stocking rate(X1)+Season(X2)	50,4	58,0	P < 0,001
period)	Stocking rate(X1)+Season(X2)+Breed(X3)	64,9	68,3	P < 0,001
Y2(calf gain	Stocking rate(X1)+Season(X2)+Breed(X3)+Sex(X4)	67,1	70,7	P < 0,05
between the start	Stocking rate(X1)+Season(X2)+Breed(X3)+Sex(X4)+			
of the grazing	Initial mass(X5)	72,4	72,6	P < 0,05
period and weaning)				

Regression equations:

Y1 = 204,8−10,1(X1)−26,2(X2)−9,4(X3)−3,0(X4)+0,37(X5)   R = 0,85;   P < 0,001
Y2 = 238,4−17,2(X1)−16,7(X2)−9,1(X3)−4,4(X4)+0,24(X5)   R = 0,85;   P < 0,001

1. Masses and gains were computed on the basis of those obtained for an equal number of male and female calves.

2. The mean calving date over the three seasons was 22 September.

3. Calf masses at the start of the grazing period in the Simmentalers were assumed identical for each of the stocking rates. The same assumption was made for the Hereford-crosses. Initial masses were calculated from recorded birth masses (Table 12) and actual daily gains from birth until the start of the grazing period. These averaged 0,79 kg/day in Simmentaler, and 0,71 kg/day in Hereford-cross calves. Initial masses calculated in this manner were similar to mean masses measured at the commencement of the grazing period over the three seasons.

Calf performance as estimated by the regression equations, together with the mean dates on which grazing commenced and weaning was performed, are summarized in Table 15. An increase in stocking rate was associated with a decrease in weaning mass, but an increase in the amount of calf mass produced per hectare. Calves in the group stocked at 6,74 cows and calves/ha produced approximately 60% more beef per hectare than those in the group stocked at 3,0 cows and calves/ha. Over all stocking rates the Simmentaler calves produced approximately 13% more beef per hectare than their Hereford-cross counterparts. The overall relationship between stocking rate, weaning mass and the amount of calf mass produced per hectare is diagrammatically illustrated in Fig. 8. Extrapolation of the relationship depicted in Fig. 8 over a wider range of stocking rates than was used in the present study, and on the basis of the model proposed by Jones &

Table 15.   Overall calf performance as estimated by a multiple regression equation, and the mean dates on which grazing commenced and weaning was performed.

Mean date on which grazing period commenced	Stocking rate (cows & calves/ha)	Breed	Estimated calf mass at start of grazing period	Mean date of weaning	Estimated weaning mass	Estimated production of calf mass per hectare(kg/ha)
2 November ± 17 days	3,0	Simm.	66,7	19 June ± 13 days	244,8	734,4
		Her.-X	62,3		220,4	661,2
	4,12	Simm.	66,7	5 June ± 18 days	225,5	929,1
		Her.-X	62,3		201,1	828,5
	5,34	Simm.	66,7	20 April ± 33 days	204,5	1092,0
		Her.-X	62,3		180,0	961,2
	6,74	Simm.	66,7	17 April ± 33 days	180,4	1215,9
		Her.-X	62,3		156,0	1051,4
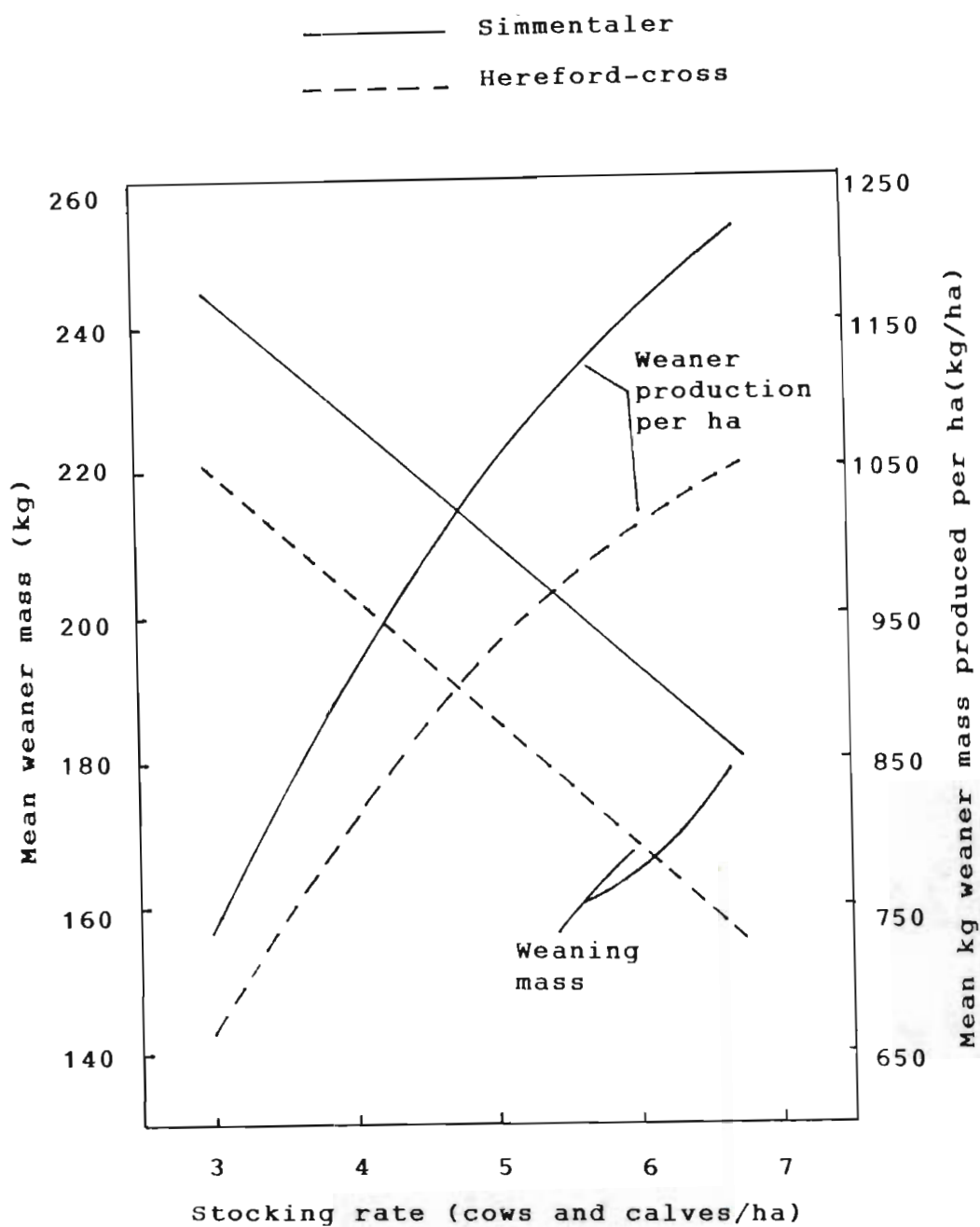
Fig. 8. The relationship between stocking rate, mea[n] weaning mass and mean weaner production per ha over three grazing seasons.

Sandland (1974), provides only a theoretical indication of
calf performance at stocking rates below and above those used
in this study. Nevertheless, it is interesting to note that on
the basis of such extrapolation (Fig. 9) the maximum
production of calf mass per hectare in the Simmentalers (1276
kg) would in theory be achieved at a stocking rate of 8,61
cows and calves/ha, and that weaners would weigh 148,2 kg at
this stocking rate. Hereford-cross calves would in theory
weigh 136,0 kg at the stocking rate of 7,9 cows and calves/ha,
at which a maximum production of 1074 kg of beef per hectare
would be anticipated. At a stocking rate of one cow and
calf/ha a theoretical weaning mass of 275 kg would be obtained
in the Simmentalers, and a mass of 250 kg in the
Hereford-crosses.

Post-weaning performance

Calves fed pasture

Growth rates in the two groups of calves placed on pasture
subsequent to weaning during the 1982/83 season are summarized
in Table 16. Simmentaler calves originating from groups
stocked at 5,34 and 6,74 cows and calves/ha prior to weaning
grew significantly (P < 0,05) faster than their Hereford-cross
counterparts, but the pre-weaning stocking rate did not
influence post-weaning performance on grass. Surprisingly
large gains of approximately 0,66 kg/day in the Simmentaler
and 0,55 kg/day in the Hereford-cross calves were obtained
over the 88-day period between mid-March and early June.
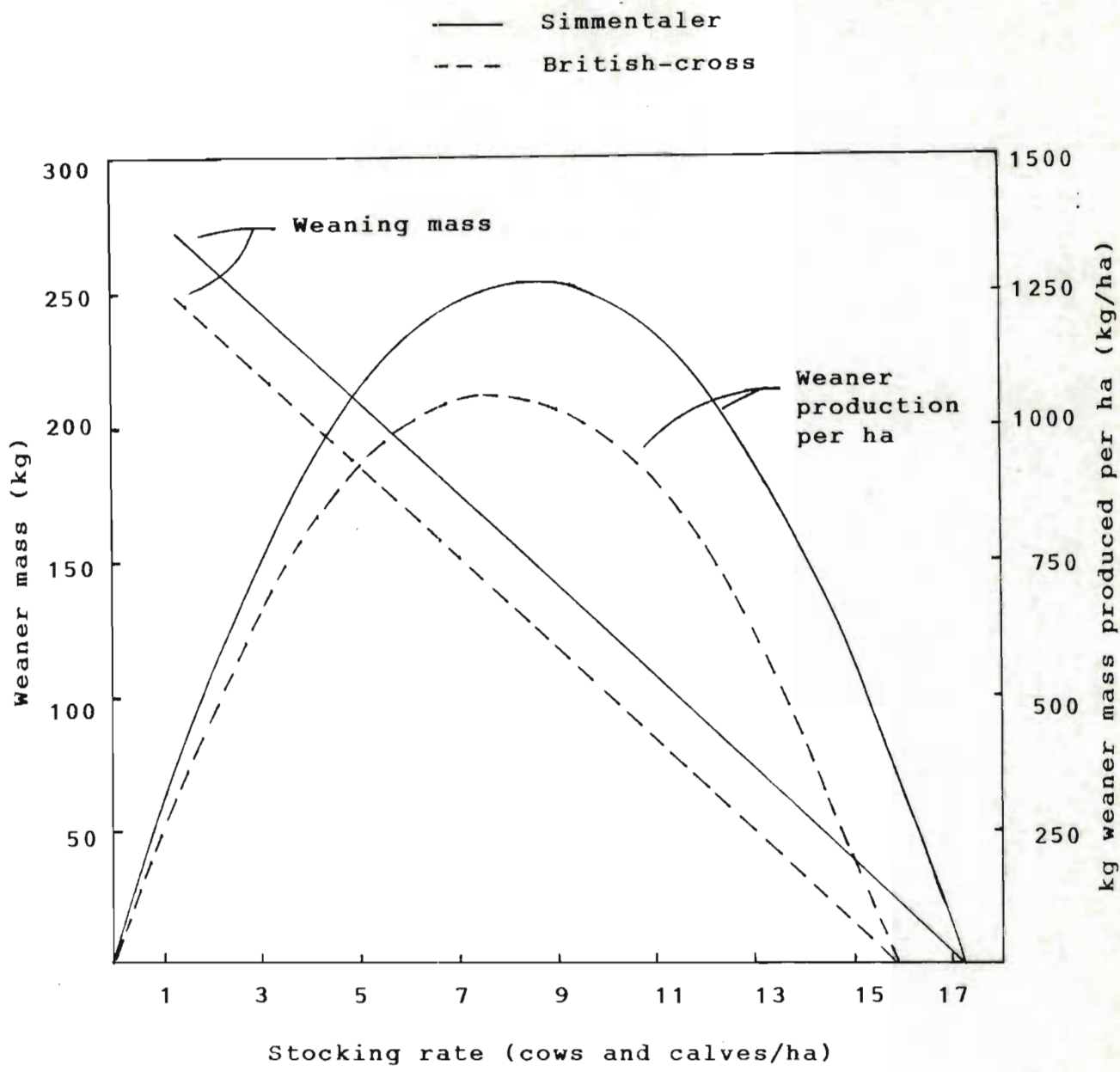
Fig. 9. The theoretical relationship between stocking rate, weaning mass and weaner production per ha, based on extrapolation of the relationship between stocking rate and weaning mass measured in this study.

Table 16.   Post-weaning growth rates on pasture in calves
            stocked at rates of 5,34 and 6,74 cows & calves
            / ha prior to weaning during the 1982/1983
            season.

Pre-weaning stocking rate (cows & calves /ha)	Breed	Post-weaning calf gain on kikuyu over a 88-day period between 14.3.83 and 10.6.83 (kg/day)
5,34	Simmentaler Hereford-cross	$0,66 \pm 0,13$ $0,56 \pm 0,09$ $\Big]$ *
6,74	Simmentaler Hereford-cross	$0,66 \pm 0,09$ $0,51 \pm 0,05$ $\Big]$ **

Means joined by vertical bars differed significantly from
each other

     * $P < 0,05$
     ** $P < 0,01$

Calves fed silage

Table 17 summarizes post-weaning feed intakes in the four
groups of calves which, together with their dams, were
subjected to the four stocking rates during the 1981/82
season. Calves from the group subjected to the stocking rate
of 3,0 cows and calves/ha consumed significantly (P < 0,01)
more silage per day on average than the groups subjected to
the stocking rates of 4,12, 5,34 and 6,74 cows and calves/ha.
This result was not unexpected, since calves from the group
stocked at 3,0 cows and calves/ha were significantly heavier
than calves from the other groups. However, it is evident from
Table 17 that the heavier the stocking rate employed during
the grazing season (and the lighter the calves produced at
weaning), the larger was the post-weaning dry matter intake,
expressed as a percentage of mean bodymass over the feeding
period.

Post-weaning growth rates were not affected by calf sex,
and consequently those obtained in male and female calves were
pooled, and are presented in Table 18. The calves were
group-fed after weaning, but for each group the gains in the
Simmentaler calves are presented separately from those in the
Hereford-crosses. The Simmentaler and Hereford-cross calves
subjected to the stocking rate of 3,0 cows and calves/ha grew
significantly (P < 0,01) faster, and as a group converted
their feed more efficiently than the calves subjected to the
other (heavier) stocking rates prior to weaning. A regression
analysis indicated that growth rates in individual calves were
not affected by masses at weaning.

The relationship between pre-weaning stocking rate,

Table 17. The influence of pre-weaning stocking rate on the feed intake of calves over a 88-day period subsequent to the 1981/1982 grazing season.

Pre-weaning stocking rate (cows & calves/ha)	Mean calf mass at weaning (kg)	Mean over 88 days of average daily maize silage intake per calf (kg)	Mean daily lick intake per calf (g)	Mean dry matter intake as a percentage of mean bodymass over feeding period (%)
3,0	$254,3 \pm 44,9^a$	$15,1 \pm 1,3^a$	174	1,73
4,12	$229,9 \pm 40,4^b$	$13,9 \pm 1,3^b$	132	1,75
5,34	$221,0 \pm 37,9^b$	$13,6 \pm 1,2^b$	227	1,85
6,74	$201,5 \pm 36,3^c$	$13,5 \pm 1,2^b$	175	1,96

a,b: Within the same column means with different superscripts differ significantly ($P < 0,05$) from each other.

Table 18. The influence of pre-weaning stocking rate on the post-weaning growth rate and efficiency of feed conversion in calves over a 88-day period subsequent to the 1981/1982 grazing season.

Pre-weaning stocking rate (cows & calves/ha)	Breed of calf	Mean mass at weaning (kg)	Mean post-weaning growth rate (kg/day)	Kg of dry matter (DM) consumed per kg of livemass gain (kg DM/kg gain)
3,0	Simm.	$275,1 \pm 32,1$	$0,65 \pm 0,3^{a}$	6,7
	Her.-X	$227,5 \pm 46,8$	$0,59 \pm 0,3^{a}$	
4,12	Simm.	$250,6 \pm 26,7$	$0,36 \pm 0,3^{b}$	10,6
	Her.-X	$196,3 \pm 36,8$	$0,36 \pm 0,3^{b}$	
5,34	Simm.	$243,7 \pm 32,6$	$0,28 \pm 0,3^{b}$	14,0
	Her.-X	$192,7 \pm 22,1$	$0,27 \pm 0,3^{b}$	
6,74	Simm.	$230,0 \pm 31,3$	$0,24 \pm 0,3^{b}$	13,6
	Her.-X	$184,1 \pm 24,6$	$0,31 \pm 0,3^{b}$	

a,b: Within the same column means with different superscripts differ significantly ($P < 0,05$) from each other.

weaning mass and the post-weaning dry matter intake in calves
is diagrammatically illustrated in Fig. 10.

Milk production

Daily yields of milk and milk constituents

Milk yields measured during the 1981/82 season were
corrected to a four percent fat basis. Production was
monitored over a period which commenced with the onset of the
grazing season on 20 November, 1981, and ended with the
weaning of the animals subjected to the stocking rate of 6,74
cows and calves/ha on 17 May, 1982.

A feature of milk yields on pasture was considerable
variation within breeds and stocking rates. For example, at
the stocking rate of 3,0 cows and calves/ha one Hereford-cross
cow produced a total of 1392 litres, whereas a second yielded
only 629 litres. At the stocking rate of 5,34 cows and
calves/ha the mean daily FCM yield in the Simmentalers varied
from 3,8 to 8,1 litres, and in the Hereford-crosses from 3,5
to 7,9 litres. Over all stocking rates the peak daily yield
was obtained on Day 68 ± 32 of lactation in the Simmentalers,
and on Day 52 ± 28 in the Hereford-crosses. This difference
between breeds was not significant. Cows were on average 62
days postpartum at the start of grazing, and 49,4% of all cows
achieved their peak yields prior to the commencement of the
grazing period.

Changes in mean daily FCM yields over time are
diagrammatically illustrated in Fig. 11. Mean yields at the
commencement of the grazing period inadvertently varied by

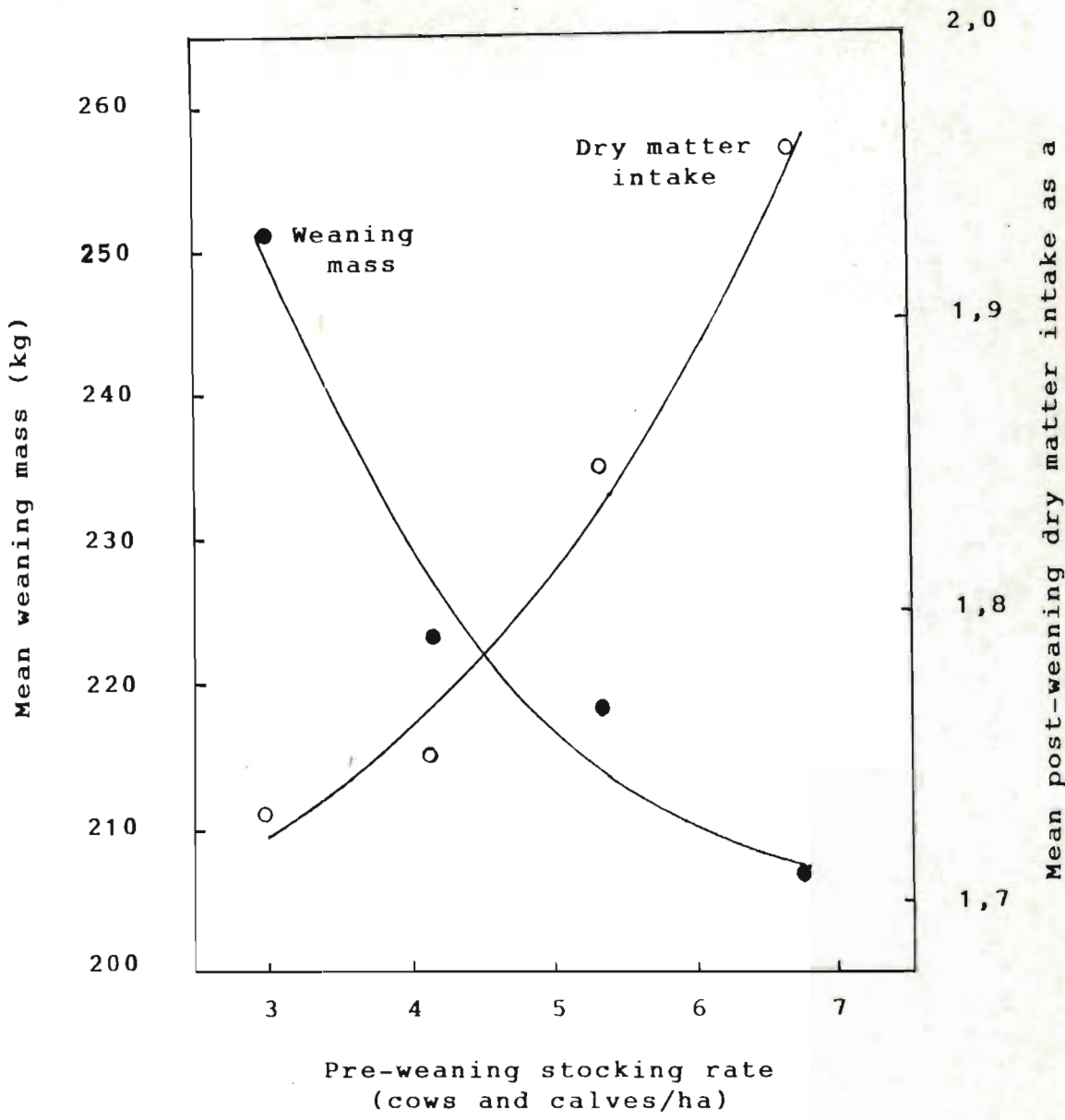Fig. 10. Relationship between pre-weaning stocking rate, weaning mass and post-weaning dry matter intake of calves fed maize silage subsequent to the 1981/82 grazing season.

Simmentalers   Hereford-crosses
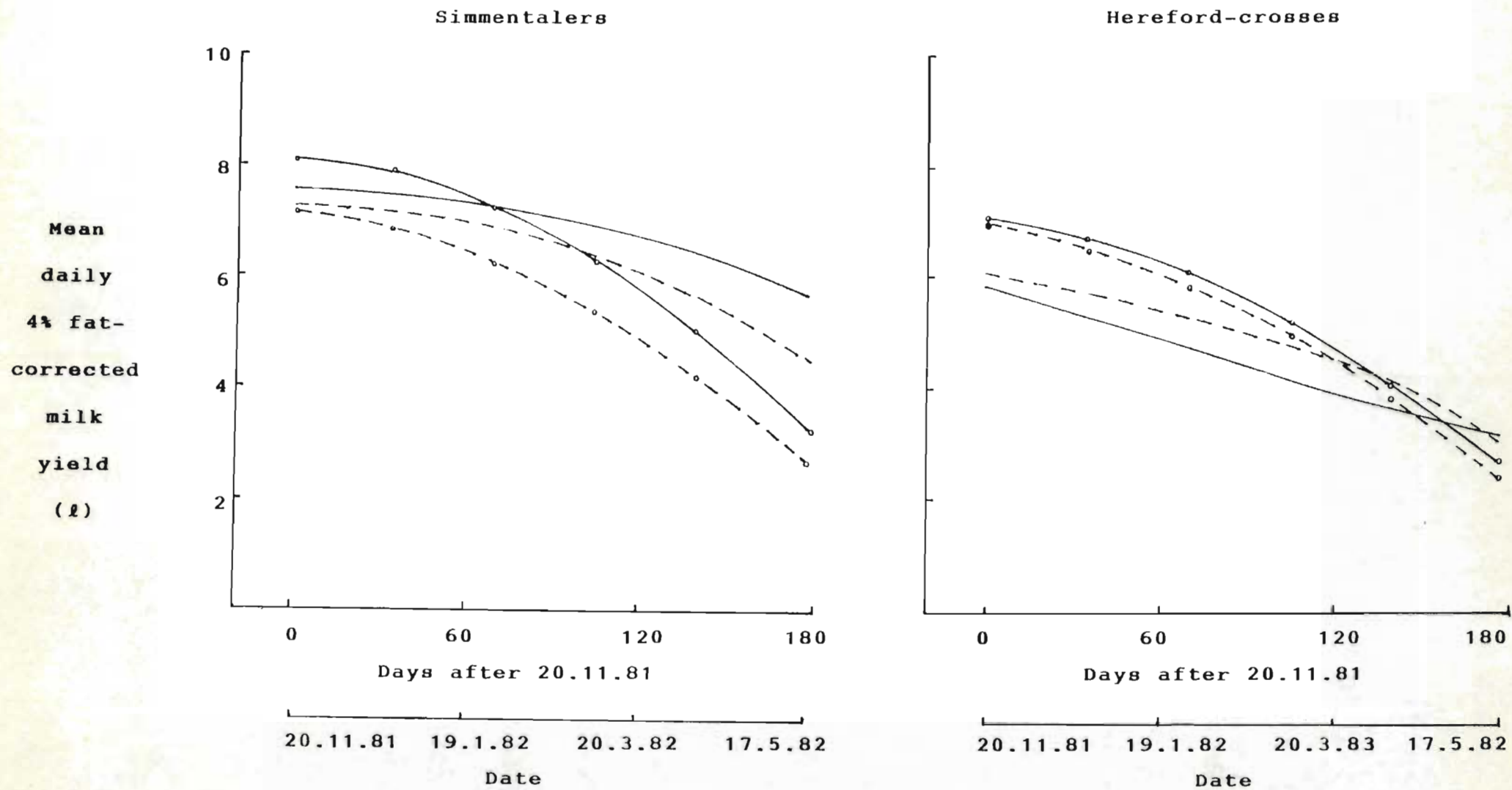
Fig. 11. Mean daily yields of 4% fat-corrected milk produced by cows stocked at 3,0(———)
4,12(— —),5,34(o———o) and 6,74 cows and calves/ha (o— —o) on pasture over a 178-day
period.

approximately 1,2 litres over the four stocking rates in both
Simmentalers and Hereford-crosses. Daily yields decreased
consistently throughout the comparable period, although
stocking rate influenced the rate at which these decreases
occurred. Table 19 summarizes two measures of relative yield
change on pasture. The first was the yield measured at the
end, relative to that measured at the start of the comparable
period, and the second the persistency of lactation, which,
after Mahadevan (1951), is defined as follows:

    A = Yield over the entire comparable period
    B = Yield over the first half of the comparable
        period

$$Persistency = \frac{A - B}{C}$$

Simmentaler and Hereford-cross cows stocked at the rates
of 3,0 and 4,12 cows and calves/ha were significantly (P <
0,05) more persistent in their production of milk than those
stocked at the rates of 5,34 and 6,74 cows and calves/ha.
Breed influenced persistency only at the stocking rate of 3,0
cows and calves/ha, at which Simmentalers were significantly
more persistent than the Hereford-crosses (Table 19).

A stepwise regression analysis was used to examine factors
responsible for variation in milk, protein, lactose and SNF
yields over the comparable period, and the results thereof are
presented in Table 20. The yield at the start of the grazing
period accounted for the major portion or 66,1% of total
variation in fat-corrected yields, and approximately 55% of

Table 19. The influence of breed and stocking rate on the persistency of milk
production over a 178-day period on pasture.

Stocking rate (cows & calves/ha)	Breed	Mean yield of FCM at weaning as a percentage of mean FCM yield at the start of the grazing period(%)	Mean persistency of lactation*
3,0	Simmentaler	$79,3 \pm 26,5^a$	$0,87 \pm 0,13^a$
	Hereford-cross	$54,4 \pm 13,9^b$	$0,71 \pm 0,09^b$
4,12	Simmentaler	$63,4 \pm 13,4^b$	$0,81 \pm 0,07^a$
	Hereford-cross	$51,9 \pm 14,1^b$	$0,77 \pm 0,06^a$
5,34	Simmentaler	$40,0 \pm 7,9^c$	$0,67 \pm 0,04^c$
	Hereford-cross	$39,1 \pm 11,8^c$	$0,67 \pm 0,07^c$
6,74	Simmentaler	$37,0 \pm 11,5^c$	$0,66 \pm 0,08^c$
	Hereford-cross	$36,2 \pm 12,5^c$	$0,64 \pm 0,10^c$

Within the same column means with different superscripts differ significantly (P <0,05)
from each other.
* See text for description of persistency of lactation.

Table 20. Factors which significantly influenced yields of FCM and milk constituents on pasture during the 1981/1982 season.*

Dependant variables	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in: [+]			
		Y1	Y2	Y3	Y4
Y1(FCM yield;litres)	Initial FCM yield(X1)	66,1	52,5	53,8	56,3
Y2(Lactose yield,kg)	Initial FCM yield(X1)+Breed(X2)	71,4	65,7	65,9	68,7
Y3(Protein yield,kg)	Initial FCM yield(X1)+Breed(X2)+Calving day(X3)	75,5	67,7	66,8	70,6
Y4(SNF yield,kg)	Initial FCM yield(X1)+Breed(X2)+Calving day(X3)+Stocking rate(X4)	77,3	70,3	70,4	73,3

Regression equations:

$Y1 = 233,9+102,0(X1)-70,5(X2)+2,4(X3)-26,2(X4)$ R=0,89;   P<0,001
$Y2 = 16,51+4,37(X1)-4,97(X2)+0,08(X3)-1,42(X4)$ R=0,84;   P<0,001
$Y3 = 14,90+2,87(X1)-2,87(X2)+0,04(X3)-1,06(X4)$ R=0,84;   P<0,001
$Y4 = 29,43+7,61(X1)-7,95(X2)+0,13(X3)-2,39(X4)$ R=0,86;   P<0,001

* Simmentalers were assumed a value of -1 and Hereford-crosses a value of 1 in the regression analysis. Calving day is that based on a season which has 1 July as Day 1 and 30 June as Day 365.

the variation in the yields of the different milk constituents. The initial yield was measured prior to the implementation of the four stocking rates, and provides an indication of the cow's genetic milk-producing ability. Breed, calving day and stocking rate also significantly (P < 0,05) influenced milk and constituent yields, but accounted for a relatively small proportion of the variation (Table 20). Factors which exerted no influence on yields were cow age, cow mass and condition score , mass changes in cows during the suckling period and calf birth mass and sex. Birth mass did however influence milk yield during early lactation. Correlation coefficients of 0,39 and 0,38 (P < 0,05) were obtained for the relationship between calf birth mass and cummulative milk yield between 30 and 90 days of lactation in the Simmentalers and Hereford-crosses, respectively.

Table 21 summarizes the predicted yields of milk and milk constituents, obtained from the regression equation provided in Table 20. The actual mean initial yield of 7,4 litres per day in the Simmentalers and 6,5 litres per day in the Hereford-crosses and the actual mean calving date of 19 September in all cows were used to obtain predicted yields. Cows were thus assumed to be 62 days into lactation at the start of the grazing period on 20 November.

Fig. 12 illustrates changes in the fat, protein, lactose and SNF content of the milk produced on pasture. Stocking rate did not influence the percentages of the constituents, and they were consequently pooled over stocking rates for each of the breeds. At the commencement of grazing the fat content of milk produced by Simmentalers averaged 4,3%, which differed significantly (P < 0,01) from the 4,9% in milk produced by the

Table 21. The influence of breed and stocking rate on daily yields of FCM, protein, lactose and SNF, as estimated by multiple regression equations.*

| Stocking rate (Cows & calves/ha)	Breed	Daily yield of:			
		FCM (ℓ)	Protein (g)	Lactose (g)	SNF (g)
3,0	Simmentaler	6,6	217,0	314,8	545,2
	Hereford-cross	5,2	188,3	236,9	417,5
4,12	Simmentaler	6,4	210,6	305,9	530,2
	Hereford-cross	5,1	163,8	228,0	402,4
5,34	Simmentaler	6,3	203,3	296,2	513,8
	Hereford-cross	4,9	156,6	218,3	386,1
6,74	Simmentaler	6,1	195,0	284,9	495,0
	Hereford-cross	4,7	148,3	207,0	367,2

* See text for assumptions made
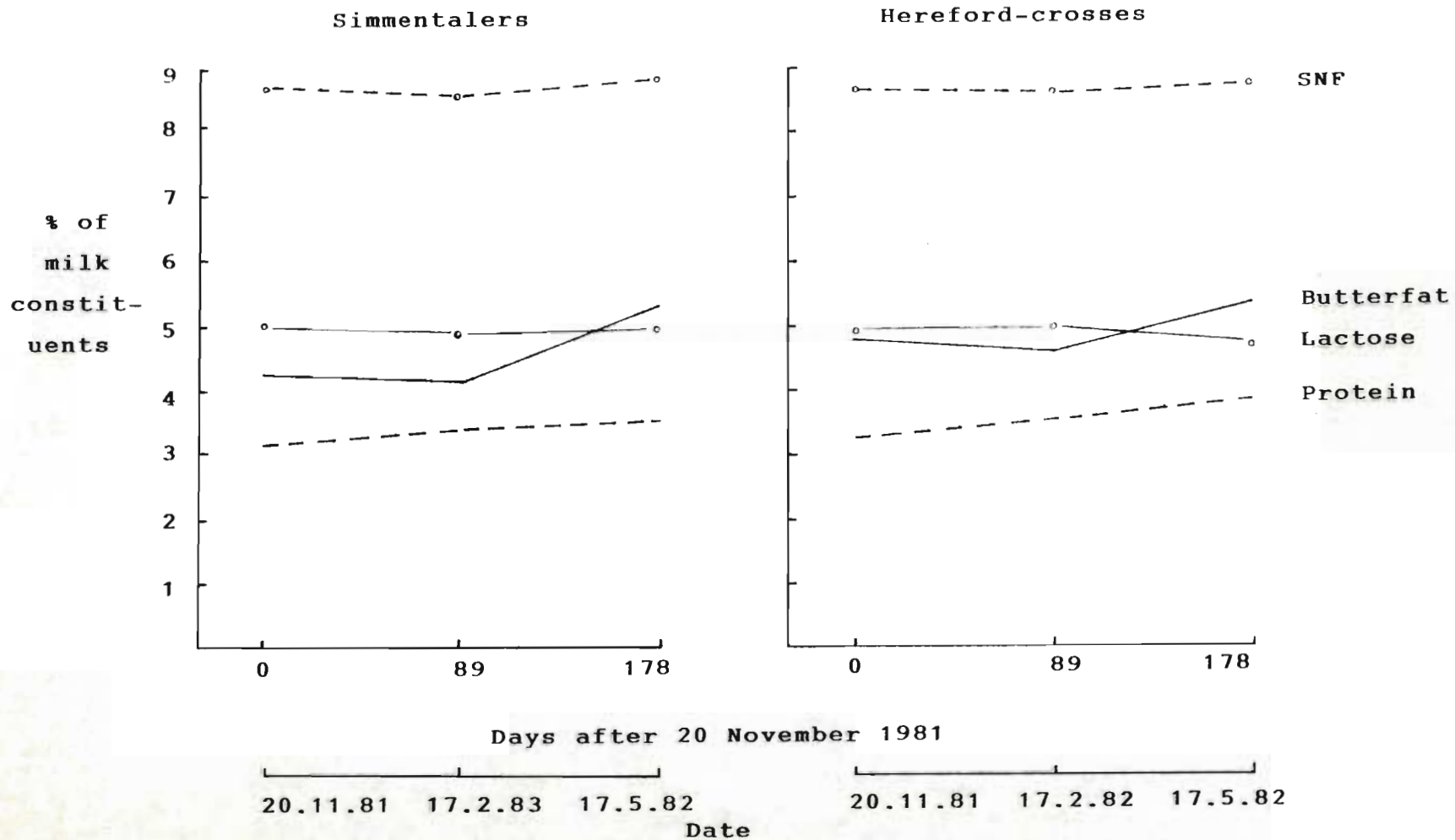
Fig. 12. Mean changes in the composition of milk produced by cows on pasture.

Hereford-crosses. Milk butterfat decreased by about one quarter of a percent over the first half of the comparable period in both breeds. During the second half of the period in question the milkfat content in Simmentalers increased more rapidly than in Hereford-crosses, and at the end of the period a mean fat content of 5,3% was recorded in both breeds (Fig. 12). The milk protein content increased gradually from approximately 3,2 to 3,9%, and the SNF content remained relatively constant at approximately 8,7% in the two breeds. Over the period in question the lactose content decreased from approximately 5,0 to 4,9% in the Simmentalers and 4,7% in the Hereford-crosses.

The inter-relationships beween milk and constituent yields and percentages are summarized in Table 22. The correlation coefficients which describe the relationships between milk and constituent yields were positive and of the order of 0,97. The same applied for the coefficients which explain the relationships between constituent yields. The correlations of milk yield and constituent percentages were low and predominantly negative. Of these only the protein percentage was significantly (P < 0,05) and negatively correlated with milk yield. Protein and SNF, and lactose and SNF percentages were significantly (P < 0,01) correlated in both breeds. Fat percentages were significantly (P < 0,05) correlated with protein and SNF percentages in the Hereford-crosses only (Table 22).

Relationship between milk yield and calf gain

Table 23 summarizes the results of a stepwise regression

Table 22. Correlation coefficients which describe the relationship between milk and milk constituent yields and percentages in Simmentalers (above diagonal) and Hereford-crosses (below diagonal).*

Variable	Milk yield	FCM yield	Fat yield	Protein yield	Lactose yield	SNF yield	Fat %	Protein %	Lactose %	SNF %
Milk yield		0,94	0,86	0,91	0,99	0,99	0,04	-0,33	0,29	-0,04
FCM yield	0,98		0,98	0,89	0,93	0,94	0,37	-0,24	0,29	0,05
Fat yield	0,94	0,99		0,83	0,85	0,87	0,53	-0,18	0,28	0,10
Protein yield	0,95	0,95	0,93		0,89	0,93	0,15	0,08	0,22	0,18
Lactose yield	0,99	0,97	0,94	0,96		0,99	0,04	-0,34	0,42	0,05
SNF yield	0,99	0,97	0,94	0,98	0,99		0,08	-0,24	0,37	0,11
Fat %	-0,06	0,15	0,26	0,03	-0,05	-0,02		0,24	0,08	0,28
Protein %	-0,37	-0,31	-0,27	-0,09	-0,29	-0,25	0,36		-0,15	0,54
Lactose %	0,24	0,25	0,24	0,31	0,37	0,34	0,03	0,13		0,57
SNF %	-0,24	-0,19	-0,15	-0,03	-0,11	-0,09	0,34	0,8	0,47	

* Simmentalers:
  $r = 0,30$ required for significance at $P < 0,05$
  $r = 0,39$ required for significance at $P < 0,01$

Hereford-crosses:
  $r = 0,33$ required for significance at $P < 0,05$
  $r = 0,42$ required for significance at $P < 0,01$

analysis on calf gain against a number of selected variates, including milk production. This procedure was followed in order to obtain an estimate of the extent to which calf gain is influenced by the quantity of milk produced by the dam. Approximately 40% of the total variation in gain was ascribed to milk production. It accounted for as much of the total variation as did the combined effect of stocking rate, breed, calving date and sex. Milk yields and calf gains in all Simmentalers were pooled, and a similar procedure adopted in the Hereford-crosses. This step allowed the examination of yield:gain relationships in two relatively large groups, the yields and gains of which varied considerably. Linear regression procedures indicated that the correlation coefficients which describe the relationships between calf gain and either milk, FCM, protein or lactose yield did not differ significantly in both breeds (Table 24). In the Simmentalers the protein yield was more closely associated with calf gain than milk yield, and the yields of the other constituents. The relationships between gain and yield in the Simmentalers did not differ from those in the Hereford-crosses (Table 24). Milk production between 30 and 90, and 90 and 180 days of lactation was also regressed against the corresponding gain in each of the breeds. This allowed a study of the relationship between calf growth and milk yield, irrespective of calving date. In the Hereford-crosses the correlation between FCM yield and gain over the period 30 to 90 days (r = 0,73) was significantly (P < 0,05) larger than that over the period 90 to 180 days (r = 0,14). Milk yield was also more closely associated with calf growth during the earlier than the latter period in the Simmentalers, but in their case the

Table 23. Factors which influenced calf gain during the 1981/1982 season, as determined by a stepwise multiple regression analysis.*

Dependant variable	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in calf gain $(R^2 \times 100)$	Significance of added independant variable
Y(calf gain over comparable period)	FCM yield(X1)	40,1	P < 0,001
	FCM yield(X1)+Stocking rate(X2)	58,5	P < 0,001
	FCM yield(X1)+Stocking rate(X2)+Breed(X3)	72,9	P < 0,001
	FCM yield(X1)+Stocking rate(X2)+Breed(X3)+Calving day(X4)	78,2	P < 0,001
	FCM yield(X1)+Stocking rate(X2)+Breed(X3)+Calving day(X4)+Sex(X5)	80,2	P < 0,05

Regression equation:

$$Y = 141,8 + 6,2(X1) - 8,2(X2) - 8,6(X3) - 0,31(X4) - 4,2(X5) \quad R = 0,89; \quad P < 0,001$$

* Simmentalers and males were assigned a value of -1, and Hereford-crosses and females a value of 1 in the regression analysis. Calving day is that based on a season which has 1 July as Day 1 and 30 June as Day 365.

Table 24. Linear regression equations which describe the relationship between milk production and calf gain.

Dependant variable	Independant variable	Simmentalers		Hereford-crosses	
		Regression equation	r	Regression equation	r
Calf gain over comparable period (kg)	Milk yield (ℓ)(X1)	$y=88,8+0,06(X1)$	0,52	$y=81,4+0,05(X1)$	0,48
	FCM yield (ℓ)(X2)	$y=97,9\pm0,05(X2)$	0,47	$y=79,1+0,04(X2)$	0,52
	Lactose yield(kg)(X3)	$y=91,1+1,2(X3)$	0,55	$y=57,0+1,49(X3)$	0,53
	Protein yield(kg)(X4)	$y=70,9\pm2,31(X4)$	0,62	$y=51,8+2,28(X4)$	0,54
	SNF yield(kg)(X5)	$y=83,8+0,77(X5)$	0,57	$y=55,0+0,87(X5)$	0,52
Calf gain 30-90 days (kg)	FCM yield(ℓ)(X6)	$y=34,3+0,04(X6)$	0,59	$y=18,0+0,06(X6)$	0,73
Calf gain 90-180 days(kg)	FCM yield(ℓ)(X7)	$y=56,9+0,05(X7)$	0,36	$y=45,9+0,04(X7)$	0,41

Correlation coefficients joined by vertical bars differ significantly ($P<0,05$) from each other.

correlation coefficients did not differ significantly (Table 24).

Milk conversion rates

Factors which influenced the efficiency whereby milk was converted to calf gain were examined by a stepwise regression analysis, the results of which are summarized in Table 25. From the regression equation provided it is evident that:

1. The conversion of milk to calf gain was less efficient at higher than at lower milk yields. The quantity of milk required to produce a kg of calf gain increased by 0,5 litres for every 100 litres increase in the total milk yield.

2. Milk was less efficiently converted to calf gain at higher than at lower stocking rates. Calves stocked at a rate of 3,0 cows and calves/ha required 2,3 litres of milk less per kg of calf gain than calves stocked at the rate of 6,74 cows and calves/ ha.

3. Simmentaler calves tended to convert milk to gain more efficiently than the Hereford-cross calves. The overall difference between the two breeds in the quantity of milk required to produce a kg of calf gain was approximately 1,3 litres.

4. Male calves required approximately 0,45 litres of milk less per kg of gain than the female calves.

Milk conversion rates over the entire, and the first and second halves of the comparable period are diagrammatically illustrated in Fig. 13. Differences in conversion rate due to stocking rate were larger during the second than the first

Table 25.   Factors which influenced the conversion of milk to calf gain as estimated by a stepwise
            regression analysis.*

Dependant variable	Independant variable(s)	Contribution of independant variables or combinations thereof to total variation in milk conversion rate(R^2 X100)	Significance of added independant variable
Y	FCM yield(X1)	37,8	$P < 0,001$
(milk	FCM yield(X1)+Stocking rate(X2)	60,1	$P < 0,001$
conversion	FCM yield(X1)+Stocking rate(X2)+Breed(X3)	74,7	$P < 0,001$
rate)	FCM yield(X1)+Stocking rate(X2)+Breed(X3)+Sex(X4)	76,7	$P < 0,05$

Regression equation:

$Y = -0,22+0,0052(X1)+0,501(X2)+0,63(X3)+0,23(X4)$ $R = 0,88$; $P < 0,001$

* Simmentalers and males were allocated a value of -1, and Hereford-crosses and females a value of 1 in the
regression analysis.

half of the comparable period. It is also evident from Fig. 13 that although Simmentaler calves on average required less milk per kg of gain than the Hereford-crosses, this trend was actually reversed at the lightest stocking rate (3,0 cows and calves/ha).

Economic analysis

Physical data obtained over the three seasons were subjected to an economic analysis in order to examine the relative profitabilities of systems involving the two breeds, each stocked at the four rates. The following criteria were used as basis for the analysis:

1. Regression models previously described, and which effectively provide overall means for the three seasons, were used to generate production parameters in cows and calves. Actual changes in condition were used in the analysis, in view of the relatively small proportion (20,4%) of total variation explained by the independant variables (Table 8).

2. Pasture was utilized exclusively by lactating cows and suckling calves. All systems incorporated the sale of calves off their mothers immediately after weaning.

3. The costs involved in rearing replacement heifers and maintaining dry cows were assumed identical for all systems, and were not included in the analysis.

For various reasons the feed intakes of cows stocked at different rates during summer were not measured on a group basis during winter. The intake of winter feed is a function of

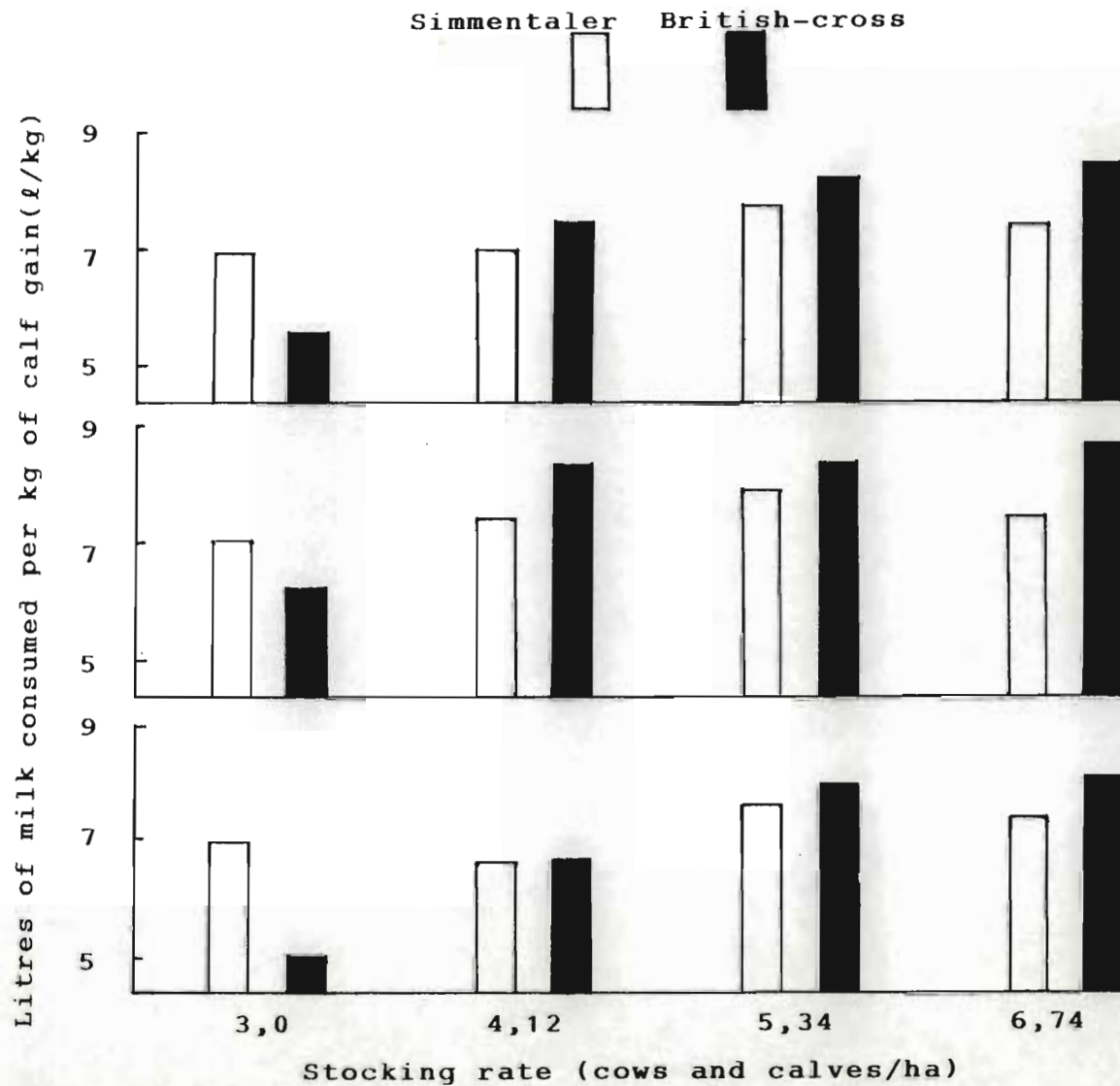a) the length of the winter feeding period, and

Fig. 13. The efficiency of conversion of milk to calf gain over two periods on pasture.

b) the mass and condition score of the cow when removed from grazing. The relationship between condition score and mass at the start of winter and the feed necessary to achieve and maintain a condition score of 3,0 until calving, as described by van Niekerk (1982), was used to calculate the intake of winter feed (maize silage). From calving until the onset of the summer grazing period actual mean daily intakes per cow of maize silage of 34,0 kg in the Simmentalers, and 33,0 kg in the Hereford-crosses, were applied. Each cow consumed on average 300 g of NPN-mineral lick per day during the winter months, and was fed 0,4 kg of HPC per day from calving until the start of the grazing period.

It was assumed that cows consumed 120 g of summer lick each day on pasture.

4. The following feed costs were assumed:

Kikuyu pasture	: R275 per hectare
Maize silage	: R 28,1 per 1000 kg
Summer lick	: R538,5 per 1000 kg
NPN-mineral lick	: R366,7 per 1000 kg
HPC	: R420,0 per 1000 kg

Table 26 summarizes overall mean production parameters in cows and calves. Two measures of profitability were calculated, namely the margin over feed costs per cow, and per hectare. The margin per cow is the difference between the income derived from each cow, and the total (summer and winter) feed cost. The income per cow constituted the sale value of the calf, and 8,3% of the salvage value of the cow (an annual replacement rate of 12% in cows was used as basis

Table 26. Overall mean production parametres for Simmentaler and Hereford-cross cows and calves stocked at four rates on kikuyu.

Stocking rate(cows & calves/ha)	3,0		4,12		5,34		6,74	
Breed	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X
Calving date	22 September							
Date onto pasture	2 November							
Initial cow mass on 2 Nov.(kg)	467,3	451,2	467,3	451,2	467,3	451,2	467,3	451,2
Initial calf mass on 2 Nov.(kg)	66,7	62,3	66,7	62,3	66,7	62,3	66,7	62,3
Initial cow condition on 2 Nov.	2,89	3,17	2,98	3,11	3,02	3,12	2,88	3,10
Weaning date	19 June	19 June	5 June	5 June	20 April	20 April	17 April	17 April
Weaning mass of calves(kg)	244,8	220,4	225,5	201,1	204,5	180,0	180,4	156,0
Mass of cows at weaning(kg)	506,7	493,9	489,0	476,2	469,7	456,9	447,6	434,8
Cows removed from pasture:								
Date	29 June	29 June	14 June	14 June	7 May	7 May	22 April	22 April
Mass	502,2	489,8	482,9	470,5	462,0	449,6	437,9	425,5
Condition score	2,79	3,13	2,62	2,92	2,86	3,08	2,41	2,78
Winter feed intake per cow:								
Maize silage(tons)	3,6	3,53	4,0	3,92	4,94	4,89	5,35	5,30
NPN/mineral lick(kg)	37,8	37,8	42,3	42,3	53,7	53,7	58,2	58,2
HPC(kg)	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4
Summer lick intake per cow(kg)	31,1	31,1	29,1	29,0	24,2	24,2	22,2	22,2

for this assumption). The margin per hectare is the difference between the total income per hectare, and the annual feed costs for cattle sustained on a hectare of pasture. The two margins are presented in Table 27. Over the four stocking rates the margin per Simmentaler cow was between R12 and R23 larger than per Hereford-cross cow. In both breeds the margin per cow was largest at the lightest stocking rate, and it progressively decreased with an increase in stocking rate to become smallest (even negative) at the heaviest stocking rate (Table 27). On a hectare basis the largest margin (R314,8) was obtained in the Simmentalers stocked at a rate of 4,12 cows and calves/ha. From Fig. 14, which diagrammatically illustrates feed and margin over feed costs, it is evident that winter feed accounted for approximately 50 and 76% of total feed costs at the stocking rates of 3,0 and 6,74 cows and calves/ha, respectively. The impact on returns of the relatively high costs of wintering cows, especially those stocked at heavy rates during summer, become evident in a theoretical exercise in which it was assumed that winter feed costs were 40% of those applied in the analysis described above. A maximum margin over feed costs of R165 per cow was then obtained in the Simmentalers stocked at the rate of 3,0 cows and calves/ha , and the maximum margin over feed costs per hectare (R753) was obtained in the Simmentalers stocked at the rate of 5,34 cows and calves/ha.

Table 27. Margins over feed costs per cow and per hectare in Simmentaler and Hereford cross cattle subjected to four stocking rates on pasture.

| Stocking rate (cows & calves/ha)	3,0		4,12		5,34		6,74	
Breed	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X	Simm.	Her.-X
Income per cow:								
Calf weaning mass (kg)	244,8	220,4	225,5	201,1	204,5	180,0	180,4	156,0
Assumed price/kg calf livemass	115c	114c	114c	113c	113c	112c	112c	110c
Value of weaner (1)	R 281,5	R 251,3	R 257,1	R 227,2	R 231,1	R 201,6	R 202,0	R 171,6
8,3% X salvage value of cow at R 0,9/kg livemass (2)	R 37,8	R 36,9	R 36,5	R 35,6	R 35,1	R 34,1	R 33,4	R 32,5
Total income (1+2) = A	R 319,3	R 288,2	R 293,6	R 262,8	R 266,2	R 235,7	R 235,4	R 204,1
Feed costs per cow:								
Summer cost (Pasture & lick)	R 108,4	R 108,4	R 82,4	R 82,4	R 64,5	R 64,5	R 52,8	R 52,8
Winter cost (Silage, HPC, lick)	R 115,3	R 104,4	R 134,8	R 119,4	R 151,5	R 143,7	R 183,2	R 162,7
Total cost = B	R 223,7	R 212,8	R 217,2	R 201,8	R 216,0	R 208,2	R 236,0	R 215,5
Margin over feed cost:								
Per cow (A-B)	R 95,6	R 75,4	R 76,4	R 61,0	R 50,2	R 27,5	- R 0,6	- R 11,4
Per hectare	R 286,8	R 226,2	R 314,8	R 251,3	R 268,1	R 146,9	- R 4,04	- R 76,3
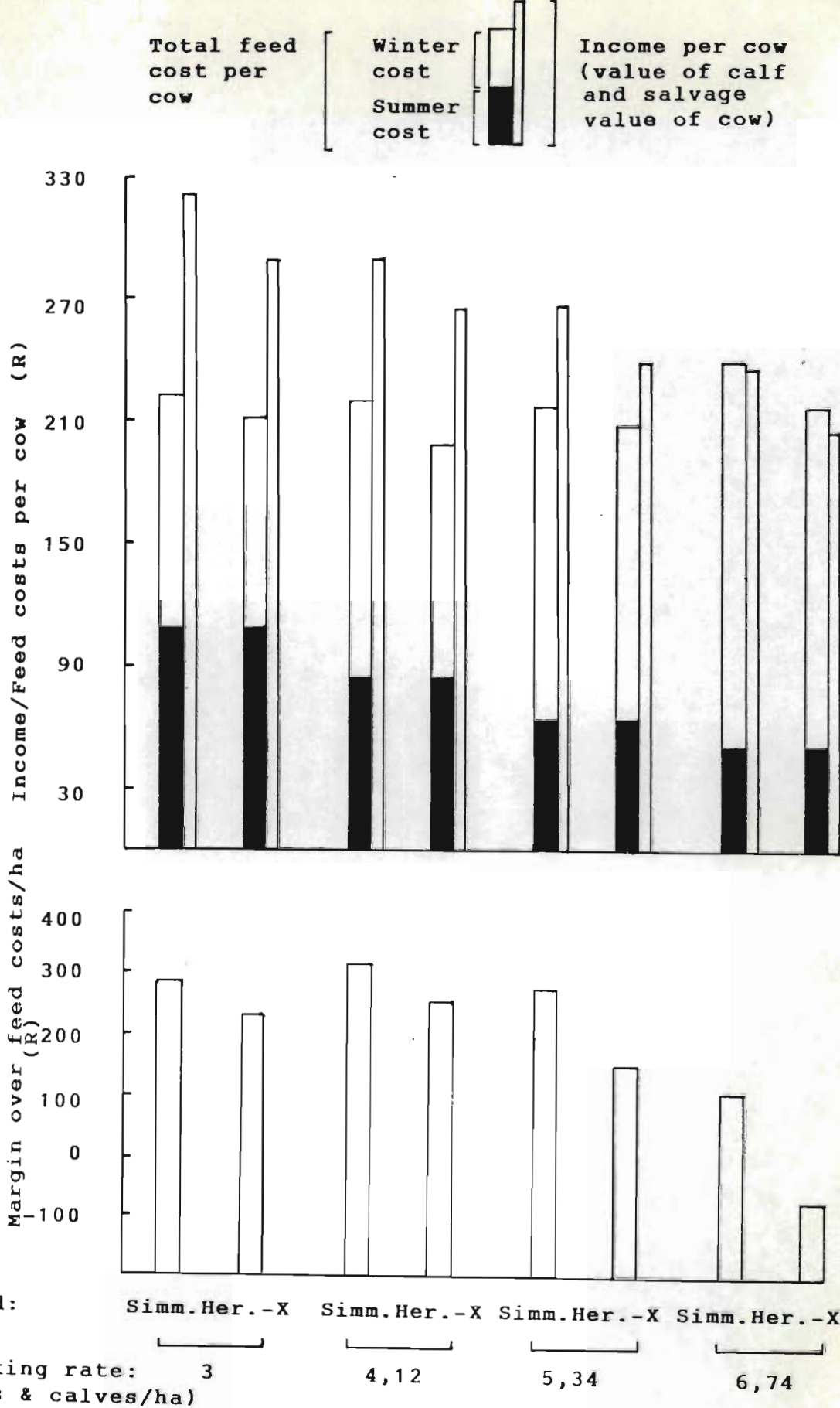
Fig. 14. Income per cow, feed costs per cow and margin over
feed costs per ha in Simmentalers and Hereford-
crosses subjected to four stocking rates on pasture.

DISCUSSION

The Simmentaler cattle used in the present investigation can be regarded as being somewhat small in size, relative to those investigated in an extensive study by Eden & Smit (1982), and to those subjected to the performance testing scheme in South Africa (Bosman, Hunlun & Gibson, 1984). Thus, the mean birth mass of 34,1 kg (Table 12) and the cow mass after calving of 480,2 kg is approximately nine and four percent lighter than that measured by Eden & Smit (1982), and 12,6 and 7,0% lighter than the means for commercial performance-tested Simmentalers, respectively. When comparing mean masses of the Hereford-crosses used in the present investigation with those of performance-tested pure Herefords, it is evident that birth masses are virtually identical at 33 kg, and cow masses differ by approximately 12 kg (465,6 kg in the present study and 454 kg in performance-tested herds). On average the Simmentaler cows in the present study were only 15 kg heavier than their Hereford-cross counterparts.

The amount of rain recorded during the three seasons investigated was relatively low when compared to the long-term average precipitation (Fig. 1). Whilst this phenomenon can be regarded as being unfortunate from the point of view of gaining production parameters under average rainfall conditions, it does hold one advantage. Trials involving the measurement of animal responses to different treatments serve a useful purpose only when the results thereof are judiciously used to predict future responses. Future rainfall trends cannot be forecast with accuracy, and the prediction of results based on data obtained during "good" rainfall years may lead to serious economic implications during ""bad" years. The results obtained under the relatively low rainfall conditions of the present study do thus provide conservative

estimates of production parameters obtainable on pasture.

Season exerted an influence on virtually all parameters of cow and calf performance on pasture (Tables 6, 13, 14). The exceptions were condition score changes (Table 8) and reconception rates in cows. The length of the different grazing periods on pasture decreased, and cows and calves gained less (or lost more) mass as the trial progressed from season to season. The total annual rainfall on a September to August basis also progressively decreased over the three seasons, but the rain measured during the active growing season of the pasture (September to April) was highest during the second (1981/82) of the three seasons (Fig. 1). This was mainly due to exceptionally large falls during November and March of the 1981/82 season. It therefore appears that total rainfall alone did not determine production levels in this study. It was noteworthy that rainfall distribution was most favourable during 1980/81, which was the best season in terms of animal performance, and least favourable during the 1981/82 season, the one with the highest summer rainfall of the three studied. It is likely that the progressive reduction in production levels over the course of the trial was due in part to the cummulative effect on pasture yields of three relatively dry seasons in succession.

Season accounted for approximately 10% of the variation in calf gain until weaning (Table 14), a finding similar to that of Brown (1960), who noted that year effects were responsible for about seven percent of the variation in weaning mass. Brown (1960) also warned against the potential danger of confounding seasonal effects with those caused by changes in the genetic constitution of experimental herds. It seems unlikely that this phenomenon exerted a major effect on the

results obtained in the present study. Variations in calf gain due to season were caused mainly by differences in climatic conditions, which resulted in large variations in the length of the grazing periods between seasons (Table 4). On average, calf gains differed by 26 kg from season to season (Table 14), which was more than the 20 kg due to season recorded by Burgess, Landblom & Stonaker (1954), 4,0 kg by Neville (1962) and 8,1 kg measured by Rutledge, Robison, Ahlschwede & Legates (1971). Calf growth rates were also significantly influenced by season in the studies conducted by Reynolds, de Rouen & Bellows (1978) and Williams, Anderson & Kress (1979).

Stocking rate exerted a significant influence on cow mass and condition changes on pasture (Figs. 4, 6). These results are in general agreement with those of Drennan (1971a,b), Baker, Alvarez & Le Du (1981a), Baker, Le Du & Alvarez (1981b) and Baker, Barker & Le Du (1982a), who studied temperate pastures stocked at rates lighter than those used in the present study. The mass gains which followed the temporary losses in cows stocked at rates of 5,34 and 6,74 cows and calves/ha each season (Fig. 4) cannot be explained on the basis of related increases in rainfall, and therefore herbage quantity. The temporary gains possibly occurred as a result of a reduced nutrient requirement in the cows following fairly rapid decreases in their level of milk production (Fig. 11). A portion of the ingested nutrients may then have been partitioned into livemass gains, whereafter, and towards the end of the grazing season, insufficient grass was available to further sustain mass increases. Somerville, Lowman, Edwards & Jolly (1983) also noted that cows mobilize bodymass during early lactation when milk yields are relatively high, and

later regain a portion of this livemass when daily milk yields decrease.

Cows stocked at the rates of 3,0 and 4,12 cows and calves/ha gained mass and condition for the major portion of the grazing period (Figs 4, 6) This phenomenon of mass and condition gain appears inefficient from a production point of view, since overfat cows at weaning reflect unnecessarily large nutrient intakes during lactation. However, as Drennan (1971b) emphasized, this process may not be that inefficient, since the use of body reserves during the dry period results in a substantial saving of winter feed supplies. The results of van Niekerk (1982) clearly stress the economic advantage of maintaining cows in good condition as compared to feeding them in poor condition during the winter months.

Male calves were significantly and approximately 10% heavier than females at birth (Table 13). This agrees with the results obtained by a large number of workers, including Lasley, Day & Comfort (1961), Ellis, Cartwright & Kruse (1965), Reynolds, de Rouen, Meyerhoeffer, Wiltbank & Temple (1965), Koonce & Dillard (1967), Nelson & Huber (1971) and Laster, Glimp, Cundiff & Gregory (1973). A relatively large birth mass is one of the main factors contributing to the incidence of dystocia in beef cows (Sagebiel, Krause, Sibbit, Langford, Comfort, Dyer & Lasley, 1969; Bellows, Short, Anderson, Knapp & Pahnish, 1971; Laster et al., 1973), although Amir, Kali, Volcani & Perlman (1967) consider that calf size relative to maternal size is more important than birth mass per se. In the present study one would thus have anticipated a greater incidence of difficult calvings in Simmentaler than in Hereford-cross cows, and in cows giving

birth to males than to females, since Simmentaler and bull calves were heavier than, and constituted a greater proportion of their dam's mass after calving than Hereford-cross and heifer calves, respectively (Table 12). However, the incidence of dystocia in this study was relatively small. Schultze (1965) concluded that dystocia was more prevalent when birth mass constituted more than eight to nine percent of cow mass. In the present study this percentage averaged 7,2%, and this probably accounted for the virtual absence of calving difficulties. Calf losses between birth and one month thereafter were relatively large (3,7%), and it is possible that certain of the calvings considered to be normal were in fact associated with a certain degree of (undetected) difficulty, resulting in the death of calves shortly after birth.

Stocking rate was responsible for only 20% of the variation in calf gain over the common period, and 48,1% of the variation until weaning (Table 14). Differences in gain until weaning were thus largely due to differences in the length of the different periods on pasture. It is also evident from Fig. 7 that stocking rate exerted a larger influence on calf gain during the second than the first half of the different periods on pasture. This agrees with the finding of Drennan (1971b), who showed that stocking rates which varied from 2,47 to 4,94 cows and calves/ha influenced calf gains only during the final three months of a seven-month grazing period. The initial half of the grazing period in the present study coincided with the months of the year (November to January) when, due to relatively favourable conditions of rainfall and temperature (Fig. 1), the pasture was most

productive. Intake restrictions due to stocking rate were thus probably relatively small. Baker et al. (1981b) concluded that suckling calves are to a large extent buffered against the effects of a low herbage intake by the milk they receive. In the present study milk yields were larger during the initial than the final half of the grazing period (Fig. 11). This factor probably also contributed to the relatively small difference in calf gain between stocking rates during the first half of the period on pasture.

The relationship between stocking rate, weaning mass and total weaner production on a hectare basis (Fig. 8) illustrates that maximum production of calf mass per hectare was not achieved in the present study. Extrapolation of the relationship depicted in Fig. 8 indicates that calf production on a hectare will in theory be maximised at stocking rates of 8,61 and 7,9 cows and calves/ha in the Simmentalers and Hereford-crosses, respectively (Fig. 9). This exercise clearly emphasizes the danger of indiscriminate data extrapolation though, and the failure to recognize the importance of all facets of production. Thus, weaners would on average weigh only 148 kg (Simmentalers) and 136 kg (Hereford-crosses) at the stocking rates which provide for maximum calf mass per hectare. The production of such light calves is likely to lead to relatively high mortality rates, complicate future marketing strategies and increase costs of heifer raising. Reconception rates could be adversely affected in cows, and their grazing period will be shortened, leading to longer periods of winter feeding. It can therefore be concluded that an increase in stocking rate between the lightest and heaviest used in this investigation will lead to a decrease in weaning

mass and an increase in total weaner production per hectare (Fig. 8). Further research is necessary to establish the physical and economical implications of utilizing stocking rates heavier than those employed in this study.

Breed accounted for 10% of the variation in calf gain on pasture (Table 14), and on average Simmentaler calves were approximately 24 kg or 13% heavier than Hereford-crosses at weaning. South African performance-tested Simmentaler calves weigh on average 20% more at 205 days than Hereford calves (Bosman et al. , 1984). The smaller difference due to breed obtained in the present study than between the different performance-tested calves may be partly due to the beneficial effect of hybrid vigour on calf growth in the Hereford-crosses. Paterson, Venter & Harwin (1980a) noted a difference of six to 10% between adjusted weaning masses of creep-fed Simmentaler and Hereford calves kept at two locations in an intensive pasture-based system. Creep feeding may have favoured the Hereford calves more than the Simmentalers in their study, accounting for the smaller breed-related difference in weaning mass than obtained in the present investigation.

The finding that sex influenced calf mass gains on pasture (Table 14) is in agreement with that of a large number of workers, including Brown (1960), Bradley, Cundiff, Kemp & Greathouse (1966), Cundiff, Willham & Pratt (1966b), Bair, Wilson & Ziegler (1972), Fahmy & Lalande (1973) and Nelsen & Kress (1981). A literature survey clearly indicates that the magnitude of sex-related differences in calf growth varies from study to study. This variation is probably due to differences in castration age and pre-weaning nutritional

levels between studies.

Mass gains on pasture did not differ between calves nursed by dams of different ages (Table 14). This result disagrees with that of a number of workers who have studied calf performance in relation to cow age. In general they found that calf gains and weaning masses increase as dam age increases from two to four years, reach a peak when cows are five to nine years old and progressively decrease again when cows are 10 years and older (Marlowe & Gaines, 1958; Cundiff, Willham & Pratt, 1966a; Kress & Burfening, 1972; Fahmy & Lalande, 1973; Anderson & Willham, 1978; Butson, Berg & Hardin, 1980; Nelsen & Kress, 1981). A number of workers reported interactions between breed and age of dam for weaning mass (Koger, Reynolds, Meade, Kirk, Peacock & Kidder, 1962; Sellers, Willham & de Baca, 1970; Cardellino & Frahm, 1971). It was for example observed by Paterson et al. (1980b) that cows of the British Beef and Bos indicus type reach peak production (in terms of the weaning masses of their calves) at an earlier age than the Dual Purpose types. Cow age did not influence milk production in the present study (Table 20), a result at variance with that of Melton, Riggs, Nelson & Cartwright (1967), Jeffery, Berg & Hardin (1971b), Williams et al. (1979) and Gaskins & Anderson (1980). It was observed by Robison, Yusuff & Dillard (1978) that milk production increased with age in cows between two and five years, was relatively constant until cows were eight years and declined in cows nine years and older. Rutledge et al. (1971) concluded that age-of-dam effects on calf performance were mainly due to age-related differences in milk production. The number of first-calvers and mature cows used in the present

investigation was probably too small to accurately assess differences in calf gain and milk production due to cow age. Furthermore, all first-calvers were sired by bulls kept at an A I station, and probably of superior genetic ability than the bulls used to sire the mature cows. Bosman & Harwin (1966) attributed the lack of an age-of-dam effect on weaning mass to the introduction of a performance testing programme in the herds they surveyed. Young cows were most favoured by the benefits of this technique, and thus represented a higher-performing group than the older cows. Schaeffer & Wilton (1974) suggested that in relatively high-performing herds an increase in cow age above three years would produce a smaller improvement in calf gain than in low-performing herds. It is also probable that differences in calf growth due to cow age would be smaller in herds kept on established pastures than those on lower quality forages, such as veld.

There was a tendency for an increase in stocking rate during the pre-weaning period to be associated with an increase in the dry matter intake of calves, expressed as a percentage of their bodymass, when fed a silage-based ration after weaning (Fig. 10). This phenomenon could be explained on the basis of compensatory intake, should one correctly assume that calves stocked at the heaviest rates prior to weaning underwent a greater degree of intake restriction than calves stocked at the lighter rates. Winchester & Howe (1955) showed that animals previously underfed have greater feed intakes during the period of realimentation than those previously well nourished. Le Du & Baker (1978) also found a relationship between pre- and post-weaning feed consumption. In their trials the calves which consumed least silage after weaning

were those which consumed least milk, and most forage before weaning. These results cannot be compared with those of the present study, since the latter did not involve an estimation of forage intake. After weaning the calves previously stocked at the three heaviest rates grew equally fast, but significantly slower than those stocked at the lightest rate before weaning (Table 18). The latter group also converted their feed more efficiently into gain than the former group. This result cannot be explained on the basis of calf mass, since regression analyses indicated that post-weaning gains were not influenced by the mass at weaning. Further research is clearly required to examine the influence of pre-weaning stocking rate on post-weaning calf performance. The limited data obtained in the present investigation suggest that the interaction between these facets of production may influence overall profitability.

Peak daily milk yields were reached on Days 52 and 68 of lactation in the Hereford-cross and Simmentaler cows, respectively. This result concurs with those of Dawson, Cook & Knapp (1960) and Gleddie & Berg (1968) who observed peak yields on Day 60 of lactation, whereas Robison et al. (1978) showed that yields were similar for the first 60 days after calving, and declined thereafter. Other researchers reported that maximum yields occur earlier than were measured in the present study. These occurred at between seven and 14 days in beef cows treated as dairy animals (Lowman, Edwards, Somerville & Jolly, 1979), at 20 days (Kress & Anderson, 1974), 28 days (Heyns, 1960a) and during the first six weeks of the suckling period (Gifford, 1949). Amar, Frahm, Nizzel & Cobb (1977) found that daily yields tended to increase until

the third month of lactation, and declined thereafter. The rate at which milk yields decline after having peaked evidently depends on a number of factors. In the present study one such factor was stocking rate, since cows at the two heaviest rates were significantly less persistent in their production than cows at the two lightest rates (Table 19). Breed of cow influenced persistency only at the stocking rate of 3,0 cows and calves/ha, at which the higher-yielding Simmentalers were more persistent than the lower-yielding Hereford-crosses (Table 19). This result suggests that Simmentalers are inherently more persistent than Hereford-crosses, but were allowed to express this superiority only under the relatively abundant forage conditions created by the use of a light stocking rate. The results presented in Fig. 7 tend to support this suggestion. Thus, the difference in growth rate between Simmentaler (but not Hereford-cross) calves stocked at rates of 3,0 and 4,12 cows and calves/ha was considerably greater during the 1980/81 than the other seasons. The total seasonal rainfall was higher, rainfall distribution more favourable (Fig. 1) and forage production probably greater during the former than the latter seasons. Consequently, Simmentaler cows stocked at the lightest rate were probably more capable of expressing their true milk production potential than those stocked at the heavier rates during 1980/81 than during the other seasons.

Breed of cow accounted for 5,3% of the variation in FCM yields on pasture and approximately 12% of the variation in the yields of protein, lactose and SNF (Table 20). Over all stocking rates the Simmentalers produced 6,4 litres, or 27% more, than the 5,0 litres per day produced by the

Hereford-crosses over the 178-day period on pasture (Table 21). These results are consistent with the reports in the literature of relatively larger yields in Dual-Purpose and dairy-type cattle than in the British Beef breeds (Preston & Willis, 1974; Notter, Sanders, Dickerson, Smith & Cartwright, 1979a; Chenette & Frahm, 1981). Butson et al. (1980) showed that dairy-beef cows are more persistent in their production of milk than beef cows. In the present study the Simmentalers displayed greater persistency than the Hereford-crosses only at the stocking rate of 3,0 cows and calves/ha (Table 19). Certain workers (Todd, Riggs & Smith, 1968) found that breed of cow influences milk composition, whereas others (Jeffery & Berg, 1971) failed to demonstrate such an effect. In the present investigation breed influenced the total yields of the different constituents, but affected the percentage of fat only at the commencement of the grazing period, whereafter this difference became progressively smaller (Fig. 12). Other constituent levels were not affected by breed. Heterosis for milk production averages about 15% (Notter, Cundiff, Smith, Laster & Gregory, 1978), and probably affected milk yields in the Hereford-crosses. In this context it is interesting to note that Nicol (1976) obtained evidence to indicate that increased suckling time in crossbred calves is also an expression of heterosis, and this may stimulate cows to produce more milk, which in turn will lead to faster-growing calves.

Stocking rate significantly influenced milk and milk component yields on pasture, but accounted for less than four percent of their total variation (Table 20). It is also evident from Table 20 that protein yield was the milk

constituent most influenced by stocking rate. Other workers have studied milk production in beef cows grazing temperate pastures, but these were generally not as heavily stocked as in the present experiment. A significant influence of stocking rate on milk production and its components was obtained by Baker et al. (1981a), Baker et al. (1982a) and Baker, Le Du & Barker (1982b). Milk yields were influenced by stocking rate in the study by Baker et al. (1981b), but it exerted no influence on the concentrations of fat, protein and lactose. Stocking rates on pasture which varied from 2,47 to 4,94 cows and calves/ha exerted no influence on milk yield in the study by Drennan (1971a). He did however stress that the milk yield response to stocking rate can be markedly influenced by the condition of the cows at the commencement of the grazing season.

The significant influence of stocking rate on milk production observed in the present and other studies is in keeping with the important influence of nutrition on this trait in beef cows. Richardson, Oliver & Clarke (1977) concluded that "food consumption is the single most important variable to which milk yields are related in beef cows". It is a well established fact that milk yields in suckler cows are influenced by post-calving energy (Bond, Wiltbank, Warwick, Lehmann & Kinney, 1964) and protein intakes (Howes, Hentges, Warnick & Cunha, 1958).

Total FCM production on pasture increased by on average 2,4 litres for every day that calving occurred later during the calving season (Table 20). This result is in general agreement with that of Jeffery et al. (1971b) and Neville, Warren & Griffey (1974). The early-calving cows in the present

study were fed conserved feeds for a longer period after calving, and prior to grazing pasture, than the cows which calved later in the season. A possible explanation for the difference in milk yield due to calving date is that the conserved feed regime utilized after calving was inferior to kikuyu grazing as regards milk production potential. On the other hand the analysis summarized in Table 14 indicated that livemass gains on pasture were larger in calves born earlier than in those born later. This apparent contradiction could be explained on the basis of the early-born calves being heavier when placed on grass, and they subsequently grew faster due to better rumen development, despite having access to lower milk yields than calves born later in the season. Baker et al. (1982a) and Baker et al. (1982b) also found that the so-called "turnout mass" of suckling calves positively influences subsequent gains on grass. In this context it is interesting to note that by the time the calf is three months old it derives more than half of its energy from non-milk sources (Maddox, 1965).

Within each of the four stocking rates there was a tendency for cows which produced larger quantities of milk to gain less, or lose more mass than those which produced smaller yields. The correlation coefficients which describe the relationship between milk yield and mass change were not significant, but this was probably due to the relatively small number of animals studied per stocking rate. A negative relationship between milk yield and mass gain was obtained by a large number of workers, including Vaccaro & Dillard (1966), Todd et al. (1968), Wilson, Gillooly, Rugh, Thompson & Purdy (1969), Neidhart, Plasse, Weniger, Verde, Beltran & Benavides

(1979) and Trigg & Topps (1981). Improved cow condition towards the end of the suckling period has also been related to decreased lactational performance by Hohenboken, Hauser, Chapman & Cundiff (1973), Jeffery et al. (1971b), Kress & Anderson (1974) and Boggs, Smith, Schalles, Brent, Corah & Pruitt (1980).

The mass of cows within 14 days of calving (a measure of size) exerted no influence on milk yield on pasture (Table 20). The majority of workers in this field (Lampkin & Lampkin, 1960; Christian, Hauser & Chapman, 1965; Gillooly, Wilson, Thompson, Rugh, Long & Purdy, 1967; Todd et al., 1968; Hohenboken et al., 1973) similarly failed to obtain a relationship between milk production and cow size. Correlations describing the association between body measurements and milk production were also small and nonsignificant (Williams et al., 1979). A tendency for milk production to increase with cow size was noted by Wilson et al. (1969) and Rutledge et al. (1971), whereas Richardson et al. (1977) observed a significant positive relationship between calving mass and milk yield between 36 and 91 days of lactation. Jeffery et al. (1971b) reviewed research results in dairy cattle, and concluded that selection for bodymass in beef cows is unlikely to result in an associated increase in milk yield.

Kropp, Stephens, Holloway, Whiteman, Knori & Totusek (1973) observed that Holstein cows produce as much milk during late as during early lactation. They attributed this phenomenon to the limited intake of milk during early lactation by a relatively small calf. Earlier Gifford (1953) and Heyns (1960b) also obtained evidence to show that one of

the major factors influencing the shape of the lactation curve is the milk-consuming capacity of the calf. In the present study the birth masses of Simmentaler and Hereford-cross calves influenced their dam's milk production during the initial 90 days of lactation. However, the effect of birth mass accounted for only about 15% of the variation in yield, and was diluted to become nonsignificant when regressed against milk production on pasture (Table 20). This result agrees closely with those of Eden (1970) and Robison et al. (1978). A number of researchers have reported a positive relationship between calf birth mass and milk yield (Drewery, Brown & Honea, 1959; Neville, 1962; Schwulst, Sumption, Swiger & Arthaud, 1966; Drennan, 1971a; Rutledge et al., 1971; Nicol, 1976; Neidhart et al., 1979; Somerville et al., 1983). On the other hand certain authors failed to demonstrate such an association (Brumby, Walker & Gallagher, 1963; Christian et al., 1965; Gleddie & Berg, 1968; Baker et al., 1982a). Nicol (1976) observed that the time spent suckling by calves was not related to their birth mass. The aforementioned disagreement in the literature can probably be ascribed to differences in the level of milk production, relative to calf appetite. In the present study birth mass influenced milk production during early lactation, whereafter it seems likely that factors such as stocking rate (Fig. 11) became relatively more important as determinants of milk yield level.

The relationship between milk production and calf growth has been widely studied, in attempts to guage the extent to which calf performance is dependant on the milk supply of the dam. The relationship between these variables is not really comparable from study to study, because of different genetic

and environmental inputs utilized by different researchers.
For example, the influence of milk production on calf growth
is not always studied over lactation periods of equal length.
Gleddie & Berg (1968) have suggested that correlations
describing this relationship would decrease in magnitude with
delayed weaning, since it is known that milk yield and calf
growth rate are more strongly associated during the earlier
(month one to three) than the later stages of the suckling
period (Nevillle, 1962; Melton et al., 1967; Boggs et al.,
1980; Holloway, Worley & Butts, 1983). In the present study
correlation coefficients of approximately 0,65 and 0,38 were
obtained for the relationship between milk yield and calf
growth between 30 and 90, and 90 and 180 days of lactation,
respectively (Table 24). Heyns (1960b), working with Africaner
cattle on veld, measured corresponding coefficients of 0,7 and
0,5, respectively. Gifford (1949) observed a coefficient of
0,6 for the first three months of lactation, whereafter milk
yield and calf gain were not associated. Furthermore,
correlation coefficients are not comparable because of
differences in forage quality between studies. Holmes, Takken
& Seifert (1968) concluded that milk production may be as
important, in terms of its influence on calf growth, during
the sixth as during the first month of the suckling period,
depending on the quality of the available grazing. The
association between milk consumption and calf gain also
becomes less strong when calves have access to creep feed
(Carpenter, Fitzhugh, Cartwright & Thomas, 1972; Hohenboken
et al., 1973; Marshall, Parker & Dinkel, 1976). A correlation
coefficient of 0,88 for the relationship between milk yield
and calf gain was reported by Totusek et al. (1973). They

suggested that this strong association was due to the limited quantity of supplemental feed available to calves. Further factors which complicate a comparison of the degree of association between milk production and calf gain between studies are the different techniques used to measure milk yield and to analyse data. It is therefore clear that a comparison of results obtained in the present and other studies should be viewed with caution.

Milk yield of the dam accounted for half of the explainable variance, and 40% of the total variation in calf gain on pasture (Table 23). A number of workers have used multiple regression procedures to determine the extent to which calf gains are influenced by milk production. Milk yield accounted for 71% (Gleddie & Berg, 1968), between 66 and 72% (Furr & Nelson, 1964) and 60% (Jeffery & Berg, 1971; Jeffery, Berg & Hardin, 1971a) of the variation in calf gain. Milk yield normally accounts for a smaller proportion of the variation in weaning mass than in pre-weaning gain (Jeffery & Berg, 1971). Simple linear regression analyses of milk yield on calf gain yielded correlation coefficients of 0,14 to 0,4 (Gifford, 1953; Melton et al., 1967; Todd et al., 1968; Hohenboken et al., 1973; Chenette & Frahm, 1981), 0,4 to 0,6 (Wilson et al., 1969; das Neves, Wallace & Herbel, 1974; Reynolds et al., 1978; Somerville et al., 1983) and in excess of 0,6 (Furr & Nelson, 1964; Gleddie & Berg, 1968; Holmes et al., 1968; Jeffery et al., 1971a). In the present investigation correlation coeffients of approximately 0,5 were obtained for the milk yield : calf gain relationship on pasture, 0,59 (Simmentaler) and 0,73 (Hereford-cross) for the period between 30 and 90 days of lactation, and approximately 0,38 for the

period between 90 and 180 days of lactation (Table 24). An examination of the experimental procedures followed in other trials fails to provide clear-cut reasons for the widely varying correlations reported between studies. The relatively lower proportion (40%) of the total variation in calf gain accountable for by milk production in the present study than in others could be ascribed to the use in this trial of four stocking rates, a procedure likely to diminish the influence of milk supply on calf gain, relative to studies in which a single stocking rate (or feeding regime) was used. Thus, between 46 and 76% of the variation in calf gain could be attributed to milk when this relationship was separately studied at each of the four stocking rates. There was no trend for calves to be more dependant on milk at certain than at other stocking rates, or for Simmentaler calves to be more dependant on milk than Hereford-cross calves. However, from the results presented in Table 24 it is evident that the association between milk yield and calf gain was stronger in the Hereford-crosses than in the Simmentalers during early lactation (Days 30 - 90).

Overall it would appear that the hypothesis postulating that calves are not dependant on the milk yield of their dams to achieve acceptable growth rates on high quality pasture can be rejected with confidence. The positive association recorded between these traits (Tables 20, 24), although not as strong as in certain other studies, justifies such a conclusion.

Various workers agree that milk quantity rather than quality is an important determinant of growth rate in suckling calves (Gleddie & Berg, 1968; Wilson et al., 1969; Jeffery et al., 1971a; Rutledge et al., 1971; Butson et al., 1980

Mondragon et al., 1983). The results of the present study tend to support these findings, since correlations between calf gain and milk volume did not differ from those between calf gain and the yields of the different components (Table 24). The finding by Heyns (1960b) that the correlation between calf gain and protein yield was higher than that between gain and milk yield agrees with the results obtained in the Simmentalers, but not in the Hereford-crosses (Table 24). Christian et al. (1965) found that weaning masses were more closely associated with butterfat and SNF production than milk volume during the first 60 days of the calf's life. They attributed this finding to the calf's need for a highly concentrated source of energy at a time when consumption is limited by the stomach capacity. Gifford (1953) and Melton et al. (1967) showed that the correlation of calf gain on fa yield was smaller than that of gain on milk yield.

Certain generalisations may be made when relating milk component levels measured in the present experiment to those obtained by other workers, although these are not strictly comparable. Milk butterfat percentages on pasture varied from approximately 4,1 to 5,3% (Fig. 12), and were considerably higher than the overall means of approximately 2,8% reported by Heyns (1960a) and Melton et al. (1967). The relatively low percentages recorded by these workers might have been, as was suggested by Heyns (1960a), the result of incomplete let-down of milk during the process of withdrawal. The fat percentages measured in the present study are also generally higher than the three to four percent recorded by Gifford (1949), Dawson et al. (1960), Klett, Mason & Riggs (1965), Gleddie & Berg (1968), Todd et al. (1968) and Wilson et al. (1969). They are

however similar to the percentages (4,1 to 5,1) obtained in Hereford cows grazing sub-tropical and legume pastures in Australia (Holmes et al., 1968). The milk protein percentages measured in the present study (3,2 to 3,9%; Fig. 12) are in fairly close agreement with the percentages of 4,1 measured by Heyns (1960a) and 3,5 obtained by Gleddie and Berg (1968), but are somewhat higher than the 2,97 to 3,03% obtained by Schwulst et al. (1966). The SNF level of approximately 8,7% agrees closely with that obtained by Schwulst et al. (1966), Melton et al. (1967), Gleddie & Berg (1968) and Todd et al. (1968), but is somewhat lower than the 10,6% recorded by Heyns (1960a). The overall lactose level of 4,7 to 5,0% measured in the present study is also lower than the 5,6% obtained by Heyns (1960a).

There seems little doubt that milkfat percentages increase as lactation progresses (Gleddie & Berg, 1968; Jeffery & Berg, 1971; Lawson, 1981). The results obtained in the present study (Fig. 12) substantiate this finding, and could be explained in part on the basis of an increase in the fibre content of the kikuyu grass during the latter stages of the suckling period. A relatively high fibre content in forage is associated with relatively high milkfat levels (Chenette & Frahm, 1981). Mondragon et al. (1983) surprisingly found that milkfat concentrations were highest during early lactation. The observation that SNF percentages remain fairly constant throughout lactation (Fig. 12) agrees with that of Klett et al. (1965), Gleddie & Berg (1968) and Rutledge et al. (1971). It was reported by Lawson (1981) and Mondragon et al. (1983) that protein levels gradually increase as lactation progresses, and this agrees with the results summarized in

Fig. 12. Lactose percentages appear to vary little during lactation (Mondragon et al., 1983; Fig. 12 of the present study).

The strong positive relationship (a r-value in excess of 0,95) between milk volume and the yields of the different components (Table 22) agrees with the reports of a number of workers, including Heyns (1960a), Jeffery & Berg (1971), Totusek et al. (1973), Butson et al. (1980) and Chenette & Frahm (1981). The weak and predominantly negative association between milk yield and the percentages of the different constituents (Table 22) concurs with results reported by Heyns (1960a), Gleddie & Berg (1968), Wilson et al. (1969), Jeffery & Berg (1971), Totusek et al. (1973) and Chenette & Frahm (1981).

Butterfat and protein percentages were positively correlated in the Simmentalers and Hereford-crosses, although this relationship was significant only in the latter breed-type (Table 22). This result is at variance with that of Gleddie & Berg (1968), who reported a negative and nonsignificant relationship between the levels of these components.

A comparison of milk conversion rates obtained in the present study with others reported on in the literature should be performed with caution, since the efficiency of conversion is sensitive to factors such as the length of lactation, the rate of calf gain and the level of milk production. Calves which suckled high-producing dams made smaller gains from a given volume of milk than those which suckled low-yielding cows (Table 25). This finding agrees with results reported by Drewry et al. (1959) and Deutscher & Whiteman (1971). The

detailed study by Wyatt, Gould, Whiteman & Totusek (1977)

probably best illustrates this effect. They showed that the

milk conversion efficiency is reduced by 51% in calves given

access to more than 10 litres of milk per day, relative to

those which receive less than five litres each day. It is

possible that calves which consume more milk also substitute

more milk for grass, and the resultant combination of milk and

grass is less condusive to a given livemass gain than in

calves which consume less milk. Support for this explanation

is provided by Wyatt, Gould, Whiteman & Totusek (1977), who

showed that calves which receive the large allowance of milk

consume 26% less creep feed than those which receive the small

allowance. Possibly calves which consume more milk deposit a

larger quantity of fat in their bodies than those consuming

less milk, and the conversion of milk to fat is less efficient

than that of milk to protein (or muscle). Calves consuming

more milk are also generally larger and have a higher

maintenance requirement than those receiving less milk, and

this factor could contribute to the poorer conversion

efficiency in the former group.

Less milk was required per kilogram of calf gain during

the second than the first half of the period on pasture (Fig.

13). This result is similar to that obtained by Drewry et

al. (1959), Heyns (1960a), Lampkin & Lampkin (1960), Boggs et

al. (1980) and Holloway et al. (1982). These workers observed

that calves make more efficient use of milk as they become

older, and attributed this phenomenon to an increase in the

proportion of the diet from non-milk sources. The finding that

male calves make more economical use of the milk they consume

than females (Table 25) agrees with that of Lampkin & Lampkin

(1960), and probably reflects the overall superior growth

efficiency of steers above heifers. Simmentaler calves were

also more efficient in their use of milk than the

Hereford-crosses (Table 25). A breed difference was also noted

in the study of Amar et al. (1977), in which Hereford calves

required less milk per kilogram of gain than their Angus

counterparts.

Margins over feed costs per cow were between R12 and R23

larger in the Simmentalers than in the Hereford-crosses over

the four stocking rates investigated (Table 27). Margins over

feed costs per hectare also favoured the Simmentalers by more

than R60 throughout. Simmentaler calves were about 25 kg

heavier at weaning than the Hereford-crosses (Table 26), and

this difference was largely responsible for the higher

margins obtained in the former breed. Income from Simmentaler

cows was only marginally favoured by their higher salvage

value, relative to the Hereford-crosses (Table 27). On average

the Hereford-cross cows were only about 12 kg lighter, but in

better condition (approximately a third of a score higher)

than the Simmentalers (Table 26). Wintering costs per

Hereford-cross cow were consequently between eight and 20 Rand

lower than per Simmentaler cow. Rebreeding efficiency did not

differ significantly between the two types (Table 10).

Consequently, one might conclude that the Simmentalers were

more profitable, and therefore more suited to the conditions

employed in the present study than the Hereford-crosses.

However, as usually applies to results obtained from this type

of research, conclusions need to be qualified. This

investigation compared cowherds which yielded the weaner calf

as end-product. It is possible that British Beef cowherds will

be more profitable than the Dual Purpose types in systems
involving the deferment of weaners for subsequent rearing and
ultimate marketing off the farm with a minimum of grain
feeding. Under these conditions the relatively early stage at
which British Beef cattle attain carcase maturity is a decided
advantage. It could outweigh the disadvantage of a slower
growth rate, relative to that attainable in the Dual Purpose
types. Clearly, the marketing options available to the
producer should be carefully evaluated prior to deciding on
the cowherd type for use on intensive pastures. From the
results of the economic analysis conducted in this study
(Table 27) it is evident though that Dual Purpose cowherds are
more profitable than their British-cross counterparts when
utilizing cultivated pastures, and when calves are marketed at
or shortly after weaning.

The margin over feed costs per cow was largest at the
lightest stocking rate in both breeds, and decreased with an
increase in stocking rate (Table 27). On a hectare basis the
largest margins were achieved at a stocking rate of 4,12 cows
and calves/ha, and at 5,34 cows and calves/ha when winter feed
costs were assumed to be 40% of those incurred in the present
study. It is clear therefore that there is no "best" or most
profitable stocking rate for all situations. Limiting physical
resources need to be identified for each potential production
strategy, prior to deciding on which stocking rate to utilize.

Conclusions relating to reproductive rates in the present
study should be drawn with care, since cow numbers were
relatively small. The impact on rebreeding efficiency of one
cow conceiving or failing to become pregnant was therefore

relatively large. It is evident though that the overall
reconception rate of 65% (Table 10) was disappointingly low.
Various factors which could have influenced rebreeding
efficiency were examined (Table 11), but none provided
clear-cut reasons for the relatively poor results obtained.
Calving occurred significantly earlier in the Simmentalers
which reconceived than those which subsequently failed to
conceive, but no such effect was apparent in the
Hereford-crosses. Most cows (approximately 93%) exhibited
oestrus during the mating season. This finding, together with
the fact that the ability to conceive was not affected by
stocking rate and mass and mass changes in cows during the
breeding season, suggests that the cause of the problem might
be sought in oestrous detection, the handling of semen, the
insemination technique and the handling of oestrous cows. Poor
technique would be expected to exert its influence on all
treatments. Another factor common to all treatments was the
frequent handling of, and the possible stresses imposed on the
animals by the high grazing intensity. Paterson, Harwin,
Ehret, Avis & Twine (1983) reported reconception rates of
72,9% when AI was used in relatively large herds on intensive
pastures. They also found that these rates increased to 88,2%
when AI was followed by the introduction of cover-up bulls
during the second half of a 60-day breeding season. It seems
likely that cover-up bulls would have improved reconception
rates in the present study, since only 69,1% of cows which
were presented for AI ultimately conceived. The use of
clean-up bulls in conjunction with an AI programme appears
especially warranted in herds which contain a complement of
Bos indicus breeding. Paterson et al. (1983) showed that

conception rates to AI were lower, and the response to the introduction of cover-up bulls greater, in <u>Bos</u> <u>indicus</u> than in <u>Bos</u> <u>taurus</u> types. In the present study the reconception rates in the Simmentalers tended to be higher than in the Hereford-crosses (which contained <u>Bos</u> <u>indicus</u> breeding), but this difference was not significant.

Perkins & Kidder (1963) and Casida, Graves, Lauderdale, Riesen, Saiduddin, Hauser & Tyler (1968) showed that conception rates in cows are lower when breeding during the early postpartum period, or at the first postpartum oestrous period, than at subsequent heat periods. In the studies by Reeves & Gaskins (1981) and Wells (personal communication) the use of restricted suckling regimes reduced the length of the acyclic period after calving, but did not influence the interval from calving to conception, relative to that measured in cows suckled normally. It therefore appears that cows have to be in a state of physiological "readiness" before they will conceive. Certain of the cows which displayed heat but failed to conceive in the present study might not have reached this physiological stage. The relatively poor reproductive performance achieved (Table 10) prompted a study into factors which influence the length of the intercalving period. The nursing stimulus clearly suppresses sexual activity (Wagner & Hansel, 1969). Consequently, suckling effects on reproductive function were investigated in the study to be described in Chapter 2.

CHAPTER 2

THE EFFECT OF RESTRICTED SUCKLING ON LH AND OVARIAN STEROIDS AFTER INDUCED OVULATION IN BOS TAURUS AND BOS INDICUS COWS

INTRODUCTION

The mass of calves at weaning exerts a major influence on the profitability of intensive beef production systems (Harwin, Fourie & Lombard, 1966). Selection for increased weaning mass in beef herds is likely to lead to greater milk production, which in turn is associated with increased suckling activity by calves (Drewry et al.,1959). Inskeep & Lishman (1978) have suggested that these changes may prolong the interval between calving and reconception. It is well established that the stimulus of suckling by the calf (apart from the process of lactation per se) delays the resumption of oestrous cycles in the postpartum cow (Saiduddin, Riesen, Graves, Tyler & Casida, 1967; Wagner & Hansel, 1969). Wiltbank & Cook (1958) for example found that the delay between calving and subsequent oestrus was 30 days longer in nursed cows than in those milked twice daily. Level of nutrition undoubtedly influences post-calving reproductive performance (Wiltbank, Rowden, Ingalls, Gregory & Koch, 1962) but the frequency and intensity of suckling affects the length of the anoestrous period independently of the nutritional state of the cow (Short, Bellows, Moody & Howland,1972; Randel & Welker, 1977; Wetteman et al., 1978).

A number of workers have exploited the knowledge of an adverse effect of suckling on the return to oestrus by reducing or removing the suckling stimulus. Early weaning clearly shortens the anoestrous period after calving (Smith & Vincent, 1972; Laster, Glimp & Gregory, 1973; Bellows, Short, Urick & Pahnish, 1974). This technique is generally impractical though, because of the large costs involved in raising the weaned calves. An added disadvantage is the relatively large number of "short" luteal phase cycles which occur subsequent to the ovulation induced by the weaning process (Ramirez-Godinez, Kiracofe, Schalles & Niswender, 1982). Temporary weaning (for eight days) was only moderately successful in reducing the anoestrous period in young Bos indicus cows (Symington & Hale, 1967). It did however reduce the interval from calving to oestrus in cows fed a high, but not a low plane of nutrition, and in Mashona, but not in Africaner cows (Hollness, Hopley & Hale, 1978). The strategic separation of cow and calf for relatively short periods (two to three days) also increases ovulation rate in cows treated with steroids and/or gonadotropin releasing hormone (GnRh) during the early postpartum period (Smith, Burrel, Shipp, Sprott, Songster & Wiltbank, 1979; Smith, Tervit & Goold, 1980; Troxel, Kesler, Noble & Carlin, 1980). Once daily suckling (for 30 minutes) reduced the interval from calving to ovulation by 48 and 99 days in the Brahman-crosses studied by Randel & Welker (1976) and Randel (1981), respectively. Randel & Welker (1977) obtained similar spectacular results and concluded that a once daily suckling programme could shorten the postpartum anoestrous period in cows fed sub-optimal levels of nutrition. Less favourable, yet positive responses

to once daily suckling were achieved in British Beef cattle by Reeves & Gaskins (1981) and Thompson, Stuedemann, Caudle, Wilkinson, Williams & Ciordia (1983). These authors recorded a greater number of "short" cycles in cows suckled once daily than in those allowed continual access to their calves. Once daily suckling failed to reduce the interval between calving and oestrus in the Hereford cows studied by Pflantz, Irvin, Morrow, Garverick & Day (1979).

The mechanism by which suckling prolongs anoestrus is not clear, and results relating to the influence of suckling on hormone secretion are somewhat inconsistent. Short et al. (1972) obtained data to indicate that the mammary glands mediate suckling-induced postpartum anoestrus. In a comparison of non-suckled intact and non-suckled mastectomized cows it was demonstrated that mastectomy reduced the duration of the postpartum anoestrous period. On the other hand it was observed by MacMillan (1983) that the suckling stimulus might not be essential for the maintenance of a bond between cow and calf, although the bond could contribute to the longer postpartum anoestrous period observed in suckled cows than in cows milked twice daily. The ovaries of cows appear to be competent despite suckling, since follicular growth is present within two weeks of calving (Oxenreider & Wagner, 1971). Ovulation can also be induced within three weeks of calving by exogenous gonadotropins (Foote, Sawhney, Quevedo & Peterson, 1966; Oxenreider, 1968) or synthetic GnRh (Webb, Lamming, Haynes, Hafs & Manns, 1977). However, corpora lutea induced by these means are often short-lived and non-functional (Lishman, Allison, Fogwell, Butcher & Inskeep, 1979; Sheffel, Pratt, Ferrel & Inskeep, 1982). Plasma luteinizing hormone (LH)

levels vary at relatively low levels shortly after parturition but increase before oestrous cycles commence in suckled and non-suckled beef cows (Short et al., 1972; Arije, Wiltbank & Hopwood, 1974). Riley (1982), as cited by Haresign, Foxcroft & Lamming (1983), gained evidence to show that the ability of the cow to resume cyclic activity is dependant on the restoration of episodic LH secretion. This is absent during the early postpartum stage, and appears by 10 to 15 days after calving in the milked animal (Peters, Lamming & Fisher, 1981). A number of workers have reported that suckling depresses tonic LH secretion during the post-calving anoestrous period (Randel, Short & Bellows, 1976; Forrest, Rhodes & Randel, 1980; Faltys, Fogwell, Short & Convey, 1983; Whisnant, Kiser & Thompson, 1983). Specifically, the frequency and amplitude of pulsatile LH releases are suppressed (Echternkamp, 1978; Carruthers & Hafs, 1980; Peters et al.,1981). The LH content of the pituitary gland in suckled and non-suckled cows is similar (Carruthers, Convey, Kesner, Hafs & Cheng, 1980; Walters, Short, Convey, Staigmiller, Dunn & Kaltenbach, 1982). Carruthers et al. (1980) showed that the same applied for the hypothalmic content of GnRh, and concluded that suckling reduces the responsiveness of the pituitary to GnRh, resulting in reduced tonic LH secretion. Schallenberger & Peterson (1982) and Acosta, Tarnavsky, Platt, Hamernik, Brown, Schoenemann & Reeves (1983) obtained evidence to suggest that suckling increases the sensitivity of the hypothalamus to the negative feedback action of oestrogen, and this leads to reduced LH release during the postpartum period. On the other hand Chang, Gimenez & Henricks (1981), Williams, Kotwica, Slanger, Olson, Tilton & Johnson (1982) and Garcia-Winder,

Imakawa, Zalesky, Day, Kittok, Schanbacher & Kinder (1983)
were unable to demonstrate a suppressive effect of suckling on
tonic LH secretion. Suckling has also been found to depress LH
release in response to GnRh in certain studies (Carter,
Dierschke, Rutledge & Hauser, 1980; Troxel et al., 1980), but
not in others (Echternkamp, 1978).

The main objective of the study to be described was to
obtain a clearer understanding of the physiological mechanisms
whereby the suckling stimulus delays the resumption of cyclic
activity in the beef cow. Tonic LH secretion, the release of
LH in response to GnRh and patterns of oestrogen and
progesterone secretion were studied in cows suckled either
normally or once daily. It was anticipated that differences in
hormone secretion and ovarian activity between the two groups
of cows would provide an answer to the question of how the
suckling stimulus alters reproductive function. Bos indicus
and Bos taurus cows were studied, since there is a substantial
body of evidence to indicate that the problem of lactation
anoestrus is greater, and overall reproductive efficiency is
lower in Bos indicus than in European breeds (Joubert, 1954;
Warnick, Meade & Koger, 1960; Coetzer, Mentz, Vermeulen &
Coetzee, 1975). Oestrus is for example of shorter duration
(Anderson, 1936; Le Roux, 1951; De Alba, Villa Corta & Ulloa,
1961; Baker, 1969) and less intense (van der Westhuysen, 1972)
in Bos indicus than in Bos taurus females. Bos indicus cattle
display a greater proportion of ovulations without oestrus
("silent heats") than European breeds (van der Westhuysen,
1972). Randel (1976) found that the interval from the onset of
oestrus to ovulation was shorter in Brahman than in Brahman x
Hereford and Hereford cattle. Corpora lutea of Bos indicus

cattle are smaller than those of their Bos taurus counterparts
(Plasse, Warnick & Koger, 1968; Irvin, Randel, Haensly &
Sorensen, 1978). Bos indicus cows have lower peak LH levels at
oestrus (Randel, 1976; Randel & Moseley, 1977) and release LH
less readily in response to GnRh (Griffin & Randel, 1977) and
oestrogen (Rhodes, Randel & Harms, 1978) than Bos taurus
cattle. Ovarian steroid secretion also differs between the two
cattle types. The pre-ovulatory surge of oestrogen occurs
earlier, relative to the onset of oestrus, in Brahman than in
Hereford cows (Randel, 1980). The latter breed also secretes
more progesterone during the luteal phase of the oestrous
cycle than their Brahman counterparts (Randel & Moseley,
1977).

PROCEDURE

Animals

A total of 37 first-calf cows and their calves, comprising
19 Drakensbergers (Bos indicus) and 18 Hereford x Simmentalers
(British-crosses) were used in the experiment. When calving
commenced on 11 August the cows were approximately three years
old. Calving continued for 45 days. Once the cows had calved
they were placed in feeding pens and fed a ration consisting
of ad lib. maize silage, approximately 3,0 kg Eragrostis
curvula hay and 0,3 kg HPC per cow per day.

Treatments

The experiment incorporated a 2 x 2 x 2 factorial design

and involved a comparison of the reproductive performance of Drakensberger and British-cross cows subjected to either normal or once-daily suckling during two stages of the postpartum period, viz. Days 35 to 50 and 60 to 75. Following calving each breed-type was divided into four groups, each balanced for cow and calf mass and date of calving. The four groups were randomly allocated to four treatments, as is set out in Table 28.

In view of the well established need for a pre-ovulatory increase of blood progesterone levels in anoestrous cows (Donaldson, Basset & Thorburn, 1970; Yuthasastrakosol, Palmer & Howland, 1975), all cows in the experiment were subjected to progesterone and oestrogen therapy, followed by an injection of GnRh, as standard treatment during the 15-day restricted or normal suckling periods. A Norgestomet ear implant (Intervet S.A.) was inserted in conjunction with an im injection of 3,0 mg Norgestomet and 6,0 mg oestradiol valerate on the first day, and removed on the tenth day of the normal or restricted suckling periods. On the eleventh day of these periods (30 hours after the removal of the ear implants) the cows were challenged for their ability to release LH and to ovulate by injecting them (im) with 500 μg GnRh (Abbott). At 18 and 42 hours after the GnRh injection (48 and 72 hours after implant removal) fixed-time inseminations were performed on the cows.

Cows subjected to restricted suckling were allowed access to their calves between 08h00 and 08h30 each morning during the 15-day period. Following suckling the cows were kept in feeding pens approximately 400 metres from the calves. The latter were housed in partly enclosed pens with free access to water, a concentrate mixture (80% maize meal, 20% lucerne

Table 28.   Outlay of experimental treatments employed.

Breed	Days postpartum during which suckling intensity was varied	Suckling intensity	n	Treatmen
British-cross	35-50	Normal	5	1
		Restricted	5	2
	60-75	Normal	4	3
		Restricted	4	4
Drakensberger	35-50	Normal	5	5
		Restricted	5	6
	60-75	Normal	4	7
		Restricted	5	8

meal) and _Eragrostis_ _curvula_ hay.

Measurements obtained

All cows were joined with masculinised teaser cows between 06h00 and 07h00, and again between 17h00 and 18h00 each day from Day 20 postpartum until five days after the second fixed-time insemination was performed. The cows were rectally palpated for the presence of corpora lutea immediately prior to the insertion of the ear implants, and again approximately one week after the injection of GnRh. Conception rates were established from subsequent calving records.

Cows and calves were weighed at fortnightly intervals throughout the experiment. The body condition of each cow was assessed immediately prior to the insertion of the ear implants by the scoring system described by van Niekerk & Louw (1982).

The influence of treatment on tonic LH secretion was investigated by bleeding the cows at intervals of 15 minutes for a period of two hours immediately prior to the insertion of the ear implants. The schedule was repeated five days after implant insertion, and two hours after implant removal. LH was also measured in samples obtained at intervals of 30 minutes for a total period of nine hours after the GnRh injection. Indwelling polyethylene catheters (Clay Adams) were inserted into the jugular vein immediately prior to the sequential collection of the samples described above. The cows were restrained in feeding stanchions during the periods of frequent blood collection.

Blood samples were obtained via venipuncture from all cows

once daily for five days prior to, and at six-hourly intervals for 18 hours prior to the GnRh injection for subsequent analysis of total oestrogens. Progesterone concentrations were determined in samples obtained at intervals of three days for a period of 21 days after the GnRh injection.

Blood samples were collected into heparinized syringes, centrifuged within 30 minutes of collection and stored at -15 C pending analysis.

Hormone determinations

LH was measured in plasma according to the radioimmunoassay described by Niswender, Reichert, Midgley & Nalbandov (1969). Lishman (1972) provided a detailed description of the assay procedure. When samples collected to measure tonic LH secretion were analysed the assay was modified slightly in order to obtain greater sensitivity. The initial dilution of anti-LH serum was changed from 1:100 000 to 1:160 000, and the incubation of antiserum with standards and unknown plasma samples prior to the addition of labelled tracer was increased from 24 to 48 hours. The inter- and intra-assay coefficients of variation for the series of LH assays were 12,3 and 4,3%, respectively. Progesterone and oestrogen were measured according to the methods described by Butcher, Collins & Fugo (1974). Recovery of labelled progesterone added to plasma varied from 92,8 to 96,3%, and the within- and between-assay coefficients of variation were 8,8 and 12,7%, respectively. Total oestrogens were determined since oestradiol-17β obtained after column chromotography was

undetectable. Levels were corrected for recovery of tritiated
oestrogen, which varied from 72,9 to 80,0%. The within- and
between-assay coefficients of variation were 14,2 and 18,6%,
respectively.

Statistical analyses

Analyses of variance were used to test the effect of
treatment on the different paramaters of hormone secretion. In
addition, each of these parameters was subjected to an
analysis of repeated measurements, as described by Gill & Hafs
(1971). An analysis of variance was used for orthogonal
comparisons of LH response curves described by first to fourth
degree polynomials (Els, personal communication). An analysis
of covariance was applied to test whether tonic LH levels
before, differed from those measured during the normal or
restricted suckling periods. The Chi-squared test was used to
determine whether treatment affected ovulatory responses and
conception rates. The relationships between the different
parameters were investigated by regression procedures.

RESULTS

Ovulatory response of treated cows

None of the cows had exhibited oestrus or had palpable
corpora lutea prior to the insertion of the progesterone ear
implants at the commencement of the normal or restricted
suckling periods. The ovulatory response of the cows is
summarized in Table 29, and was guaged by rectal palpation of

Table 29.   The number of cows which ovulated, conceived and underwent "short" cycles in response to GnRh.

Breed	Days postpartum treated	Suckling intensity	n	No. of cows which ovulated in response to GnRh	No. of cows which conceived to fixed-time inseminations	No. of cows which under-went "short cycles" *
British-cross	35-50	Normal	5	2 (40%)	1 (20%)	0
		Restricted	5	3 (60%)	0	0
	60-75	Normal	4	3 (75%)	1 (25%)	1 (25%)
		Restricted	4	3 (75%)	2 (50%)	1 (25%)
Drakensberger	35-50	Normal	5	3 (60%)	0	2 (40%)
		Restricted	5	4 (80%)	2 (40%)	1 (20%)
	60-75	Normal	4	2 (50%)	1 (25%)	1 (25%)
		Restricted	5	5 (100%)	3 (60%)	0

the ovaries approximately one week after the GnRh injection. In addition the pattern of progesterone secretion during the 21 days which followed the administration of GnRh was used to indicate ovulations. The progesterone profiles of the cows are presented in Figs. 15 and 16. Between 40 and 100% of the cows subjected to the individual treatments ovulated in response to the GnRh injection. It is evident from Table 29 that there was a tendency for a greater ($P > 0,05$) proportion of the cows suckled once daily to ovulate in response to GnRh than those suckled normally, and this effect was most marked in the Drakensberger cows treated between Days 60 and 70 postpartum. A greater proportion of the Drakensbergers conceived when suckled once daily than when suckled normally (Table 29). This effect was more marked in the cows treated between Days 60 and 70 postpartum than in cows treated earlier (Figs. 15, 16). None of the cows which ovulated displayed overt oestrus within three days of removing the ear implants.

The progesterone profiles obtained over the 21-day period after the GnRh injection provide an indication of corpus luteum function. These profiles varied considerably between cows. Certain animals did not exhibit elavated progesterone levels at all, and rectal palpations confirmed that they had failed to ovulate in response to the GnRh. In other cows the progesterone concentrations increased markedly about six days after the GnRh injection and remained relatively high throughout, or decreased to reach baseline levels at 15 to 20 days after the GnRh treatment. Rectal palpations indicated that ovulation had occurred in these animals. Approximately 16% or six of the 37 animals had elevated progesterone levels for only about six of the 21 days which constituted the
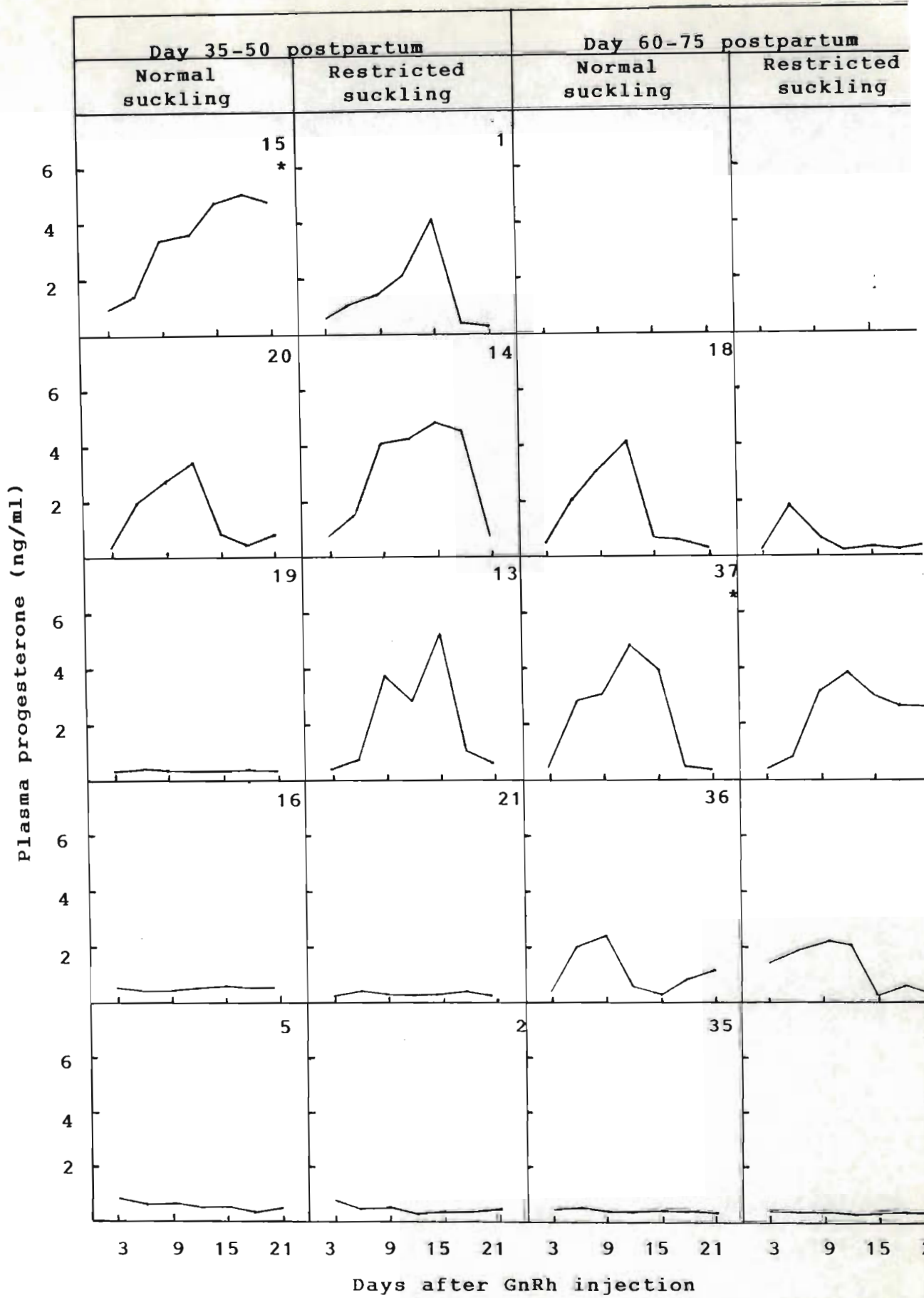
Fig. 15. Plasma progesterone levels subsequent to the GnRh injection in British-cross cows.
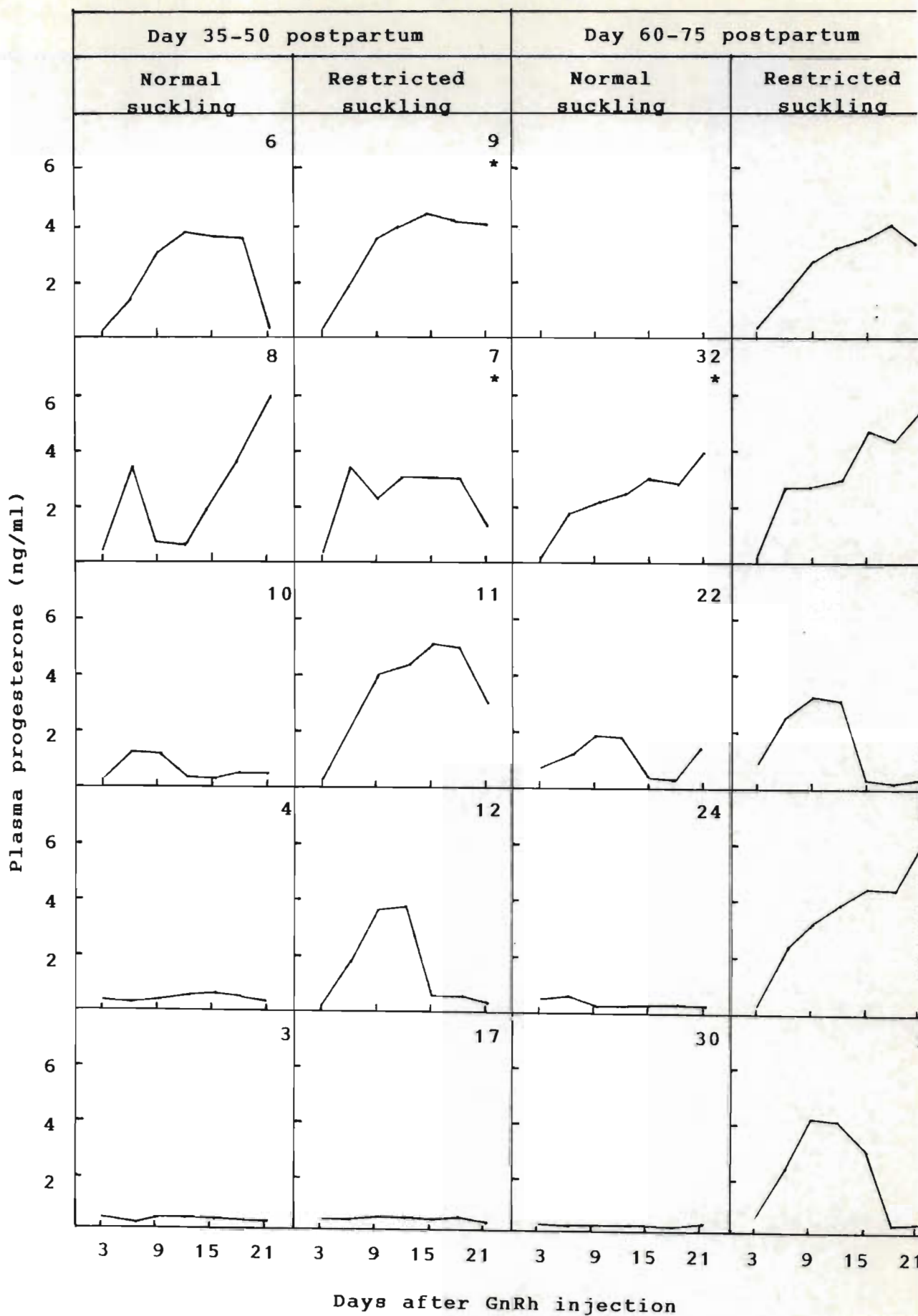* Donates cows which conceived to fixed-time insemin tions.

Fig. 16. Plasma progesterone levels subsequent to the GnRh injection in Drakensberger cows.
* Donates cows which conceived to fixed-time inseminations.

sampling period (Figs. 15, 16). Palpation of the ovaries confirmed that these cows had ovulated, but it is evident from Figs. 15 and 16 that the corpora lutea were short-lived. The incidence of such "short" cycles was not affected by treatment in the British-cross cows, but 50% less "short" cycles occurred in the Drakensberger cows suckled once daily than those suckled normally (Table 29).

Hormone levels

Concentrations of oestrogen in samples obtained on a daily basis for five days prior to the removal of the ear implants and then on a six-hourly basis between the removal of the implants and the GnRh injection fluctuated considerably from day to day (Fig. 17). Changes in the level of this hormone over the aforementioned period did not follow any consistent pattern. Treatment exerted no influence on mean oestrogen concentrations, and the area under the curve obtained by plotting oestrogen levels against time.

Tonic LH levels fluctuated at relatively low levels during each of the two-hour sampling periods during which samples were obtained at intervals of 15 minutes. Typical examples of tonic secretion are illustrated in Fig. 18. There was no indication that pulses of LH, as defined by Goodman & Karsch (1980), occurred during any of the sampling periods. Mean tonic LH levels prior to the commencement of the normal or restricted suckling periods were not affected by breed of cow and stage postpartum. Furthermore, the once daily suckling regime did not influence tonic LH secretion, since there were no significant differences between mean levels, and the mean
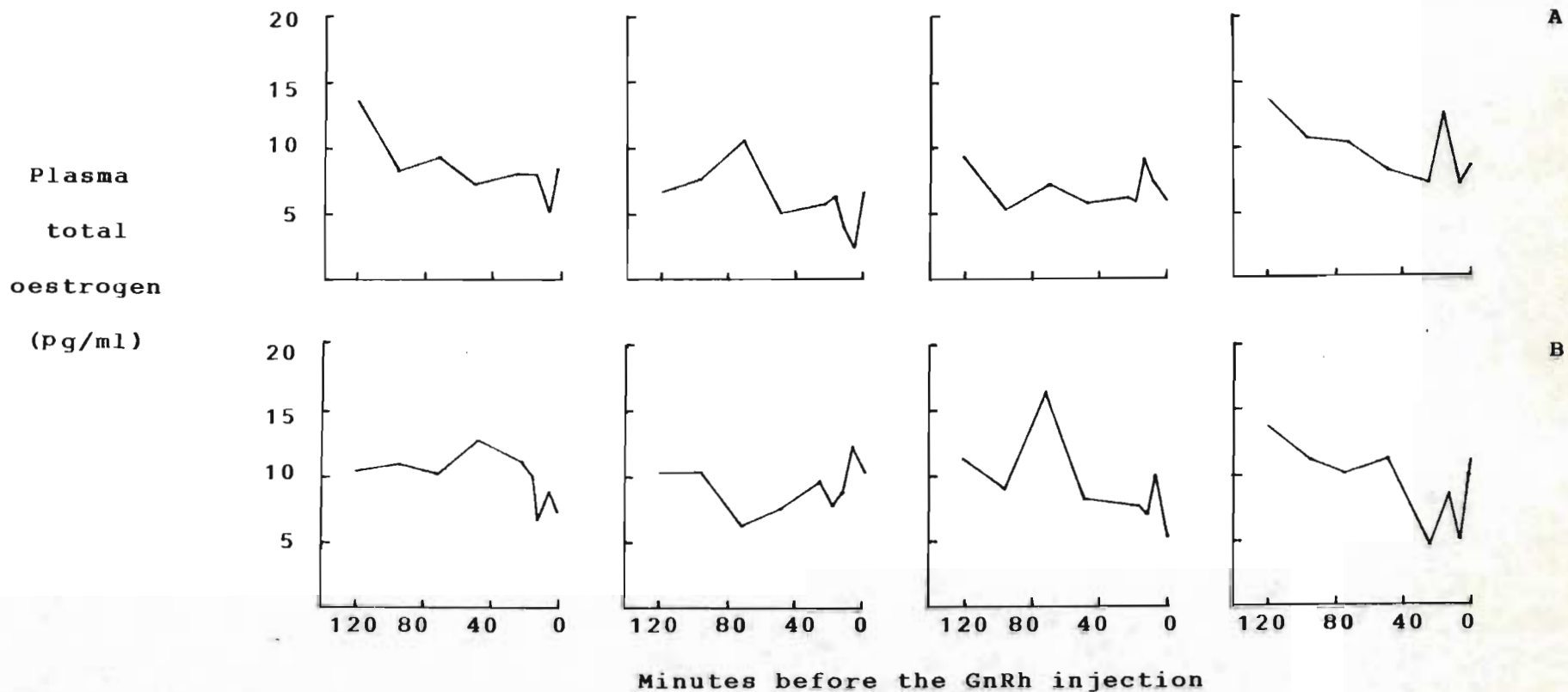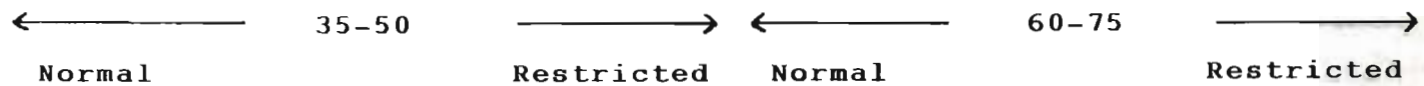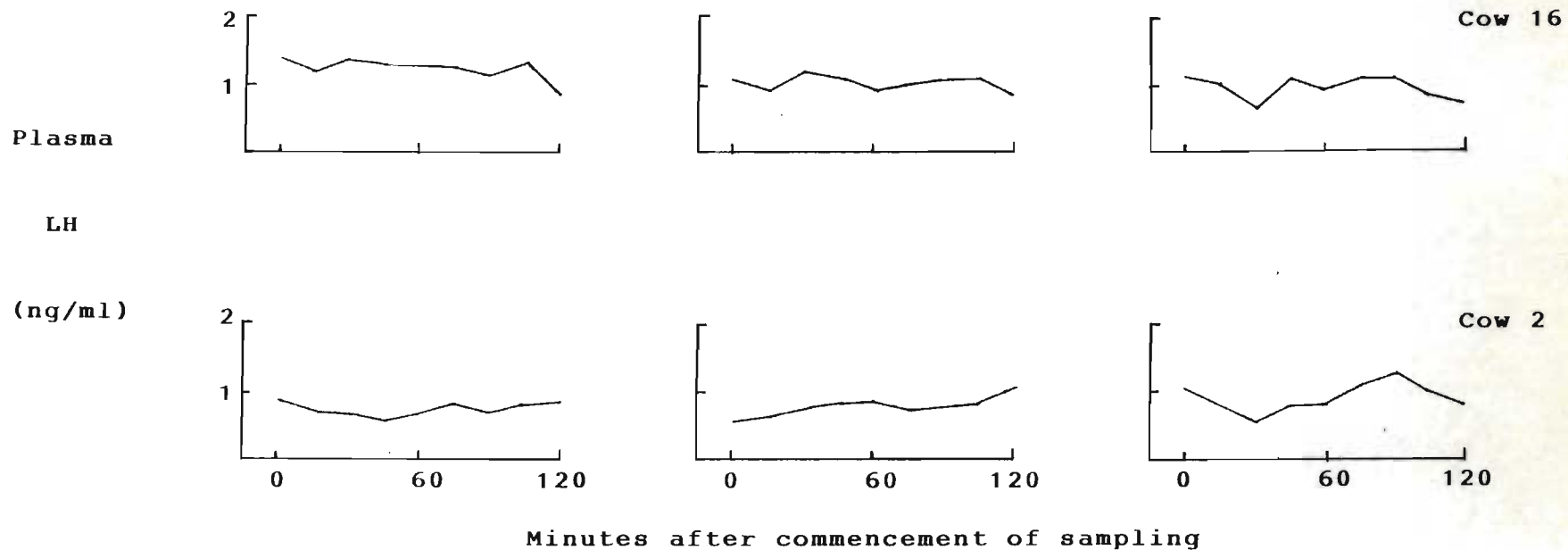
Fig. 17. Mean plasma total oestrogen levels prior to the GnRh injection in Drakensberger (A) and British-cross cows(B).

Plasma

LH

(ng/ml)

Minutes after commencement of sampling

ays from start of variable suck-
ing period:

─── −1 ───   ─── +5 ───   ─── +10 ───

g. 18.   Tonic LH secretion prior to and during periods of normal and once daily suckling. Cow 16 was a
          British-cross suckled normally, and Cow 2 a British-cross suckled once daily.

area under the respective LH curves, measured before and during the restricted suckling periods (Fig. 19).

An LH surge was measured in all cows following the injection of GnRh. The surges obtained in the British-cross and Drakensberger cows are diagrammatically illustrated in Figs. 20 and 21, respectively. LH concentrations commenced rising within 30 minutes, and maximum concentrations were reached on average after 156 minutes of the GnRh injection. The time-lapse between GnRh administration and the attainment of the maximum LH level was not influenced by treatment. The surges lasted for approximately 6,5 hours (Figs. 20,21). It was noticeable that the occurrence of ovulation was not related to the magnitude of the LH surge. For example, Drakensberger Cow 26 ovulated in response to an exceptionally small surge (a maximum level of 18,4 ng/ml), whereas Cow 22 failed to ovulate despite a relatively large surge with a maximum level of 132 ng/ml (Fig. 21). Treatment exerted no influence on the area under the LH curve, the maximum LH level and the duration of the surge (Table 30). However, comparisons amonst LH response curves described by fourth degree polynomials (a measure of the amount of hormone secreted) indicated significant (P < 0,05) differences due to breed and suckling intensity. Drakensbergers suckled normally secreted significantly (P < 0,05) more LH than the Simmentaler x Herefords. Differences due to stage postpartum were not significant. Consequently, data relating to LH release at the two stages were pooled in order to increase the number of cows representative of the two breeds and the suckling intensities. The pooled data are graphically illustrated in Fig. 22. The Drakensberger cows suckled once daily secreted significantly
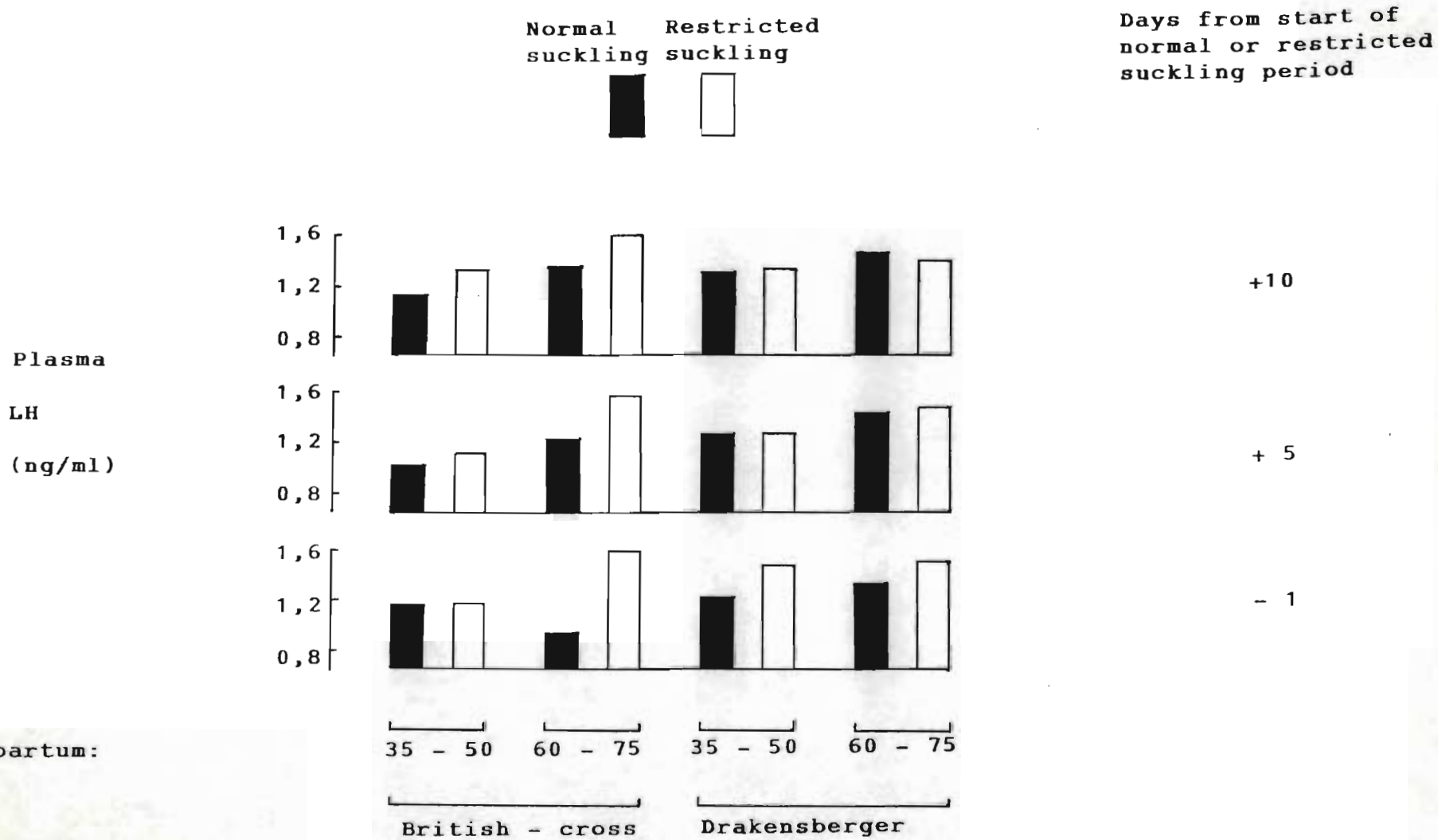
Fig. 19. Mean tonic LH levels prior to and during the periods of normal or restricted suckling.
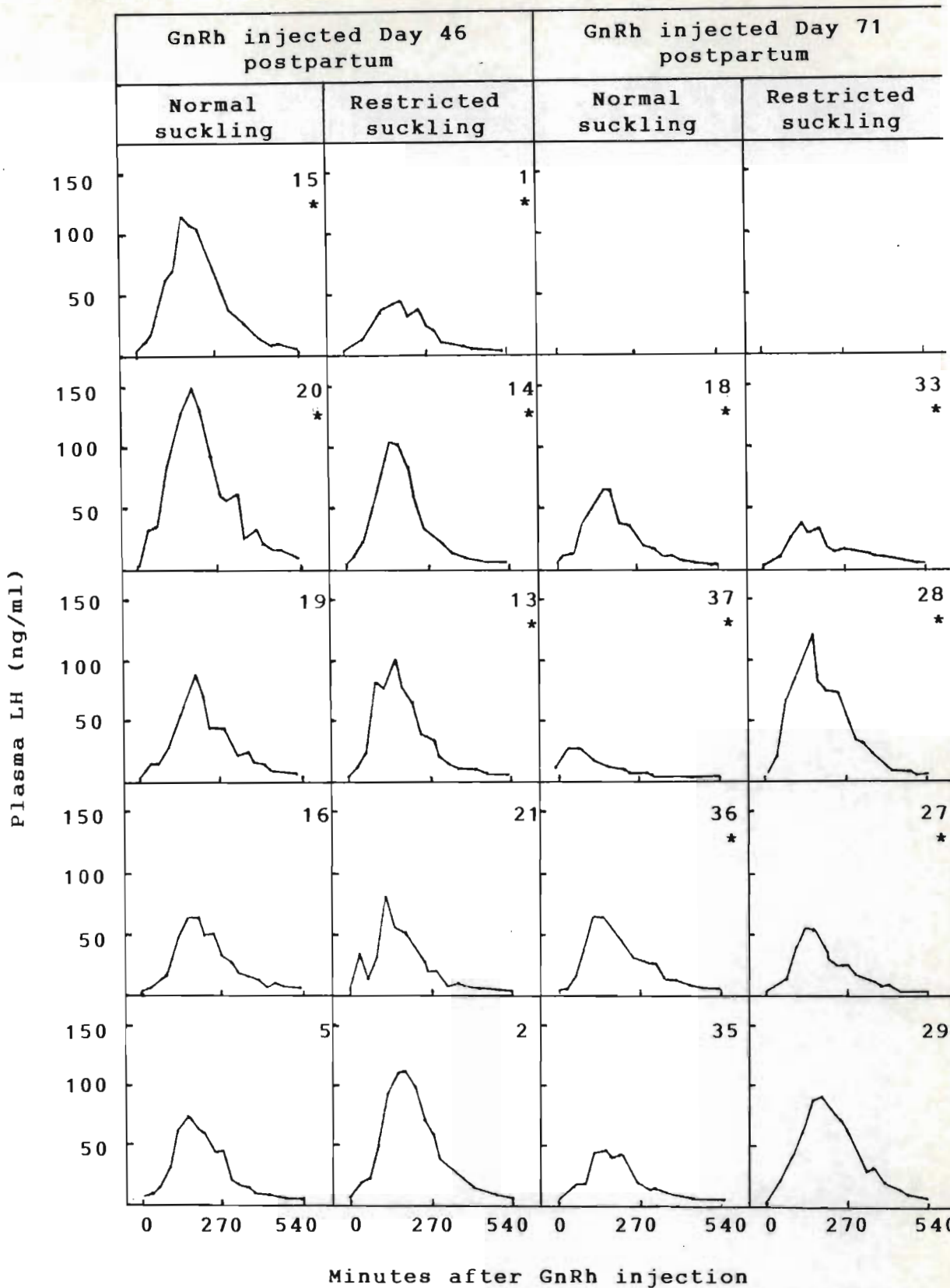
Fig: 20. The release of LH in response to 500 μg of GnRh o
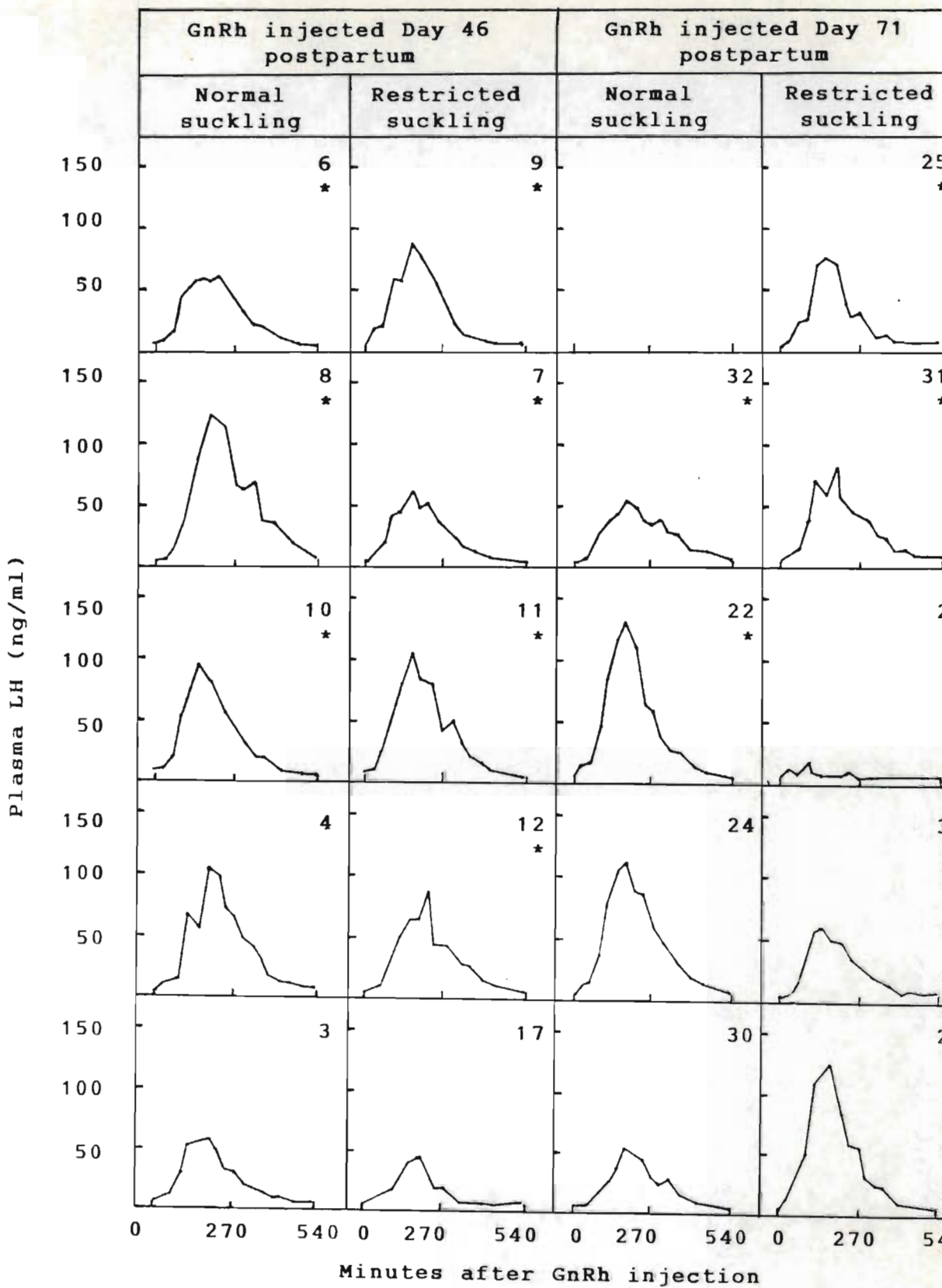Day 46 and 71 postpartum in British-cross cows.
* Donates cows which ovulated.

Fig. 21. The release of LH in response to 500 µg of
          GnRh on Day 46 and 71 postpartum in Drakens-
          berger cows.
          * Donates cows which ovulated.

Table 30.   The mean area under the curve, the maximum level and duration of the LH surge in response to the GnRh injection.

| Breed	Days postpartum treated	Suckling intensity	n	Mean Area under LH curve (mm^2)	Mean Maximum LH level reached (ng/ml)	Mean duration of LH surge (h)*
British-cross	35-50	Normal	5	$225,9^{+}_{-}40,7$	$101,0^{+}_{-}17,6$	$6,9^{+}_{-}0,6$
		Restricted	5	$202,4^{+}_{-}27,5$	$88,7^{+}_{-}12,0$	$6,2^{+}_{-}0,3$
	60-75	Normal	4	$124,6^{+}_{-}20,3$	$60,7^{+}_{-}6,7$	$6,5^{+}_{-}0,0$
		Restricted	4	$185,1^{+}_{-}47,0$	$76,9^{+}_{-}19,2$	$6,6^{+}_{-}0,4$
Drakensberger	35-50	Normal	5	$197,5^{+}_{-}19,7$	$88,8^{+}_{-}12,9$	$6,9^{+}_{-}0,4$
		Restricted	5	$173,7^{+}_{-}77,7$	$78,0^{+}_{-}11,0$	$6,1^{+}_{-}0,5$
	60-75	Normal	4	$193,6^{+}_{-}41,5$	$88,9^{+}_{-}17,5$	$7,3^{+}_{-}0,4$
		Restricted	5	$163,8^{+}_{-}37,1$	$72,2^{+}_{-}16,7$	$5,7^{+}_{-}1,0$

* Levels > 10ng/ml
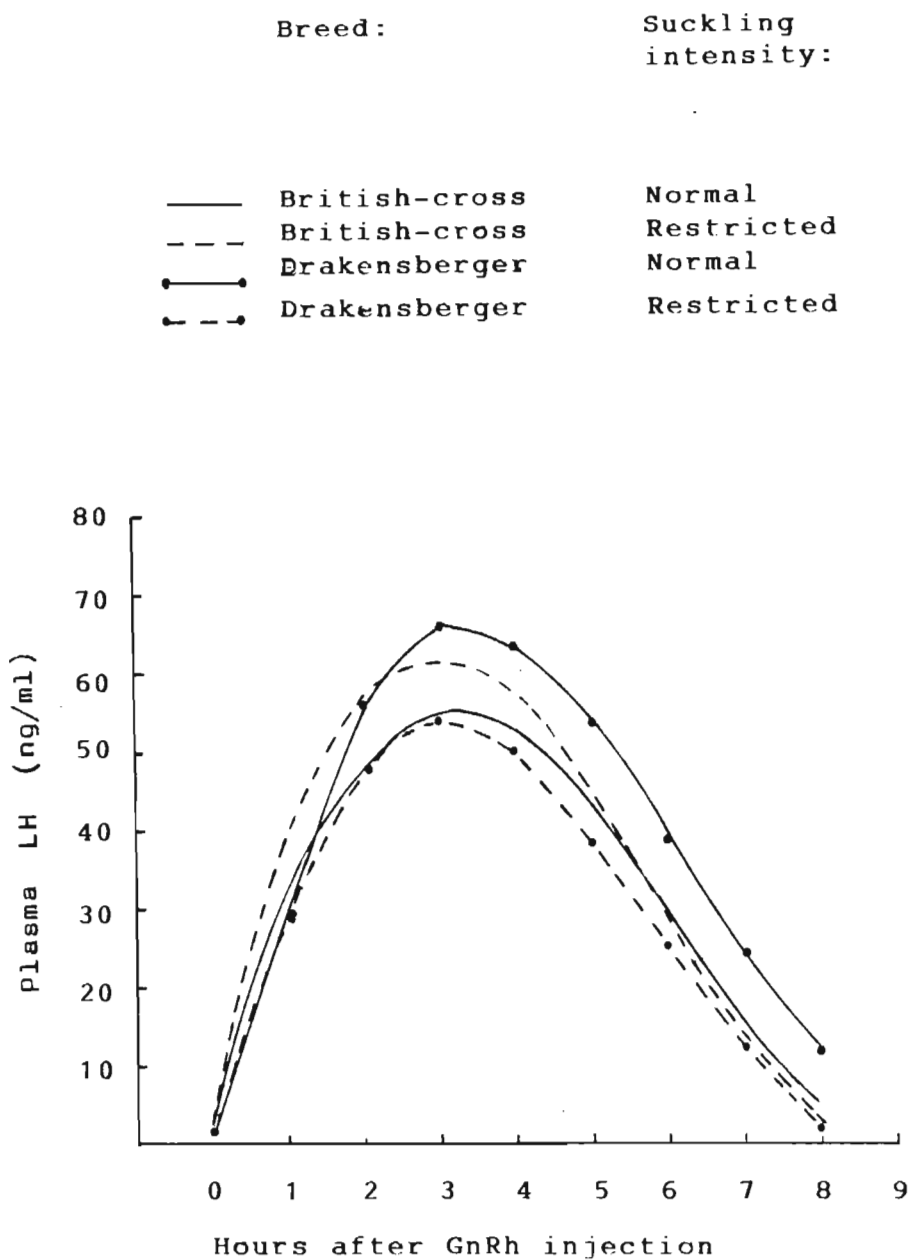
Fig. 22. LH response curves obtained in cows subsequen
to the GnRh injection (levels obtained at th
two postpartum stages pooled).

(P < 0,05) less LH than those suckled normally. In the
British-cross cows the suckling intensity did not influence LH
release, although cows suckled once daily tended to release
more LH than those suckled normally (Fig. 22).

There were no significant correlations between the
secretory patterns of the different hormones studied, the
masses of, and mass changes in cows and their ovulatory
response.

Bodymass changes

Mean masses of the Drakensberger cows within five days of
calving (461,5 ± 10,2 kg) did not differ from those of the
British-crosses (456,2 ± 9,9 kg). All cows used in this study
underwent mass losses ranging from 3,2 to 30,9 kg between
parturition and the onset of the normal or restricted suckling
periods, but these were not affected by treatment or breed.
Mean condition scores in cows treated between Days 60 and 75
postpartum (2,89 ± 0,08) tended to be lower than those in cows
treated between Days 35 and 50 (3,13 ± 0,1). Mean growth rates
in the calves between birth and 90 days of age were not
affected by the suckling intensity employed.

DISCUSSION

Approximately two-thirds (67,6%) of all cows ovulated in
response to the GnRh injection (Table 29). This result agrees
with the finding that GnRh induces ovulation in between 50 and
75% of lactating cows during the early postpartum period
(Britt, Kiser, Seguin, Hafs, Oxender & Ritchie, 1975; Webb et

al., 1977). The ovulatory response of the cows was no

influenced by their breed, the stage postpartum and the

suckling intensity employed (Table 29). However, there was a

tendency for a greater proportion of the cows suckled once

daily to ovulate in response to GnRh than those suckled

normally, and this effect was more marked in the

Drakensbergers than in the British-crosses (Figs. 15, 16). It

could be postulated that this improved response in the

Drakensbergers was due to relatively high pituitary LH levels,

which in turn would be expected to result in the release of

relatively larger quantities of LH in the cows suckled once

daily than those suckled normally. However, the results

summarized in Fig. 22 indicate that Drakensbergers suckled

once daily secreted less LH than those suckled normally. It is

tempting to speculate that the smaller LH release in the

Drakensberger cows suckled once daily than in those suckled

normally (Fig. 22) was the result of pituitary depletion,

owing to increased tonic secretion during the period of

restricted nursing. However, the suckling intensity did not

influence tonic LH secretion in the present study (Fig. 19).

Echternkamp (1978) reported that the release of LH in

normally-suckled cows was similar to that in cows weaned at

Day 35 postpartum when a GnRh challenge was administered on

Day 42 postpartum. Williams et al. (1982) found that suckled

cows release more LH in response to GnRh at 30 days after

calving than those weaned at birth. In contrast, certain

workers (Carter et al., 1980; Troxel et al.,1980; Smith,

Lishman, Lewis, Harms, Ellersieck, Inskeep, Wiltbank & Amoss,

1983) showed that the suckling stimulus depresses the

GnRh-induced LH surge. Cows temporarily weaned for 32 hours

released more LH after GnRh than those either weaned for 24

hours, or not weaned at all (Inskeep, Lishman, Butcher &

Allison, 1977). The discrepancies described above may be due

to differences in the stages postpartum during which the

suckling intensities were varied, the degree of suckling

stimuli applied and the genetic constitution of cows used in

the different studies. Nevertheless, it appears from the

results presented in Figs. 20 and 21 that the occurrence of

ovulation was unrelated to the quantity of LH released.

Possibly the larger ovulatory response in cows suckled once

daily was due to a greater responsiveness of their ovaries to

a given stimulus of LH than in cows suckled normally.

The pattern of LH release following the GnRh injection was

similar in cows suckled normally and once daily (Fig. 22).

Inskeep & Lishman (1978) cited work by Smith & Wiltbank (1977)

which showed that removal of calves for 48 hours prior to a

GnRh injection resulted in a more rapid rise to the peak of LH

than in suckled controls. Lactation also delays the release of

LH after pregnant mare serum gonadotropin (PMSG)

administration in anoestrous ewes (Pelletier & Thimonier,

1973).

The LH surge elicited in response to GnRh lasted

approximately 6,5 hours (Table 30), which is similar to the

duration measured by Webb et al. (1977), Lishman et al.

(1979), Carter et al. (1980) and Williams et al. (1982). The

quantity of LH released and the duration of the surge on Day

46 did not differ significantly from that on Day 71 postpartum

(Table 30). This result disagrees with those of Fernandes,

Thatcher & Wilcox (1976) and Irvin, Garverick, Zaied, Kesler,

Day & Youngquist (1977), who showed that the LH response to

GnRh increases in magnitude with an increase in the number of days after calving. Nevertheless, it appears that a lack of pituitary responsiveness is not a limiting factor in the failure of suckled cows to ovulate during the early postpartum period, since beef cows release LH in response to GnRh as early as Day 13 postpartum (Webb et al., 1977; Irvin, Zaied, Day & Garverick, 1981).

The magnitude of the increase in ovulatory response due to restricted suckling tended to be greater in the Drakensberger than in the British-cross cows (Table 29). This finding, together with the varying influences of breed on LH release after GnRh (Fig. 22) lends support to the contention that the reproductive ability of Bos indicus cows differs inherently from that in Bos taurus females. The relatively larger improvement of the ovulatory response in the Drakensberger than in Simmentaler x Hereford cows cannot be explained on the basis of LH release after GnRh (Fig. 22). The results presented in Fig. 22 differ from those of Griffin & Randel (1977), who showed that Bos indicus cows release less LH when challenged with GnRh than Bos taurus females. In the present study tonic LH secretion (Fig. 19), oestrogen (Fig. 17) and progesterone secretion (Figs. 15, 16) did not differ between the two breeds. Radford, Nancarrow & Mattner (1978) and Montgomery (1982) have suggested that the inhibition of ovarian activity brought about by suckling may be due to the association between cow and calf. This association may be "stronger" in Bos indicus than in Bos taurus breeds. The temporary interruption of the association through the once daily suckling regime used in the present study may thus have been responsible for the relatively larger increase in the

proportion of _Bos_ _indicus_ cows which ovulated than in their _Bos_ _taurus_ counterparts.

The finding that approximately 16% of all cows underwent "short" cycles (Table 29) was not unexpected, since the occurrence of short-lived corpora lutea after GnRh treatment during early lactation is well established (Webb _et al_., 1977; Sheffel _et al_., 1982). Measures such as FSH pre-treatment have been unable to improve the lifespan of induced bovine corpora lutea (Lishman _et al_., 1979), but Grobbelaar (1984) markedly improved luteal function in ewes by continual PMSG stimulation. In the present study the once daily suckling regime tended to reduce the incidence of "short" cycles in the Drakensberger, but not in the British-cross cows (Table 29). The removal of calves for at least 24 hours prior to GnRh administration failed to lengthen luteal lifespan in the study by Inskeep _et al_. (1977).

The results presented in Table 29 disagree with those of Carter _et al_. (1980), who reported a greater incidence of "short" cycles in non-suckled than in normally-suckled cows. In the latter investigation the GnRh was administered at an earlier stage postpartum than in the present study, and this could account for the different results. An increase in the incidence of "short" cycles concomitant with a decrease in the length of the postpartum anoestrous period has been attributed to restricted suckling by Reeves & Gaskins (1981) and Thompson _et al_. (1983). It appears that this problem arises in part because of insufficient progesterone secretion prior to the ovulation induced by the limited suckling regime. Progesterone administration prior to an injection of GnRh in anoestrous cows reduces the incidence of short-lived corpora lutea

(Troxel et al., 1980; Ramirez-Godinez et al., 1982; Troxel & Kesler, 1983; Smith et al., 1983).

Over all treatments 10 or 52,6% of the 19 cows which ovulated and subsequently displayed "normal" cycles also conceived to the fixed-time inseminations (Table 29). The stress of frequent handling may have contributed to the relatively low conception rates, although these are usually lower in progesterone-synchronized than in cattle bred normally (Roche, 1974). Furthermore, the induced ovulation was the first which followed calving, and it is known that conception rates are lower at the initial than at subsequent postpartum oestrous periods (Perkins & Kidder, 1963; Casida et al., 1968).

Tonic LH levels were not affected by the breed of cow, stage postpartum and the suckling intensity employed (Fig. 19). In a number of previous investigations suckling has been shown to cause varying levels of depression on tonic LH concentrations. Carruthers et al.(1980), Chang et al. (1981) Walters, Kaltenbach, Dunn & Short (1982), Whisnant et al. (1983) and Faltys et al. (1983) showed that cows which are weaned during the early postpartum period exhibit higher mean tonic LH levels and more frequent pulsatile releases of LH shortly after calf removal than suckled controls. Carruthers & Hafs (1980) reported that the frequency and amplitude of episodic LH peaks are lower in suckled cows than in those milked every 12 hours. Milked cows exhibit episodic surges of LH by Day seven postpartum, whereas these are absent in suckled cows (Carruthers, Kosugiyama & Hafs, 1977). Peters et al. (1981) observed that cows which suckle more than one calf secrete smaller quantities of LH, and have a less distinct

pulsatile pattern of LH release within 20 days of calving than those milked twice daily. Mean tonic LH levels were also higher in cows suckled once than those nursed twice daily (Forrest et al., 1980). In the present study the mean tonic LH level measured over all treatments was $1,32 \pm 0,04$ ng/ml, which is similar to levels reported during the postpartum period by Ingalls, Convey & Hafs (1973), Edgerton & Hafs (1973), Arije et al. (1974), Carter et al. (1980) and Forrest et al. (1980). It should be noted though that in the present study LH concentrations in the majority of samples were measurable at, or just above, the lower limit of sensitivity for the LH assay. It is thus possible that the assay was not sensitive enough, or the number of animals used was too small to detect differences in tonic LH secretion owing to treatment. The finding that the LH levels prior to and after the insertion of the progesterone implants did not differ supports this conclusion, since Chang et al. (1981), Ireland & Roche (1982) and Walters, Smith, Harms & Wiltbank (1982) have shown that tonic LH levels are suppressed by progesterone therapy. Furthermore, mean tonic levels on Day 35 did not differ from those on Day 60 postpartum, whereas Arije et al. (1974), Echternkamp (1978) and Carruthers & Hafs (1980) have shown that baseline LH levels increase as do the number of days after calving. However, the results summarized in Fig. 19 are similar to those obtained by a relatively small number of workers who reported that suckling exerts no influence on tonic LH secretion. Williams et al. (1982) ascribed this lack of an effect to a short sampling period, whereas Chang et al. (1981) showed that suckling exerts no influence on mean L levels and the number of individual peaks, but did influence

the mean peak level. The latter authors collected blood at 30-minute intervals, which, according to Randel (personal communication) are too long to accurately assess tonic LH secretion. It is also possible that the two-hour sampling periods (during which blood was collected every 15 minutes) in the present study were too short to accurately establish treatment effects.

It was anticipated that oestrogen levels would provide an indication of follicular development following the withdrawal of the progesterone implants, and the effect thereon of treatment. However, oestrogen concentrations varied considerably within and between individual cows (Fig. 17). The concentration of this steroid varied between 5 and 20 pg/ml, which is considerably lower than that of approximately 125 pg/ml measured throughout the cycle by Christensen, Hopwood & Wiltbank (1974). It is evident that a larger number of animals than was used in this experiment may be necessary to measure an effect of oestrogen secretion. Such studies appear warranted, since Bellin, Hinshelwood, Robinson, Ax & Hauser (1982) found that fewer and smaller follicles, which contain smaller quantities of oestrogen, occur in suckled than in non-suckled cows. Troxel et al. (1980) showed that the magnitude of the GnRh-induced LH release was positively correlated with pre-treatment oestrogen concentrations in suckled cows, but not in those subject to short-term (36-hour) calf removal. Williams et al. (1982) maintain that ovarian steroids have a profound effect on the sensitivity of the pituitary to a GnRh stimulus, since increased pre-treatment oestrogen concentrations enhance LH release in response to GnRh. Oestrogen (provided via an ear implant) also enhances LH

secretion in ovariectomized cows suckled once daily during the early postpartum period (Garcia-Winder et al., 1983). Acosta et al. (1983) provided data to indicate that suckling increases the sensitivity of the hypothalamus to the negative feedback effect of oestrogen, and this results in reduced LH release.

Restricted suckling programmes in beef herds are unlikely to gain application in practice should they seriously affect calf growth. The once daily suckling regime used for 15 days in the present study exerted no influence on calf performance, and it was noticeable how soon cows and calves became accustomed to, and eventually "accepted" the procedure. There was also no evidence of digestive upsets in the calves suckled once daily. Other workers allowed nursing once daily for 30 minutes between about Day 25 postpartum and the occurrence of oestrus at approximately 40 days (Reeves & Gaskins, 1981) and 69 days after calving (Randel, 1981). Calf performance was not seriously affected by this treatment. Reeves & Gaskins (1981) reported that normally-suckled calves were 11,5 kg, and not significantly heavier at weaning than those suckled once daily, whereas Randel (1981) showed that gains were lower during the treatment period in calves suckled once daily than in controls, but masses at weaning were similar in the two groups. Twice daily suckling until weaning at Day 90 postpartum did not reduce calf gains in the study by Suzuki & Sato (1981), who also reported a mass advantage of 20 kg in cows nursed twice daily over those suckled normally. Short-term (48-hour) calf removal significantly reduced weaning masses and calf gains in the studies by Tervit, Smith, Goold, Jones & Vandien (1982) and Wettemann & Lusby (1983),

respectively. Calf removal for 72 hours at Day 30 postpartum had no detrimental effect on milk production in the investigation by Dunn, Smith, Garverick & Foley (1983).

The beneficial effect of restricted suckling obtained in this (Table 29) and other studies (Randel, 1981) indicates that it may hold promise as a means of increasing reproductive rates in commercial beef herds. It would appear impractical to reduce the suckling intensity in the entire cowherd before or during the mating season, since the technique places considerable demands on managerial time and handling facilities. However, restricted suckling programmes could successfully reduce postpartum anoestrous periods in "problem" cows, such as first-calvers, late-season calvers and Bos indicus females, which normally have longer periods of anoestrus after calving than other cows (Warnick et al.,1960; Harwin, Lamb & Bisschop, 1967). Randel & Welker (1977) found that a once daily suckling programme between Day 21 postpartum and subsequent oestrus largely overcame the influence of a relatively low pre- and post-calving nutritional level on the return to oestrus in first-calf cows. Nutritional levels are often inadequate in South African beef cowherds (Luitingh, 1974), and it appears that restricted suckling techniques could to a degree overcome this problem. Their use under practical farming conditions clearly warrants attention.

CHAPTER 3

THE INFLUENCE OF SEASON ON TONIC LH AND PROGESTERONE
LEVELS IN CATTLE IN A SUB-TROPICAL ENVIRONMENT

INTRODUCTION

Harwin & Lombard (1974) have questioned the application of
restricted breeding seasons in beef cowherds provided with
relatively high quality forages throughout the year. They
proposed that individual cows could be drafted for mating from
50 days after calving in schemes involving all-year breeding.
It would appear that this proposal has merit, providing that
management input is not limiting, and cows sustain a
relatively high degree of breeding soundness throughout the
year. Although cows are regarded as continuous breeders
(Hafez, 1968), evidence has been obtained to support the
viewpoint amongst farmers that season of the year exerts an
influence on the reproductive efficiency of cattle (Bulman &
Lamming, 1978; Montgomery, Davis & Hurrel, 1980). Several
reports (Buch, Tyler & Casida, 1955; Thiebault, Courot,
Martinet, Mauleon, Du Mesnil Du Buisson, Ortavant, Pelletier &
Signoret, 1966; de Kruif, 1975) indicate that postpartum
anoestrous periods and calving intervals are longer for cows
calving in autumn and winter than those calving in spring and
summer. Hansen & Hauser (1983) reached the same conclusion,
and stated that seasonal variation in management and diet was
not responsible for this effect. On the other hand it was
found that beef and dairy cows calving in the spring months

are acyclic for longer periods after parturition than those calving in autumn (Peters & Riley, 1982b; Claus, Karg, Zwiauer, Von Butler, Pirchner & Rattenberger, 1983). Various authors, including Hillen & Rupel (1960), Stott & Williams (1962), Labhsetwar, Tyler & Casida (1963) and Gwazdauskas, Wilcox & Thatcher (1975) have reported reduced reproductive performance during the summer months, and attributed this effect mainly to temperature. Mercier & Salisbury (1947), Sweetman (1950) and Deas (1971) reported lowest reproductive efficiency during the winter period and Bonsma (1951) concluded that conception rates were higher during autumn and spring than during other seasons. The conflicting and often confusing results relating season to reproductive efficiency in cattle may be due to differences in climatic conditions between studies. Boyd (1977), de Kruif (1978) and Tucker (1982) have also suggested that seasonal effects on anoestrus may be related to differences in nutrition and management. However, a number of studies of a more basic nature have indicated significant effects of season on reproductive efficiency. Peters & Riley (1982a) showed that cows exposed to longer photoperiods during late pregnancy undergo shorter acyclic periods after calving, and vice versa. Hansen, Kamwanja & Hauser (1982) reported that an increase in photoperiod bought about by supplemental lighting during the summer months led to a greater oestrogen-induced release of LH in ovariectomized heifers than in unsupplemented controls. Follicular development in heifers was greater after a period of increasing than decreasing photoperiod in the study by Kamwanja & Hauser(1983). Harrison, Hansen & Randel (1982) reported smaller pre-ovulatory LH surges during the winter

than the spring months, whereas Harrison & Randel (1981)
showed that tonic LH concentrations are lower and the
pre-ovulatory LH surge smaller during winter than spring.
Pre-ovulatory LH surges did not differ between heifers
subjected to photoperiods of eight hours of light and 16 hours
of dark, and vice versa, in the study by Rzepkowski, Ireland,
Fogwell, Chapin & Tucker (1982). Increasing daylength was
associated with increased LH levels due to a higher pulse
frequency in mares (Fitzgerald, I'Anson, Loy & Legan, 1983).
Madan & Johnson (1973) found that heat stress inhibits tonic
and pre-ovulatory LH secretion in cattle. Serum progesterone
levels were influenced by season in certain studies
(Rosenberg, Folman, Herz, Flamenbaum, Berman & Kaim, 1982) but
not in others (Harrison et al., 1982; Rhodes, Randel & Long,
1982). However, Rhodes et al. (1982) found that corpora lutea
removed from cows during winter had a lower capability of
releasing progesterone in vitro than those removed during
summer. It appears that the hormone most influenced by season
is prolactin, which concentrations increase with an increase
in temperature and photoperiod (Karg & Schams, 1974; Radford
et al., 1978; Tucker, 1982).

Season exerts an influence on the sexual activity of sheep
(Hunter, 1962; Watson & Radford, 1966), horses (Sharp,
Kooistra & Ginther, 1975; Freedman, Garcia & Ginther, 1979)
and certain pigs (Asdell, 1964; Dobao, Rodriganez & Silio,
1983). A knowledge of the influence of season on the
reproductive ability of cattle is important to obtain maximum
breeding efficiency in the dairy herd and intensive beef
systems, especially in the tropical and sub-tropical regions.
It is known for example that excessively high temperatures

change the length of the oestrous cycle, diminish the intensity of oestrus and if the heat stress is of sufficient magnitude, can induce anoestrus (Hall, Branton & Stone, 1959; Stott & Williams, 1962; Labhsetwar et al., 1963; Gangwar, Branton & Evans, 1965; Bond & McDowell, 1972; Monty & Wolff, 1974; Wolff & Monty, 1974; Fuquay, 1981). Ambient temperatures above the thermoneutral zone in cows ($28°$ C) also reduce conception rates (Ingraham, Gillette & Wagner, 1974; Thatcher, 1974). The object of this study was therefore to elucidate the influence of season on tonic LH and progesterone secretion, since the secretion of these two hormones is inter-related (Roche & Ireland, 1981) and their secretory patterns have been related to conception rates in cattle (Carstairs, Morrow & Emery, 1980).

PROCEDURE

Experimental protocol

The experiment was conducted between December of one year and September of the following year at the Cedara Research Station. Maximum and minimum temperatures, relative humidity and daylight length over the experimental period were obtained from the Meteorological Data Section at the Station.

In order to avoid the confounding effects of lactation and pregnancy on LH and progesterone secretion, a herd of 20 non-lactating and non-pregnant Friesland cows (four to nine years of age) was used. All cows were cycling normally at the commencement of the trial. The feeding regime imposed on the herd consisted of natural veld grazing, supplemented with

mineral or urea-containing licks from 15 October to 15 May and

Eragrostis _curvula_ hay (ad lib.), supplemented with a mineral

lick, from 16 May to 14 October. This programme was devised to

result in mass maintenance in the cows, thereby eliminating

the influence, if any, of gain or loss in bodymass on LH and

progesterone secretion. Bodymass of the cows was measured at

fortnightly intervals thoughout the experiment.

Blood samples were obtained from a proportion of cows

during each of four sampling periods over the course of the

study. The sampling periods were during summer (11 - 24

December), autumn (26 April - 7 May), winter (29 June - 11

July) and spring (8 - 22 September).

To establish the occurrence of oestrus prior to each

sampling period the cows were joined with an active,

masculanized teaser cow in the early morning (05h00 - 07h00)

and late afternoon (17h00 - 18h30). From Days six to 15 of the

oestrous cycle (day of oestrus = Day 1) blood samples were

obtained daily at 07h00 from seven cows during the summer,

five cows during the autumn, six cows during the winter and

six cows during the spring sampling periods. During each

sampling period a different set of animals was drawn for blood

collection, on the basis of the cows having exhibited heat

within a four- to five-day period. This procedure was adopted

to prevent the use of excessively long sampling periods.

Certain cows were sampled in more than one sampling period.

The blood samples were heparinized, and centrifuged within 30

minutes of collection. The plasma obtained was stored at -15

C pending analysis.

Hormone assays

All plasma samples were analysed for progesterone and LH. The method described by Butcher et al. (1974) was used for progesterone, and the levels were corrected for recovery of tritiated progesterone added to plasma, which varied from 72 to 86%. Progesterone concentrations were not corrected for water blank values, which varied from 15 to 25 pg/ml water. The intra- and inter-assay coefficients of variation for the progesterone level of a pooled plasma sample measured in each of the individual assays were 8,6 and 10,7%, respectively. LH was measured according to the method described by Niswender et al. (1969), except that the initial dilution of anti-serum to LH was changed from 1:100 000 to 1:160 000, and the incubation of the anti-LH serum with standards and unknown plasma samples prior to the addition of labelled LH was increased from 24 to 48 hours. The sensitivity was 0,24 ng LH/ml plasma. The LH levels in all plasma samples collected in the study were measured in duplicate and in a single assay, thereby eliminating inter-assay variation. The intra-assay coefficient of variation was 11,8%.

Statistical analyses

Hormone levels, cow masses and meteorological parameters obtained during the four seasons were examined by least squares procedures. An analysis of repeated measurements (Gill & Hafs, 1971) was also used to test for differences in hormone secretion between seasons. Regression analyses were used to study the relationship between hormone levels and

meteorological parameters.

RESULTS

Fig. 23 illustrates various climatological parameters measured over the experimental period. Mean daily temperatures during the spring (16,7 ± 9,7°C), summer (17,9 ± 0,3°C) and autumn (16,1 ± 0,7 °C) sampling periods did not differ significantly from each other, but were significantly (P < 0,05) higher than the mean temperature during the winter sampling period (11,1 ± 0,7 °C). The mean daily relative humidity during the spring (78,9 ± 3,4 %), summer (83,0 ± 3,3 %) and autumn (75,6 ± 2,2 %) was also significantly higher than that measured during the winter sampling period (63,9 ± 3,3 %). As expected, season exerted a significant (P < 0,01) influence on daylight length (Fig. 23).

It is evident from Fig. 24, in which mass changes in the herd of cows prior to and during the experimental period are presented, that relatively small changes occurred, and these were unrelated to season. The mean masses of the cows sampled during each of the four sampling periods did not differ significantly, and bodymasses were unrelated to LH or progesterone levels.

Tonic LH levels measured between Day six and 15 of the oestrous cycle fluctuated from day to day at relatively low levels (Fig. 25). The day of the cycle did not influence LH levels, although there was a trend for these to decline between Days six and 15, notably during the summer and autumn sampling periods. Mean LH levels obtained over the 10-day sampling period during autumn (2,26 ± 0,07 ng/ml) were
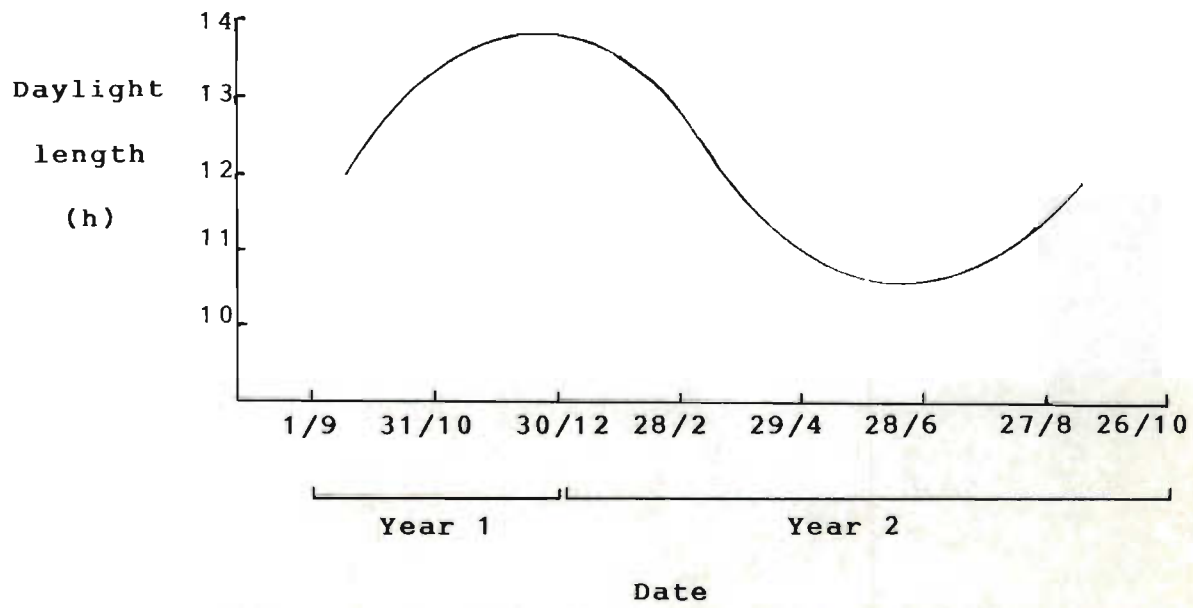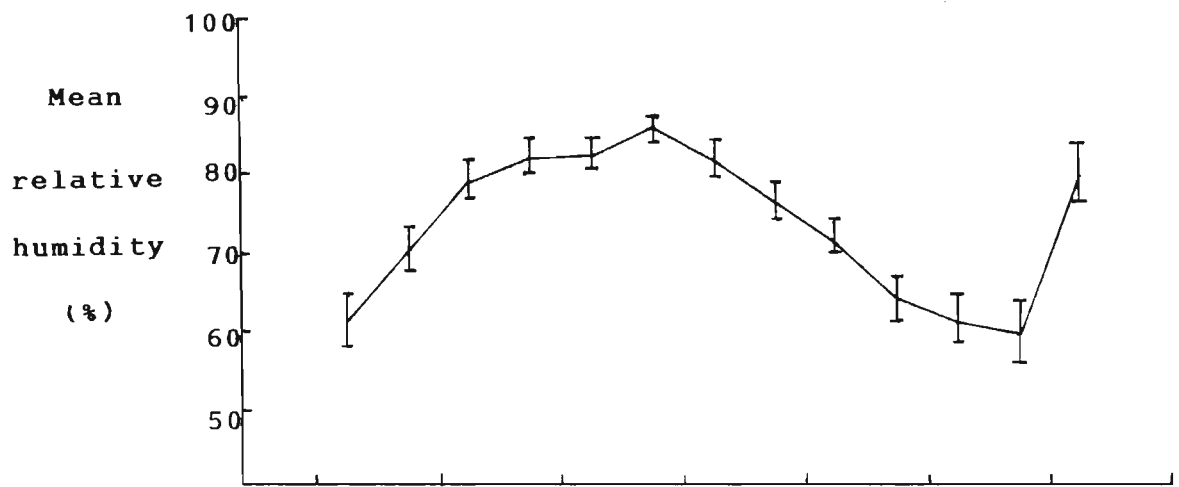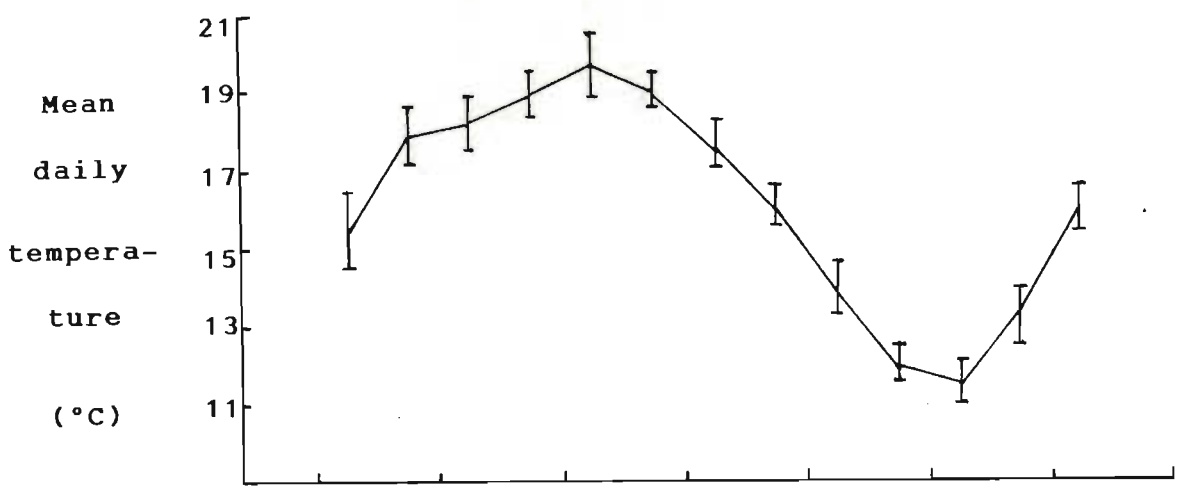
Fig. 23. Changes in climatological parameters during the experimental period.
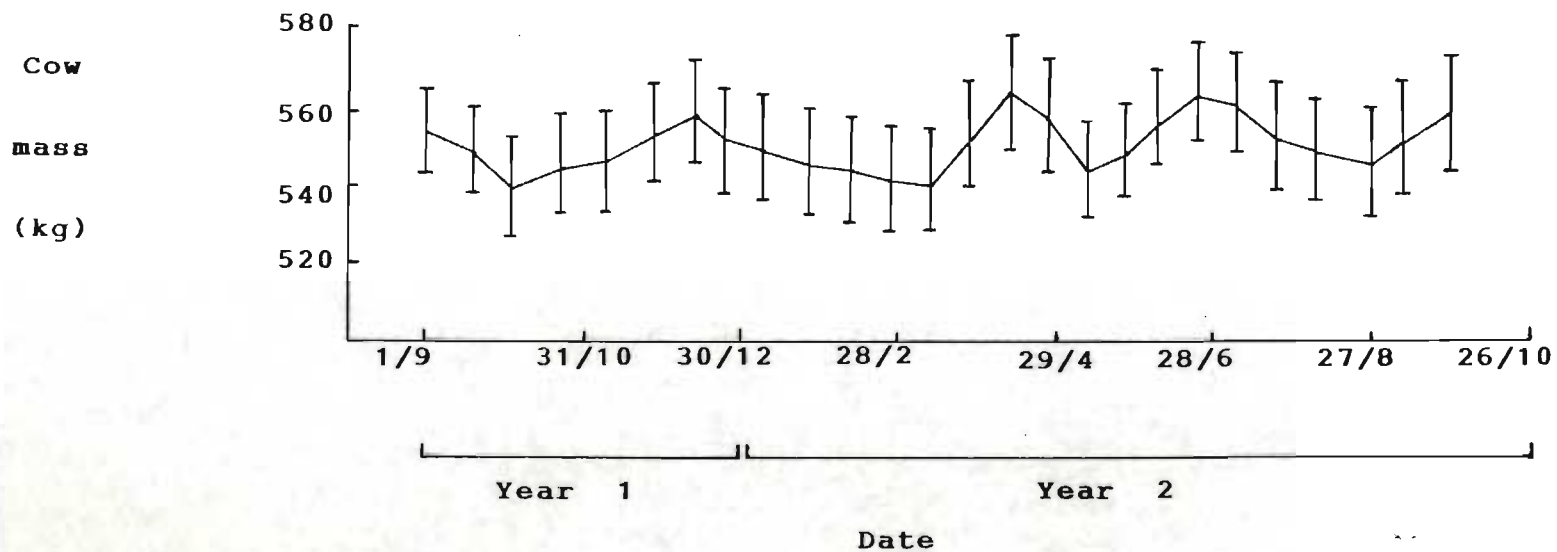
Summer   Autumn   Winter   Spring

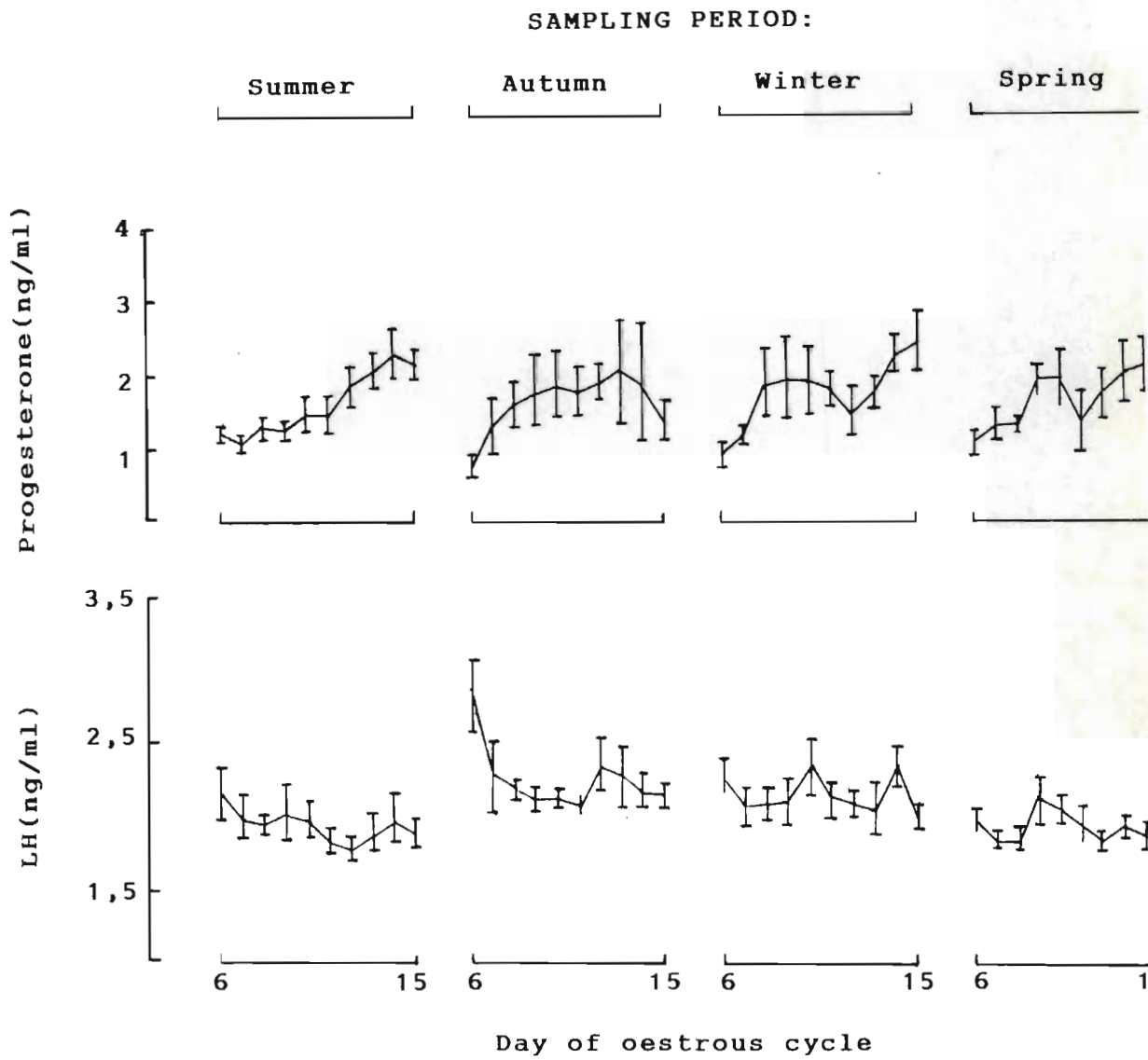Fig. 24. Changes in bodymass of cows during the experimental period.

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Fig. 25. Mean daily tonic LH and progesterone levels i
cows during four seasons of the year.

significantly (P < 0,01) higher than those obtained during summer (1,95 ± 0,06 ng/ml) and spring (1,94 ± 0,07 ng/ml), but not those obtained during winter (2,15 ± 0,07 ng/ml). The spring and summer levels did not differ significantly from each other. Mean daily levels exceeded 2,0 ng/ml on each day from Day six to 15 of the cycle during the autumn and winter sampling periods, whereas these levels exceeded 2,0 ng/ml on only two of the 10 days during the spring and summer sampling periods (Fig. 25). The mean area under the LH curve (an indication of the total quantity of LH released) for autumn (20,1 ± 0,7 mm^2) was also significantly (P < 0,05) greater than the mean for summer (17,7 ± 0,59 mm^2) and spring (17,4 ± 0,64 mm^2). The day of the oestrous cycle significantly (P < 0,05) influenced progesterone secretion, and mean levels on each of Days 13 to 16 were significantly (P < 0,05) higher than those measured on each of Days five to eight. However, it is evident from Fig. 25 that season did not influence the pattern or the total quantity of progesterone secreted.

DISCUSSION

Mass changes in the cows prior to and during the experimental period were relatively small and unrelated to season (Fig. 24). It therefore appears unlikely that plane of nutrition, as reflected by changes in livemass, could have influenced levels and secretory patterns of LH and progesterone.

The pattern of LH secretion measured during the luteal phase of the oestrous cycle (Fig. 25) is similar to that

obtained by Sprague, Hopwood, Niswender & Wiltbank (1971), Echternkamp & Hansel (1973) and Arije et al. (1974), although the magnitude of day to day variations in the present study was smaller than that obtained by the aforementioned workers. Schams & Karg (1969), Hansel & Snook (1970) and Snook, Saatman & Hansel (1971) noted that secondary LH surges, the peak levels of which were significantly higher than normal tonic levels, occurred during the luteal phase of the cycle in certain cows. More frequent sampling than was performed in this study may be necessary to detect such secondary surges. The day of the cycle did not influence tonic LH levels, a finding in agreement wih that of Rahe, Owens, Fleeger, Newton, & Harms (1980), although these workers found that the frequency and amplitude of individual surges varies significantly between days of the luteal phase of the cycle.

Season exerted a significant influence on tonic LH secretion (Fig. 25). The finding that LH levels were higher during autumn and winter than during spring and summer confirms recent work by Critser, Miller, Gunsett & Ginther (1983) which showed significantly higher basal LH levels during the winter than the summer period. Critser et al. (1983) studied ovariectomized heifers, and concluded that the seasonal difference was not controlled by the ovaries, but caused by differences in photoperiod. In contrast, Harrison & Randel (1981) showed that tonic LH levels are lower during winter than during spring. The reason for this discrepancy is not clear, but it is interesting to note that Friesland and Holstein cows were used in the present study and by Critser et al. (1983), respectively, whereas Harrison & Randel (1981) studied Brahman cows. It is thus possible that the influence

of season on tonic LH secretion differs between Bos
taurus-type and Bos indicus females. Should this conclusion be
correct, it lends further support to the evidence that
reproductive function differs between these cattle types
(Randel & Moseley, 1977; Griffin & Randel, 1977; Adeyemo &
Heath, 1980).

Madan & Johnson (1973) have noted that a heat load
sufficient to raise the core temperature of heifers by 1,0 to
1,5° C depressed both tonic and pre-ovulatory LH levels.
Results obtained in the present study suggest that factors
other than temperature and relative humidity might exert an
influence on tonic LH secretion. Thus, the correlation
coefficients describing the relationship between these
climatological paramaters and tonic LH levels were not
significant, and although autumn tonic levels were
significantly higher than those measured during spring and
summer, daily temperatures and relative humidities did not
differ significantly between these seasons. On examining the
climatological data presented in Fig. 23 with LH levels
presented in Fig. 25 it appears more likely that the gradual
decrease in daylight length which preceded the autumn sampling
period resulted in the significantly higher tonic LH levels
during this season, as opposed to lower levels measured during
spring and summer, the two seasons preceded by an increase in
daylight length. LH levels and daylight length measured over
the four seasons were significantly (P < 0,01) correlated (r =
-0,67). It is a well established fact that a decrease in
daylight length leads to increased sexual activity in sheep at
high latitudes (Hafez, 1952). It is of interest though that
mean basal LH levels do not differ significantly between

anoestrous ewes (during spring) and cyclic ewes (during autumn), but the number of individual LH peaks per day is greater in cycling than in anoestrous ewes (Yuthasastrakosol, Palmer & Howland, 1977).

Season exerted no influence on progesterone concentrations (Fig. 25), but in view of the considerable animal to animal variation in progesterone levels obtained, a larger sample than was used in this study might be necessary to accurately measure a seasonal effect. Rhodes et al. (1982) found no difference in serum progesterone levels due to season, but corpora lutea removed from cattle during winter secreted less progesterone in vitro than those removed during summer. Other research results relating climate, and notably temperature, to progesterone secretion are somewhat inconsistent. It was observed by Rosenberg, Herz, Davidson & Folman (1977) and Rosenberg et al. (1982) that progesterone levels were lower during summer than during winter, and Stott & Wiersma (1973) found that high environmental temperatures depress progesterone secretion. Conversely Mills, Thatcher, Dunlap & Vincent (1972), Gwazdauskas, Thatcher & Wilcox (1973) and Abilay, Johnson & Madan (1975) showed that the stress of a relatively high temperature is associated with increased progesterone secretion. There is clearly a need to accurately establish the influence of temperature on progesterone secretion in different localities, since a positive casual relationship has been established between conception rate and the quantity of progesterone secreted during the oestrous cycle preceding conception (Folman, Rosenberg, Herz & Davidson, 1973; Rosenberg et al., 1977, Carstairs et al., 1980).

The physiological mechanism whereby season influenced tonic LH secretion in the present study can only be speculated upon. Evidence has been obtained implicating the pineal gland in the transfer of photoperiodic information to the hypothalamo-hypophyseal-gonadol axis in various laboratory animals (Reiter, 1980). Data relating the pineal gland to seasonal changes in breeding activity in ruminants are less clear. Earlier work in sheep indicated that the pineal gland might not be implicated in this effect (Roche, Karsch, Foster, Takagi & Dziuk, 1970; Kennaway, Obst, Dunstan & Friesen, 1981). However, the link between photoperiod and seasonal changes in the reproductive ability of sheep is now considered to involve the pineal-melatonin system (Bittman, Dempsey & Karsch, 1983; Kennaway & Gilmore, 1984). A number of workers have suggested that the secretion of LH during the oestrous cycle is governed primarily by oestrogen, which acts upon two independant feedback systems, a negative one controlling tonic secretion and a positive system governing the pre-ovulatory LH surge (Brown, Cumming, Goding & Hearnshaw, 1972; Diekman & Malven, 1973; Karsch & Foster, 1975). More recently evidence has been gained to indicate that progesterone exerts an important role in the regulation of tonic LH secretion in the ewe (Karsch, Legan, Hauger & Foster, 1977) and the cow (Convey, Beck, Neitzel, Bostwick & Hafs, 1977; Roche & Ireland, 1981; Ireland & Roche, 1982). In this context it is interesting to note that the inverse relationship between progesterone and LH levels measured in the present study was flexible (Fig. 25), and it therefore appears that factors other than progesterone may be involved in the control of tonic LH secretion in cattle.

The significant influence of season on luteal-phase LH secretion obtained in the present and other studies (Harrison & Randel, 1981; Critser et al., 1983) indicates a need for further research into the phenomenon of seasonality in cattle. Research of this nature may indicate significant influences of season on overall reproductive efficiency. The application of such information is unlikely to lead to sudden, drastic improvements in reproductive function, but could contribute to improved performance and profitability over the long term, especially in more intensive beef and dairy systems in which abundant and nutritious forage is available during all seasons. Mating periods could then be synchronized with the season of maximal reproductive efficiency. The data obtained in this experiment show seasonal changes in one component of reproductive function; more information is required to assess the overall effect.

GENERAL DISCUSSION

The series of investigations performed in this study was directed at questions likely to arise among producers considering or implementing intensification programmes in their beef cowherds. Major emphasis was placed on the utilization of cultivated pastures. There is no doubt that the use of pastures offers an opportunity of increasing herd numbers on most farms in the high-rainfall, eastern areas of the Republic (Van Marle, 1974). Margins over feed costs obtained in cows on pasture were relatively small (Table 27), when considering that they exclude expenditure on bulls, raising replacements, veterinary remedies, labour and interest charges. The use of cultivated pastures for the beef cowherd is therefore not easily justifiable in the present economic climate, a conclusion shared by Theron & Harwin (1983). At present, established pastures provide rewarding financial gains when utilized by young, growing stock (Bartholomew & Louw, 1982; Jordaan, 1984). However, there seems little doubt that in years to come the increased demand for potential slaughter stock will favour, and even necessitate, the use of pastures to carry lactating beef cows. Although 75% more dry than lactating cows can be supported on a given area of pasture (Neville & McCormick, 1983), the likelihood of pastures being utilized by the former class of cow seems remote.

Means of improving margins above those obtained in the present study (Table 27) require evaluation, since pastures at present support cowherds on certain farms with limited

quantities of veld grazing. An evaluation of the cost structure summarized in Table 27 indicates that reductions in the cost of winter feed will significantly improve the profit position. Relatively expensive conserved winter feed formed the basis of the wintering programme in the present study. Cheaper roughages such as crop residues, spared veld and sweetveld will markedly improve monetary returns, and their use should be a major consideration in the planning of programmes involving summer pastures for beef cows. Attention should also be directed at improving the income per cow on pasture. Two strategies warrant consideration, namely the use of multiple suckling regimes, and the so-called "dairy ranching" system. The latter scheme involves the cropping of milk in addition to weaner calves. Preston & Willis (1974) quoted preliminary reports on this technique, in which calves were allowed to suckle either once or twice daily, immediately after their dams were milked. Although weaning was performed at 70 days, results were encouraging in that acceptable calf growth rates and yields of saleable milk were achieved. Under conditions of the present study the overnight separation of cow and calf, followed by milking in the morning and rejoining of the cow-calf pair during the day, appears the most practical approach. The production of industrial milk from Dual Purpose cows on pasture during the four months which follow calving could in theory increase returns per cow by 31%, relative to those obtainable from the exclusive production of weaners (a 20% reduction in weaning mass was assumed for calves suckling cows which are milked). This system may lead to impaired reproductive function and calf growth, but certainly warrants attention. Harwin & Lombard

(1974) suggested that multiple suckling techniques could significantly increase productivity of cowherds under intensive conditions. Twenty five percent more beef was produced per acre in a system of double suckling, relative to the production of single calves in the study by Joblin (1969). Wyatt, Gould & Totusek (1977) showed that cows rearing two calves weaned 60% more beef, but required 72% more supplemental feed, and had longer postpartum anoestrous periods than those weaning singles. Relatively large management inputs are required in multiple suckling programmes, but their contribution to increased productivity needs to be examined in future.

Experiments designed to cater for data accumulation over a number of years do not allow frequent changing of treatments and procedures. There are indications though that a less rigid approach than was adopted in the present study has much to offer in the farming situation. Thus, when calves (and not cows) were placed on pasture subsequent to weaning during the 1982/83 season, they achieved remarkably rapid gains of approximately 0,6 kg/day over a three-month period (Table 16). This strategy appears warranted, especially when calves subjected to relatively heavy stocking rates on pasture are deferred after weaning. At light stocking rates the strategic removal of grass for silage during the mid-summer months is also unlikely to influence animal performance to a large degree, and could be considered.

As previously concluded, the exclusive use of pasture as a roughage source for beef cows is not economically justifiable at present. However, this need not exclude the strategic use of pastures for the cowherd. An example of strategic

utilization which has received recent attention is the provision of pasture as a creep feed. Thomas, Eason & Turnbull (1983) reported substantial and economical increases in calf gain with this practice, in which a considerable sparing effect on the cow (in terms of mass gain) was also recorded. Baker et al. (1981a) concluded that creep grazing was beneficial when residual sward height in forage allocated to cows was relatively low, whereas Bogley, Morrison, Feazel & De Ramus (1983) showed that older calves benefit more from pasture creep than younger calves. Anonymous (1983) reported no advantage of this technique unless the forage supplied to the cow was limiting, and stressed the importance of providing an incentive (such as shade) to calves in order to attract them to the creep. Cultivated pastures could also be used strategically before and during the breeding season in order to improve conception rates, although Smeaton, Wadams & Hockey (1982) were unable to gain a beneficial effect from this practice in New Zealand.

Stocking rate exerted a significant influence on virtually all parameters of production on pasture, including the length of the grazing period (Table 4), changes in cow mass (Table 6) and condition (Table 8), calf gains (Table 14) and milk production (Table 20). The choice of stocking rate is therefore one of the major decisions facing producers in an intensive cow/calf operation on pasture. In this context it is interesting to note that Baker et al. (1982a) concluded that cow/calf performance is not influenced by the grazing system (continuous or rotational) when operating at relatively light stocking rates. Evans (1981) is of the opinion that rotational grazing provides better utilization of pasture than continuous

grazing when stocking rates are relatively heavy. One may
infer that the stocking rate which provides maximum gain per
hectare will be most profitable. However, the situation is not
that simple, since maximum gains per hectare were achieved at
the heaviest rate (Fig. 8), but it necessitated the longest
period of winter feeding (Table 5) and was associated with the
production of relatively light weaners (Table 15), which may
be unacceptable from a marketing point of view. There is
little doubt that economic considerations should override all
others in arriving at the stocking rate of choice. The results
of the economic analysis (Table 27) indicate that maximum
margins per cow and per hectare were achieved at different
stocking rates. Sound planning of intensive cowherd programmes
should therefore evaluate whether margins per cow or per
hectare need to be maximized. In general, maximum margins per
cow (at relatively light stocking rates; Table 27) should be
considered when winter feed supplies and capital to obtain
stock for existing pastures are limiting factors, and/or a
large demand exists for heavy weaners. Relatively heavy
stocking rates should be considered when the area of pasture
(and not the number of cows) is limiting, but the farm is
capable of providing abundant, relatively cheap winter feed.
The results presented in Fig. 14 indicate that of all physical
factors, the availability and cost of winter feed is likely to
exert the greatest influence on the choice of stocking rate.
An added consideration is the quality of winter feed, since
cows stocked at heavy rates on pasture enter the winter period
in relatively poor condition (Fig. 6), and require good
quality roughage in order to regain condition before calving.
Dual Purpose cows will be at a greater disadvantage than

British-crosses when winter feed is of poor quality, since their condition at the conclusion of the grazing season was poorer than that of the British-crosses (Table 9).

The finding that Dual Purpose cows were more productive and yielded larger margins on pasture than their British-cross counterparts (Table 27) supports the recommendation by Harwin & Lombard (1974) and the suggestion by Paterson et al. (1980b) that intensive conditions favour the relatively late maturing and high-producing cow types. In the present investigation differences in inherent growth rate and milk production between the two types were probably major reasons for differences in their overall productivity. Cow size per se appeared to exert a relatively small influence on productivity, since Simmentalers were on average only about 12 kg heavier than the Hereford-cross cows. The latter breed produced less milk (Table 21) but gained more (or lost less) mass and condition than the Dual Purpose cows (Tables 6,8), and, in view of their similar masses, it appears unlikely that forage intakes would have differed markedly between the two breeds. Within each breed the size of cow influenced its mass change on pasture (Table 6) and the birth mass of its calf (Table 13), but exerted no influence on calf gain (Table 14) and milk production (Table 20). Harwin & Lombard (1974) provided evidence in favour of large over small cows under intensive conditions, including lower maintenance requirements per unit of bodymass and lower fixed costs, which accrue on a per animal basis. Earlier Kress, Hauser & Chapman (1969) concluded that larger cows are more profitable than smaller cows, whereas more recently Cartwright (1979) emphasized the complexity of evaluating animal size in relation to

efficiency, and stressed the importance of assessing size in relation to all components of the production process. Computer simulation models have also indicated that a wide range of size classes are potentially optimal, depending on the prevailing economic conditions (Notter, Sanders, Dickerson, Smith & Cartwright, 1979a,b).

Variability between animals was a feature of most measures of productivity in cows and calves on pasture. Milk yield was no exception, since it varied by as much as 213% within treatments. Considerable variation in yield within breeds and treatments was also noted by Reynecke & Bonsma (1964), Gleddie & Berg (1968), Jeffery et al. (1971b), Nicol (1976) and Boggs et al. (1980). It was observed by Howes et al. (1958) that certain cows quadrupled the yield of others within the same group, and Klett et al. (1965) measured yields which varied from 0,34 to 7,14 litres per day in cows of comparable lactational status. The variability of production was indicative of a considerable potential for the improvement of milk yield via selection. The need to study large numbers of cattle in order to overcome the problem of variability was stressed by the finding that no measure of production was influenced by cow age, whereas there is a considerable body of evidence to prove the opposite (Cundiff et al., 1966b; Kress & Burfening, 1972; Butson et al., 1980; Nelsen & Kress, 1981). Paterson et al. (1980b) demonstrated the value of studying large numbers of cattle when they showed that Dual Purpose cows kept on intensive pastures reach their peak of production (in terms of the weaning mass of their calves) at a more advanced age than earlier-maturing types. They consequently suggested that Dual Purpose cows are more productive than

earlier-maturing types when the average dam age in the herd is high.

A feature of the results pertaining to milk production on pasture was that milk quality and quantity exerted similar effects on calf gain (Table 24). A number of workers (Wilson et al., 1969; Jeffery et al., 1971a; Rutledge et al., 1971; Mondragon et al., 1983) reached the same conclusion, and it appears that in large-scale trials the calf-nursing technique should be given preference over the one whereby cows are actually milked. The latter technique presented no real problems in the present study, providing that cattle were quietely handled, and care was taken to ensure the accurate administration of oxytocin into the jugular vein. The relatively high milkfat percentages measured in this study (Fig. 12) relative to others (Heyns, 1960a; Melton et al., 1967) suggests that milk removal was complete. However, calf nursing techniques provide a more rapid and cheaper method of measuring milk production, despite the potential inaccuracies associated with urination and defecation by calves, and rainfall during the test period (Neidhart et al., 1979).

Dual purpose cows produced significantly more milk than the British-crosses (Table 20), and this was probably one of the major reasons for the greater productivity in the Simmentalers than in the Hereford-crosses. The doubts expressed concerning the importance of milk production as a determinant of calf growth under intensive conditions (van Marle, 1974) were also dispelled by the results obtained in this investigation. There is little doubt that milk production and calf growth were positively correlated (Table 24), but the conversion of milk to calf gain became less efficient as milk yields increased

(Table 25). Milk conversion rates in low- and high-yielding cows are not strictly comparable though, since calves which suckle low-yielding cows also consume larger quantities of forage, and vice versa (Kropp et al., 1973; Holloway et al., 1975; Lusby, Stephens & Totusek, 1976). Lower-yielding cows therefore produce slower-growing calves, but more favourable milk conversion rates than their high-yielding contemporaries, the calves of which rely mainly on milk as their feed source. Nevertheless, it appears that more research is needed to establish the optimum level of milk production for different nutritional regimes and production systems. This will clearly require a major research input, since milk and forage intakes, mass changes in cows and calves and reproductive performance need to be quantified. Computer simulation models could prove useful in synthesizing data of this nature. They were used by Notter et al. (1979a) to predict the effects of milk production on the economic and biological efficiency of cow/calf systems integrated with fattening of calves after weaning. They concluded that optimal milk yield will vary with the price ratio of feedlot to cowherd TDN, and will depend on the extent to which yield influences calf survival and rebreeding rate.

Post-weaning calf performance was influenced by the stocking rate applied prior to weaning (Table 18). This finding indicates a need to relate calf performance during the suckling period to subsequent productivity. The potential importance of this relationship is stressed further by reports that relatively high nutritional levels during the suckling period in heifer calves may detrimentally affect their subsequent milk production potential (Christian et al., 1965;

Mangus & Brinks, 1971; Lawson, 1981; Johnsson & Obst, 1984; Johnsson & Morant, 1984). Philips, Johnsson & Cooper (1982) suggested that heifers be managed to achieve low to moderate weaning masses, and moderate to high pre-mating masses, in order to obtain beef replacements possessing good fertility and mothering ability. It may thus be advisable to consider strategies such as early weaning on intensive pastures utilized at relatively light stocking rates and by early maturing cattle, in order to prevent the production of overfat heifers at weaning.

While there is little doubt that increased milk yields are associated with the production of heavier weaners (Table 23), there is evidence to indicate that under certain conditions this may come about at the expense of total productivity. High-yielding cows reproduce less efficiently than low-yielding females (Boggs et al., 1980), a phenomenon ascribed to inadequate nutrient supplies in the former category (Deutsher & Whiteman, 1971; Hansen, Baik, Rutledge & Hauser, 1982). Holloway et al. (1975) compared Hereford, Hereford x Holstein and Holstein cows fed different levels of supplements after calving. At moderate supplementary levels the Herefords reproduced most, and the Holsteins least efficiently. Thus, while the infusion of Dual Purpose breeding into South African beef herds is often advocated as a means of improving milk yield and weaning mass, cognizance should be taken of the increased nutrient requirements to achieve these, and to maintain acceptable reproductive performance. In the present study reproductive rates were far from acceptable (Table 10), but appeared unrelated to level of nutrition (stocking rate). Although stocking rate affected most

parameters of production at weaning, its effect was relatively small during the initial three months (November to January) of the grazing period (Figs. 7, 11). This is understandable, when considering that Kikuyu reaches its peak of production during these months (Cross, 1979). Peak production of grass also coincided with the mating season, which probably accounts for the lack of an effect of stocking rate on re-breeding performance.

A prolonged postpartum anoestrous period in some beef cows may extend the interval between successive parturitions beyond the optimal period of one year. Reducing the suckling stimulus clearly shortens the length of the acyclic period after calving (Saiduddin et al., 1967), and the major objective of the experiment described in Chapter 2 was to elucidate the physiological basis for this effect. Progesterone priming in anoestrous cows mimicks the increase in the level of this steroid which usually occurs before the first ovulation after calving (Donaldson et al., 1970). In the present study it also facilitated the collection of the close on 5000 blood samples, since sampling in each cow could be predetermined relative to a reference point, for example the GnRh injection. It was anticipated that the removal of the progesterone implants, together with the administration of synthetic GnRh, would set in motion a sequence of endocrinological events similar to those which occur before ovulation in cycling cows. The intensive sampling schedule was employed to follow certain of these events, and to establish whether they were influenced by the widely varying treatments applied. However, these exerted no influence on measures of tonic LH (Fig. 19) and oestrogen secretion (Fig. 17). The restricted suckling treatment

depressed LH release after GnRh in the Drakensbergers, and tended to increase release in the British-crosses (Fig. 22). A treatment effect which approached significance was that of restricted suckling, which led to a larger ovulatory response than normal suckling (Table 29). A possible explanation for these results is that restricted suckling might have improved the response of the ovaries to circulating tonic LH levels and the acute release of LH after the GnRh injection. One can only speculate on the mechanism whereby the ovarian response might have been improved. However, it is interesting to observe that Walters, Kaltenbach et al. (1982) showed that the removal of the suckling stimulus increases follicular fluid prolactin concentrations, and this is related to an increase in the concentration of LH receptors in the largest ovarian follicle.

The lack of an effect of suckling on tonic LH levels and oestrogen secretion could also be explained on the basis of the respective assays not being sensitive enough to measure treatment effects. Thus, basal LH levels were also not affected by progesterone therapy and stage postpartum (Fig. 19), whereas considerable evidence exists to show the opposite (Arije et al., 1974; Echternkamp, 1978; Carruthers & Hafs, 1980; Chang et al., 1981; Ireland & Roche, 1982). Haresign et al. (1983) reviewed patterns of hormone secretion during th anoestrous period in livestock and concluded that a delay in the restoration of episodic LH secretion is one of the main reasons for extended acyclic periods in lactating cows. Support for this conclusion was provided via the finding by Walters, Short et al. (1982) that the administration of small doses of GnRh at two-hourly intervals over a four-day period

reduces the length of the acyclic period. They also concluded that suckling prolongs the postpartum interval by reducing the frequency of pulsatile LH releases from the hypothalamus. There was no evidence of an episodic pattern of secretion in the anoestrous cows used in the present study (Fig. 18). A possible explanation for this phenomonon is that the cows were in a relatively "deep" state of anoestrus, but this seems unlikely, since 67% of the cows ovulated in response to the GnRh (Table 29). It again seems more likely that the LH assay was not sensitive enough to measure an episodic pattern of secretion.

Oestrogen fluctuated at relatively low levels before the GnRh injection (Fig. 17), and there was no indication of a distinct surge as occurs before the pre-ovulatory LH release in cycling cows (Hansel, Concannon & Lukaszewska, 1973; Christensen et al., 1974). The relatively low oestrogen levels measured prior to the GnRh injection (Fig. 17) may have been indicative of inadequate follicular development. This in turn could have contributed to the absence of ovulation, and the incidence of "short" cycles in certain cows (Table 29). Follicle size influences the release of LH in response to GnRh in anoestrous cows (Inskeep et al., 1977; Lishman et al., 1979), and Smith et al. (1983) found that cows with larger follicles are more apt to form corpora lutea after a GnRh stimulus than those with smaller follicles.

The total quantity of LH released in response to GnRh did not determine whether cows ovulated or not, and whether they subsequently underwent "short" or normal cycles (Figs. 20, 21). This result supports the explanation that the improved ovulatory response in cows suckled once daily was due to an

improvement in the responsiveness of their ovaries to circulating LH. As far as could be ascertained a relationship between the size of the LH surge and the occurrence of ovulation has not been established in cattle. More research is clearly needed to define the factors, other than the quantity of LH released, which determine whether ovulation will occur or not.

It is not clear from the results obtained in this investigation why certain cows undergo "short" cycles after ovulating in response to GnRh (Table 29). Inadequate follicular development prior to ovulation may be one reason, but the answer might be sought in the support of the corpus luteum formed after the induced ovulation. It is well established that LH is the major luteotropin in the cow (Hansel & Convey, 1983) and that prolactin is not luteotropic (Hoffman, Schams, Bopp, Ender, Gimenez & Karg, 1974). The continuous infusion of PMSG improves luteal function in sheep (Grobbelaar, 1984), and this approach may well eventually yield the solution to the problem of short-lived corpora lutea in cattle.

There is an ever-increasing body of evidence to indicate that reproductive function differs betweeen Bos taurus and Bos indicus cattle. Generally, Bos indicus cows reproduce less efficiently than their Bos taurus counterparts. In the present study the improvement in ovulatory response due to restricted suckling was greater in the Drakensberger than in the Simmentaler X Hereford cows. Furthermore, normally-suckled Drakensberger cows secreted more LH in response to GnRh than Simmentaler x Herefords, and the restricted suckling treatment exerted different effects on the GnRh-induced LH release in

the two breeds (Fig. 22). Further research into the basic causes of the differences in reproductive function between the two breed-types is urgently required, since 60% of all South African beef cows contain <u>Bos</u> <u>indicus</u> breeding (Coetzee, 1983). Such studies should not be used as motivation to downgrade or discriminate against <u>Bos</u> <u>indicus</u> cattle, since they contain various outstanding attributes conducive to productivity in large areas of the Republic which have harsh climatic and forage conditions. Results from basic studies of this nature should ideally be applied to improve reproductive function in existing <u>Bos</u> <u>indicus</u> herds. For example, Inskeep, Dailey & Rhodes (1982) have suggested, on the basis of research data, that certain modifications to accepted artificial breeding techniques be applied in <u>Bos</u> <u>indicus</u> cows. These include the more frequent detection of oestrus and the insemination of females at the onset of oestrus or shortly thereafter, rather than the use of the conventional "AM-PM" rule advocated by Trimberger & Hansel (1955). Administration of human chorionic gonadotropin (HCG) at the time of insemination was also found to increase conception rates in Zebu-bred herds by as much as 10% (Randel, 1979).

There is clearly a need to examine the phenomonon of seasonality in cattle on a far wider basis than was attempted in the study described in Chapter 3. In seeking an explanation for the significant effect of season on luteal-phase LH secretion obtained in the present study (Fig. 25) and by Critser <u>et al</u>. (1983) one is confronted with a vast number of possibilities. One of these is that differences in basal secretion due to season reflect differences in pituitary LH concentrations. The issue is far more complicated though,

since tonic LH secretion is controlled by negative feedback effects of progesterone (Convey et al., 1977; Ireland & Roche, 1982) and oestrogen (Hobson & Hansel, 1972). One may logically also question the implications of seasonal differences in tonic LH secretion. LH is the luteotropic hormone in cattle (Hansel, 1966; Hansel & Convey, 1983) and is involved in the maturation of ovarian follicles (Baird, 1978). Does this mean that corpus luteum function and follicular development will also differ between seasons? Are seasonal differences in hormone secretion related to differences in ovarian function and inherent fertility? A host of questions therefore arise in response to the fragmented, yet positive indications of a seasonal influence on endocrine function in cattle (Harrison & Randel, 1981; Harrison et al., 1982; Rosenberg et al., 1982; Critser et al., 1983). Obtaining answers to these questions provides an exciting challenge to reproductive physiologists. They may well take the lead provided by researchers who have studied the phenomenon of seasonality in sheep. According to Karsch, Goodman & Legan (1980) the phenomenon of seasonal breeding in ewes may be explained on the basis of a profound seasonal change in the responsiveness of the system which governs tonic LH secretion. Hereby oestrogen is a potent negative feedback hormone during anoestrus, but ineffective during the breeding season. McNatty, Hudson, Henderson, Lun, Heath, Gibb, Ball, McDiarmid & Thurley (1984) concluded that anovulation during seasonal anoestrus is due to a reduced frequency of high-amplitude LH discharges from the pituitary. The long-term iv administration of small quantities of LH or GnRh in anoestrous ewes stimulated cyclic activity comparable to that observed during the breeding season (McNatty, Ball,

Gibb, Hudson & Thurley, 1982; McNatty, Hudson, Gibb, Ball, Fannin, Kieboom & Thurley, 1984). Tonic and pre-ovulatory LH levels in sheep appear to be highest shortly before and during the period of greatest ovulatory activity (Schanbacher & Lunstra, 1976; Howland, Palmer, Sanford & Beaton, 1978). Harrison et al. (1982) suggested that a reduction in pre-ovulatory LH levels during winter in Brahman cows may be analogous to the situation in ewes, wherein the absence of an LH surge is a major factor in causing the anovulatory condition (Legan & Karsch, 1979). On the basis of knowledge gained in ewes the dynamics of pulsatile LH secretion and the pre-ovulatory LH surge during different seasons may thus provide a fertile field of study in resolving how season influences the reproductive process in cattle.

The work described in this dissertation aimed at gaining a clearer understanding of the animal responses involved in industry-orientated and the more basic aspects of intensive beef production. The series of investigations provided answers to many of the questions origonally posed, but clearly the scope of the investigation needs to be widened in future. Specific research needs have been identified and discussed, but in general, future efforts should concentrate on establishing the inter-relationships between different facets of production, and the relation of information of a more basic nature to the farming situation. For example, beef cow/calf performance on pasture needs to be studied in relation to post-weaning calf performance, and seasonal differences in bovine hormone secretion related to breeding efficiency. Furthermore, it will become increasingly important to resist the temptation of neglecting the economic implications of

advice   based on research into intensive animal production. By
taking cognizance of this principle a meaningfull contribution
to intensification in the high-potential areas is possible.

SUMMARY

CHAPTER 1.

The comparitive performance of spring-calving beef cowherds comprising either Dual Purpose (Simmentaler) or British-cross (Hereford x Africaner) cows and calves was investigated on kikuyu pasture over three seasons. The study commenced during 1980 and ended during 1983. The influence of stocking rate on animal performance was investigated by utilizing four rates, namely 3,0, 4,12, 5,34 and 6,74 cows and calves/ha. The post-weaning performance of calves fed a silage-based ration was measured subsequent to the 1981/1982 grazing season. Bodymass changes in cows and calves, condition score changes in cows and reconception rates were monitored. Emphasis was placed on the importance of milk production as a determinant of calf growth on pasture. Milk yields were obtained at monthly intervals during the 1981/1982 season.

The main findings and conclusions were:

1. The seasonal rainfall was betweem 73,7 and 83,7% of the long-term average during the three seasons studied. Season did not influence mean maximum and minimum temperatures.

2. Over the four stocking rates the total calf metabolic mass per hectare constituted between 15,0 and 21,1% of total cow and calf metabolic mass/ha at the start of the grazing season, and approximately one-third of total cow and calf metabolic mass/ha at weaning.

3. Over the three seasons grazing commenced on 2 November ± 17 days, and calves were weaned on 19 June ± 13 days, 5 June ± 18 days, 20 April ± 33 days and 17 April ± 32 days at the

stocking rates of 3,0, 4,12, 5,34 and 6,74 cows and calves/ha, respectively. Cows were removed from pasture approximately 10 days after weaning.

4. A stepwise multiple regression analysis was used to examine factors responsible for variation in mass changes in cows on pasture. Stocking rate, mass at the start of the grazing period and season accounted for 42,0, 16,2 and 1,4% of the variation in cow mass changes on pasture, respectively. Mass changes were not influenced by breed and cow age.

5. Stocking rate, breed, initial condition score and stage postpartum when grazing commenced contributed significantly to the variation in condition score changes in cows on pasture. These factors in combination explained only 20,4% of the variation in score changes. Hereford-cross cows gained more (or lost less) condition on pasture than Simmentalers.

6. On average 65% of the lactating cows reconceived each season. Reconception rates were not influenced by season, parity status, breed and stocking rate. Masses and mass changes in cows which reconceived did not differ significantly from those which failed to become pregnant. Calving occurred significantly (P < 0,05) earlier in Simmentalers which reconceived than in those which failed to produce a calf, but no such an effect was apparent in the Hereford-crosses. On average 7,4% of the cows subjected to each of the stocking rates failed to exhibit oestrus during the breeding season.

7. Male calves of both breeds were 10% heavier at birth than females. Birth masses of Simmentaler calves of both sexes were on average 6,0% heavier than the Hereford-crosses. In both breeds the calf birth mass expressed as a percentage of cow mass was significantly (P < 0,05) greater in male than in

female calves. Cow mass, calf sex, breed and season accounted for 17,4, 14,6, 1,9 and 1,8% of the variation in birth mass, respectively. Less than 1,0% of all calvings was associated with dystocia, and calf losses between birth and one month of age averaged 3,7%.

8. Steer calves grew 6,7% faster than heifer calves on pasture. Differences in calf gain due to stocking rate were significant, and were manifested mainly during the latter half of the periods on pasture. Other factors which contributed significantly to the variation in calf gain were season, breed, sex and mass at the onset of the grazing season. At the stocking rate of 6,74 cows and calves/ha approximately 1134 kg of calf mass was produced per hectare, which was about 60% more than the 698 kg/ha produced at the stocking rate of 3,0 cows and calves/ha. On average Simmentaler calves produced 13% more beef per hectare than the Hereford-crosses.

9. Calves originating from the groups stocked at the rates of 5,34 and 6,74 cows and calves/ha were returned to pasture for a 88-day period subsequent to weaning during the 1982/83 season. The pre-weaning stocking rate did not influence post-weaning gains, which averaged approximately 0,66 kg/day in the Simmentaler, and 0,55 kg/day in the Hereford-cross calves.

10. An increase in stocking rate on pasture was associated with a decrease in weaning mass, but an increase in the dry matter intake, expressed as a percentage of bodymass, of a silage-based ration fed after weaning. There was a trend for calves stocked at the lighter rates on pasture to convert their feed more efficiently to livemass gain after weaning than the calves subjected to the heavier rates on grass.

11. Milk yields measured on pasture varied considerably within breeds and stocking rates. Cows of both breeds stocked at rates of 3,0 and 4,12 cows and calves/ha were significantly more persistent in their production of milk than cows stocked at rates of 5,34 and 6,74 cows and calves/ha. Yields of FCM, protein, lactose and SNF were influenced significantly by initial yield (measured when cows were placed on pasture), breed, calving date and stocking rate. Daily yields of FCM in the Simmentalers were on average 27% higher than in the Hereford-crosses.

12. Milk butterfat percentages increased from approximately 4,6 to 5,3%, and milk protein percentages from 3,2 to 3,9% over a six-month period on pasture. SNF percentages remained relatively constant at approximately 8,7%, and lactose concentrations decreased from approximately 5,0 to 4,7%.

13. Approximately 40% of the variation in calf gain was ascribed to milk production. Stocking rate, breed, calving date and calf sex accounted for a further 40% of the variation in gain. The correlation coefficients which describe the relationships between calf gain and either milk production or the production of the different milk constituents did not differ significantly in both the breeds. The correlation between milk yield and calf gain over the period 30 to 90 days of lactation (r = 0,73) was significantly (P < 0,05) larger than that over the period 90 to 180 days (r = 0,14) in the Hereford-crosses. In the Simmentalers these correlation coefficients did not differ significantly.

It was concluded that milk production is an important determinant of calf gain in cattle grazing intensive pastures.

14. The conversion of milk to calf gain was more efficient at lower than at higher milk yields, at lower than at higher stocking rates, in Simmentalers than in Hereford-crosses and in male than in female calves.

15. An economic analysis was conducted on the data obtained over three seasons. Regression equations were used to compute the different parameters of production. The main conclusions arrived at were:

a). Margins over feed costs per Simmentaler cow were between R12 and R23 larger than per Hereford-cross cow over the four stocking rates.

b). Margins over feed costs per cow were largest at the lightest stocking rate, and progressively decreased with an increase in stocking rate.

c). Over the four stocking rates the margins over feed costs per hectare were between R60 and R120 larger in the Simmentalers than in the Hereford-crosses. On a hectare basis the largest margin (R314,8) was obtained in the Simmentalers stocked at a rate of 4,12 cows and calves/ha.

d). Winter feed costs accounted for between 50 and 76% of total feed costs, depending on the stocking rate utilized.

It was concluded that under the conditions of this study, and when calves are sold at weaning, the Simmentaler cows are more profitable than the Hereford-crosses.

CHAPTER 2.

Ovarian and endocrinological responses associated with normal and restricted suckling in beef cattle were investigated. A total of 37 first-calf cows and their calves,

comprising 19 Drakensbergers and 18 Hereford x Simmentalers, were subjected to either normal or once-daily suckling for 15 days. The periods of varying suckling intensity commenced at either Day 35 or 60 postpartum. A 2x2x2 factorial arrangement of treatments was used.

All cows received common hormone therapy during the normal or restricted suckling periods. A Norgestomet ear implant was inserted in conjunction with an oestrogen injection on the first day, and removed on the tenth day of the variable suckling periods. The cows were injected with 500 μg GnRh 30 hours after the removal of the ear implants, and inseminated 18 and 42 hours after the GnRh injection. Cows were rectally palpated one week after the GnRh injection. Progesterone profiles obtained during the 21 days which followed the GnRh injection were also used to establish whether the cows ovulated or not.

Approximately two-thirds of all cows ovulated in response to the GnRh injection. There was a tendency for a greater ($P <$ 0,05) proportion of the cows suckled once daily to ovulate than those suckled normally, and this effect was most marked in the Drakensberger cows treated between Days 60 and 75 postpartum. In the Drakensbergers the restricted suckling regime tended to increase the proportion of cows which conceived to the fixed-time inseminations and to decrease the incidence of "short" oestrous cycles following the GnRh injection. Approximately 53% of all cows which ovulated also conceived to the fixed-time inseminations, and 16% of all cows underwent "short" cycles after the GnRh injection.

Concentrations of oestrogen measured during the five days which preceded the removal of the ear implants varied

considerably at relatively low levels, and were not influenced

by treatment.

Tonic LH levels fluctuated at relatively low levels prior

to and during the variable suckling periods, and there was no

indication of an episodic pattern of secretion. Treatment

exerted no influence on tonic LH secretion.

An LH surge was measured in all cows following the GnRh

injection. The area under the LH curve, the duration of the

surge (approximately 6,5 hours) and the maximum LH level were

not related to either the incidence of ovulation, or

treatment. LH response curves described by fourth degree

polynomials indicated significant (P < 0,05) differences due

to breed and suckling intensity. The Drakensbergers suckled

normally secreted significantly (P < 0,05) more LH than the

Simmentaler x Herefords. Drakensberger cows suckled once daily

secreted significantly (P < 0,05) less LH in response to GnRh

than those suckled normally. In the British-cross cows the

suckling intensity did not influence the amount of LH released

in response to GnRh.

Treatment exerted no influence on calf growth rates.

It was concluded that the varying ovulatory responses

obtained due to restricted suckling in the two breed-types

might have been caused by differences in the responsiveness of

the ovaries to circulating LH levels.

CHAPTER 3.

Seasonal effects on tonic LH, and progesterone secretion

were investigated in cycling Friesland cows. The levels of

these hormones were measured daily from the sixth to the

sixteenth day of the oestrous cycle during December (summer)

of one year, and April/May (autumn), June/July (winter) and September (spring) of the following year. Five to seven cows were sampled per season, and they were subjected to a plane of nutrition designed to maintain bodymass throughout the experimental period.

Mean tonic LH levels were not influenced by the day of the oestrous cycle. Mean levels during autumn (2,26 ± 0,07 ng/ml) were significantly (P < 0,01) higher than those obtained during summer (1,95 ± 0,06 ng/ml) and spring (1,94 ± 0,07 ng/ml), but not significantly higher than those obtained during winter (2,15 ± 0,07 ng/ml). The mean area under the LH curve for cows sampled during autumn (20,1 ± 0,7 mm^2) was significantly (P < 0,05) greater than that for cows sampled during summer (17,7 ± 0,6 mm^2) and spring (17,4 ± 0,6 mm^2).

The day of the oestrous cycle influenced progesterone secretion, but season did not influence concentrations of this hormone.

It was concluded that differences in photoperiod were most likely to have caused the seasonal differences in tonic LH secretion. Possible implications of this effect are discussed.

REFERENCES

ABILAY, T.A., JOHNSON, H.D. & MADAN, M.,1975. Influence of environmental heat and peripheral plasma progesterone and cortisol during the bovine oestrous cycle. J. Dairy Sci. 58, 1836.

ACOSTA, B., TARNAVSKY, G.K., PLATT, T.E., HAMERNIK, D.L., BROWN, J.L., SCHOENEMANN, M.H. & REEVES, J.J., 1983. Nursing enhances the negative effect of oestrogen on LH release in the cow. J. Anim. Sci. 57, 1530.

ADEYEMO, O. & HEATH E., 1980. Plasma progesterone concentration in Bos taurus and Bos indicus heifers. Theriogenology 14, 411.

AMAR, M.A., FRAHM, R.R., NIZZEL, R.H. & COBB, A.B., 1977. A comparison of milk production in Angus and Hereford cattle under range conditions. An. Sci. Rep. Agric. Exp. Sta. Oklah. State University & USDA. June, 1977, 17.

AMIR, S., KALI, R., VOLCANI, R. & PERLMAN, M., 1967. Early breeding of dairy heifers. Anim. Prod. 9, 268 (Abstr.).

ANDERSON, J., 1936. Studies in reproduction in cattle. The periodicity and duration of oestrus. Emp. J. exp. agric. 4, 186.

ANDERSON, B.B., 1978. Animal size and efficiency, with special reference to growth and feed conversion in cattle. Anim. Prod. 27, 381.

ANDERSON, J.H. & WILLHAM, R.L., 1978. Weaning weight correction factors from Angus field data. J. Anim. Sci. 47, 124.

ANONYMOUS, 1981. Verslag van die SAVDP aan die Ondersoekkomitee na die Rooivleisbedryf, April 1981.

ANONYMOUS, 1983. Creep grazing not always a pay off. Better Beef Business 23, 34.

ARIJE, F.R., WILTBANK, J.N. & HOPWOOD, M.L., 1974. Hormone levels in pre- and post-parturient beef cows. J. Anim. Sci. 39, 338.

ASDELL, S.A., 1964. In: Patterns of Mammalian Reproduction. Cornell University Press. Cornell.

BAIR, L.G., WILSON, L.L. & ZIEGLER, J.H., 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.

BAIRD, D.T., 1978. Pulsatile secretion of LH and ovarian oestradiol during the follicular phase of the sheep oestrous cycle. Biol. Reprod. 18, 359.

BAKER, A.A., 1969. Post-partum anoestrus in cattle. Aust. vet. J. 45, 180.

BAKER, R.D., ALVAREZ, F. & LE DU, Y.L.P., 1981a. The effect of herbage allowance upon the herbage intake and performance of suckler cows and calves. Grass and Forage Sci. 36, 189.

BAKER, R.D., BARKER, J.M. & LE DU, Y.L.P., 1982a. The influence of winter nutrition, grazing system and stocking rate on the performance of spring-calving Hereford x Friesian cows and their calves. 2. Grazing system and stocking rate. Anim. Prod. 34, 225.

BAKER, R.D., LE DU, Y.L.P. & ALVAREZ, F., 1981b. The herbage intake and performance of set-stocked suckler cows and calves. Grass and Forage Science 36, 201.

BAKER, R.D., LE DU, Y.L.P. & BARKER, J.M., 1982b. The influence of winter nutrition, grazing system and stocking rate on the performance of spring-calving Hereford x Friesian cows and their calves. 1. Winter nutrition. Anim. Prod. 34, 213.

BARTHOLOMEW, P.E. & LOUW, B.P., 1982. Beef production from Italian Ryegrass (Lolium multiflorum Lam.). Arena 5, 29.

BELCHER, C.G., FRAHM, R.R., BELCHER, D.R. & BENNET, E.N., 1980. Comparison of machine milkout and calf nursing techniques for estimating milk yields of various two-breed cross range cows. Anim. Sci. Res. Rep. Agric. Exp. Sta. Oklah. State University & USDA. April, 1980, 6.

BELLIN, M.E., HINSHELWOOD, M.M., ROBINSON, G.M., AX, R.L. & HAUSER, E.R., 1982. Distribution of follicles and intrafollicular oestrogen in suckled and non-suckled postpartum beef cows. J. Anim. Sci. 55 (Suppl. 1), 338 (Abstr.).

BELLOWS, R.A., SHORT, R.E., ANDERSON, D.C., KNAPP, B.W. & PAHNISH, O.F., 1971. Cause and effect relationships associated with calving difficulty and calf birth weight. J. Anim. Sci. 33, 407.

BELLOWS, R.A., SHORT, R.E., URICK, J.J. & PAHNISH, O.F., 1974. Effects of early weaning on postpartum reproduction of the dam and growth of calves born as multiples or singles. J. Anim. Sci. 39, 589.

BITTMAN, E.L., DEMPSEY, R.J. & KARSCH, F.J., 1983. Pineal melatonin secretion drives the reproductive response to daylength in the ewe. Endocrinology 113, 2276.

BOGGS, D.L., SMITH, E.F., SCHALLES, R.R., BRENT, B.E., CORAH, L.R. & PRUITT, R.J., 1980. Effects of milk and forage intake on calf performance. J. Anim. Sci. 51, 550.

BOGLEY, C.P., MORRISON, D.G., FEAZEL, J.I. & DE RAMUS, H.A., 1983. The effects of calf creep grazing and supplemental corn fed to fall calving beef cows. J. Anim. Sci. 57 (Suppl. 1), 30 (Abstr.).

BOND, J. & MCDOWELL, R.E., 1972. Reproductive performance and physiological responses of beef females as affected by a prolonged high environmental temperature. J. Anim. Sci. 35, 820.

BOND, J., WILTBANK, J.N., WARWICK, E.J., LEHMANN, R.P. & KINNEY, T.B., 1964. Feed intake and milk production of beef cows. J. Anim. Sci. 23, 901 (Abstr.).

BONSMA, J.C., 1951. The way to a higher calving percentage. Fmrs' Wkly Aug. 1, 10.

BOSMAN, D.J. & HARWIN, G.O., 1966. Genetic and environmental factors affecting pre-weaning traits in beef cattle under extensive ranching conditions. Proc. S. Afr. Soc. Anim. Prod. 5, 153.

BOSMAN, D.J., HUNLAN, C. & GIBSON, R.G., 1984. Summary of performance test data (1960 - 1983). Meat Board Focus 3, 6.

BOYD, H., 1977. Anoestrus in cattle. Vet. Rec. 100, 150.

BRADLEY, N.W., CUNDIFF, L.V., KEMP, J.D. & GREATHOUSE, T.R., 1966. Effects of sex and sire on performance and carcass traits of Hereford-Red Poll calves. J. Anim. Sci. 25, 783.

BRANSBY, D.I. & TAINTON, N.M., 1977. The disc pasture meter: Possible applications in grazing management. Proc. Grassld. Soc. Sth. Afr. 12, 115.

BRITT, J.H., KISER, T.E., SEGUIN, B.E., HAFS, H.D., OXENDER, W.D. & RITCHIE, H.D., 1975. Fertility after GnRh and $PGF2_\alpha$ in suckling cows. J. Anim. Sci. 41, 345 (Abstr.).

BROWN, C.J., 1960. Influence of year and season of birth, sex, sire and age of dam on weights of beef calves at 60, 120, 180 and 240 days of age. J. Anim. Sci. 19, 1062.

BROWN, J. M., CUMMING, I.A., GODING, J.R. & HEARNSHAW, H., 1972. Control of baseline levels of luteinizing hormone in the ewe. J. Reprod. Fert. 28, 134.

BRUMBY, P.T., WALKER, D.K. & GALLAGHER, R.M., 1963. Factors associated with growth in beef cattle. N. Z. J. agric. Res. 6, 526.

BUCH, N.C., TYLER, W.J. & CASIDA, L.E., 1955. Postpartum oestrus and involution of the uterus in an experimental herd of Holstein-Friesian cows. J. Dairy Sci. 38, 73.

BULMAN, D.C. & LAMMING, G.E., 1978. Milk progesterone levels in relation to conception, repeat breeding and factors influencing acyclicity in dairy cows. J. Reprod. Fert. 54, 447.

CHENETTE, C.G. & FRAHM, R.R., 1981. A comparison of different age-of-dam and sex correction factors for birth, weaning and yearling weights in beef cattle. Anim. Sci. Res. Rep. Oklah. Agric. Exp. Sta. Oklah. State University & USDA. April, 1981, 23.

CHRISTENSEN, D.S., HOPWOOD, M.L. & WILTBANK, J.N., 1974. Levels of hormones in the serum of cycling beef cows. J. Anim. Sci. 38, 577.

CHRISTIAN, L.L., HAUSER, E.R. & CHAPMAN, A.B., 1965. Association of preweaning and postweaning traits with weaning weight in cattle. J. Anim. Sci. 24, 652.

CLAUS, R., KARG, H., ZWIAUER, D., VON BUTLER, I., PIRCHNER, F. & RATTENBERGER, E., 1983. Analysis of factors influencing reproductive performance of the dairy cow by progesterone assay in milk-fat. Br. vet. J. 139. 29.

COETZEE, P.H., 1983. Openingsrede tydens Saamtrek 2 Maart. The Afrikaner 29, 9.

COETZER, W.A., MENTZ, A.H., VERMEULEN, J.A. & COETZEE, J.E., 1975. Waarnemings oor die voorkoms van bronstigheid by Afrikaner- en Jerseykoeie onder ekstensiewe toestande in Noord-Kaapland. S. Afr. J. Anim. Sci. 5, 47.

CONVEY, E.M., BECK, T.W., NEITZEL, R.R., BOSTWICK, E.F. & HAFS, H.D., 1977. Negative feedback control of bovine serum luteinizing hormone (LH) concentration from completion of the preovulatory LH surge until resumption of luteal function. J. Anim. Sci. 45, 792.

CRITSER, J.K., MILLER, K.F., GUNSETT, F.C. & GINTHER, O.J., 1983. Seasonal LH profile in ovariectomized cattle. Theriogenology 19, 181.

CROSS, G.W., 1979. The production potential of Pennisetum clandestinum in the Midlands and on the South Coast of Natal. Proc. Grassld. Soc. Sth. Afr. 14, 53.

CUNDIFF, L.V., WILLHAM, R.L. & PRATT, C.A., 1966a. Additive versus multiplicative correction factors for weaning weight in beef cattle. J. Anim. Sci. 25, 983.

CUNDIFF, L.V., WILLHAM, R.L. & PRATT, C.A., 1966b. Effects of certain factors and their two-way interactions on weaning weight in beef cattle. J. Anim. Sci. 25, 972.

DAS NEVES, A., WALLACE, J.D. & HERBEL, C.H., 1974. Milk production by Hereford cows. J. Anim. Sci. 38, 1341 (Abstr.).

DAWSON, W.M., COOK, A.C. & KNAPP, B., 1960. Milk production of Beef Shorthorn cows. J. Anim. Sci. 19, 502.

DE ALBA, J., VILLA CORTA, E. & ULLOA, G., 1961. Influence of natural service on length of oestrus in the cow. Anim. Prod. 3, 327.

DEAS, D.W., 1971. The effect of supplementary light on winter infertility in cattle. Vet. Rec. 89, 242.

DE KRUIF, A., 1975. An investigation of the parameters which determine the fertility of a cattle population and some factors which influence these factors. Tijd. Diergeneesk. 100, 1089.

DE KRUIF, A., 1978. Factors influencing the fertility of a cattle population. J. Reprod. Fert. 54, 507.

DEUTSHER, G.H. & WHITEMAN, J.V., 1971. Productivity of two-year-olds of Angus-Holstein crossbreds compared to Angus heifers under range conditions. J. Anim. Sci. 33, 337.

DIEKMAN, M.A. & MALVEN, P.V., 1973. Effect of ovariectomy and oestradiol on LH patterns in ewes. J. Anim. Sci. 37, 562.

DOBAO, M.T., RODRIGANEZ, J. & SILIO, L.,1983. Seasonal influence on fecundity and litter performance characteristics in Iberian pigs. Livest. Prod. Sci. 10, 601.

DONALDSON, L.E., BASSET, J.M. & THORBURN, G.D., 1970. Peripheral plasma progesterone concentration of cows during puberty, oestrous cycles, pregnancy and lactation, and the effects of undernutrition or exogenous oxytocin on progesterone concentration. J. Endocr. 48, 599.

DRENNAN, M.J., 1971a. Single-suckled beef production. 1. Influence of stocking rate during the grazing season, creep grazing of the calf and double suckling on live-weight changes and milk production of cows. Irish J. agric. Res. 10, 287.

DRENNAN, M.J., 1971b. Single-suckled beef production. 2. Influence of stocking rate during the grazing season, creep grazing of the calf and double suckling on calf performance. Irish J. agric. Res. 10, 297.

DREWRY, K.J., BROWN, C.J. & HONEA, R.S., 1959. Relationship among factors associated with mothering ability of beef cattle. J. Anim. Sci. 18, 938.

DUNN, R.T., SMITH, M.F., GARVERICK, H.A. & FOLEY, C.W., 1983. Effects of 72 h calf removal and/or GnRh on the reproductive performance of beef cows. J. Anim. Sci. 57 (Suppl. 1), 82 (Abstr.).

ECHTERNKAMP, S.E., 1978. Stimulation of oestrogen and luteinizing hormone secretion in postpartum beef cows. J. Anim. Sci. 47, 521.

ECHTERNKAMP, S.E. & HANSEL, W., 1973. Concurrent changes in bovine plasma hormone levels prior to and during the first postpartum oestrous cycle. J. Anim. Sci. 37, 1362.

EDEN, D.W., 1970. Melkproduksiestudies met vleisbeeste. M. Sc. Agric. Thesis, University of Pretoria.

EDEN, D.W. & SMIT, H., 1982. Simmental performance on planted pastures. Simmentaler 7, 16.

EDGERTON, L.A. & HAFS, H.D., 1973. Serum luteinizing hormone, prolactin, glucocorticoid and progestin in dairy cows from calving to gestation. J. Dairy Sci. 56, 451.

EDWARDS, P.J., 1966. Veld replacement by improved grassland in Natal. Proc. Grassl. Soc. S. Afr. 1, 63.

EDWARDS, P.J., 1982. Gains of beef cattle on moist grasslands in Natal. Arena 5, 13.

ELLIS, G.F., CARTWRIGHT, T.C. & KRUSE, W.E., 1965. Heterosis for birth weight in Brahman-Hereford crosses. J. Anim. Sci. 24, 93.

EVANS, T.R., 1981. Overcoming nutritional limitations through pasture management. In: Nutritional limits to animal production from pastures. Ed. by J.B. Hacker. Farnham Royal, U.K., Commonwealth Agric. Bureaux.

FAHMY, M.H. & LALANDE, G., 1973. Genetic and environmental trends in preweaning performance of Beef Shorthorn calves. Can. J. Anim. Sci. 53, 637.

FALTYS, G.L., FOGWELL, R.L., SHORT, R.E. & CONVEY, E.M., 1983. Influence of suckling on secretory patterns of LH and concentrations of cortisol in lactating beef cows. J. Anim. Sci. 57 (Suppl. 1), 335 (Abstr.).

FERNANDES, L.C., THATCHER, W.W. & WILCOX, C.J., 1976. LH responses to GnRh in postpartum dairy cows. J. Anim. Sci. 42, 269 (Abstr.).

FITZGERALD, B.P., I'ANSON, H., LOY, R.G. & LEGAN, S.J., 1983. Evidence that changes in LH pulse frequency may regulate the seasonal modulation of LH secretion in ovariectomized mares. J. Reprod. Fert. 69, 685.

FOLMAN, Y., ROSENBERG, M., HERZ, L. & DAVIDSON, M., 1973. The relationship between plasma progesterone concentration and conception in post-partum dairy cows maintained on two levels of nutrition. J. Reprod. Fert. 34, 267.

FOOTE, W.D., SAWHNEY, D.C., QUEVEDO, M.M. & PETERSON, D.W., 1966. Chorionic gonadotropin treatment of beef cows. J. Anim. Sci. 25, 585.

FORREST, P.K., RHODES, R.C. & RANDEL, R.D., 1980. Effect of bleeding stress and variable suckling intensity upon serum luteinizing hormone in Brangus heifers. Theriogenology 13, 321.

FREEDMAN, L.J., GARCIA, M.C. & GINTHER, O.J., 1979. Influence of photoperiod and ovaries on seasonal reproductive activity in mares. Biol. Reprod. 20, 567.

FUQUAY, J.W., 1981. Heat stress as it affects animal production. J. Anim. Sci. 52, 164.

FURR, R.D. & NELSON, A.B., 1964. Effect of level of supplemental winter feed on calf weight and on milk production of fall-calving range beef cows. J. Anim. Sci. 23, 775.

GANGWAR, P.C., BRANTON, C. & EVANS, D.L., 1965. Reproductive and physiological responses of Holstein heifers to controlled and natural climatic conditions. J. Dairy Sci. 48, 222.

GARCIA-WINDER, M., IMAKAWA, K., ZALESKY, D., DAY, M.L., KITTOK, R.J., SCHANBACHER, B.D. & KINDER, J.E., 1983. Acute effect of suckling on luteinizing hormone secretion during the postpartum period in the beef cow. J. Anim. Sci. 57 (Suppl. 1), 108 (Abstr.).

GASKINS, C.T. & ANDERSON, D.C., 1980. Comparison of lactation curves in Angus-Hereford, Jersey-Angus and Simmental-Angus cows. J. Anim. Sci. 50, 828.

GIFFORD, W., 1949. Importance of high milk production in beef cows found overestimated. J. Anim. Sci. 8, 605.

GIFFORD, W., 1953. Records of performance tests for beef cattle in breeding herds. Milk production, milk production of dams and growth of calves. Ark. Agric. Exp. Bull. 531.

GILL, J.L. & HAFS, H.D., 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33, 331.

GILLOOLY, J.E., WILSON, L.L., THOMPSON, C.E., RUGH, M.C., LONG, T.A. & PURDY, H.R., 1967. Effects of energy level and cow size on milk yield and calf gain. J. Anim. Sci. 26, 1468 (Abstr.).

GLEDDIE, V.M. & BERG, R.T., 1968. Milk production in range beef cows and its relationship to calf gains. Can. J. Anim. Sci. 48, 323.

GOODMAN, R.L. & KARSCH, F.J., 1980. Pulsatile secretion of luteinizing hormone: differential suppression by ovarian steroids. Endocrinology 107, 1286.

GRIESSEL, M., 1979. A protein utilization strategy for South Africa. S. Afr. J. Anim. Sci. 9, 119.

GRIFFIN, J.L. & RANDEL, R.D., 1977. Luteinizing hormone response of ovariectomized Brahman and Hereford cows to 500 μg GnRh. Abstracts 69th Ann. Mtg. Amer. Soc. Anim. Sci. University of Wisc., 164 (Abstr. 413).

GROBBELAAR, J., 1984. Luteal function during early postpartum in the ewe. Ph. D. Thesis, University of Natal.

GWAZDAUSKAS, F.C., THATCHER, W.W. & WILCOX, C.J., 1973. Physiological, environmental, and hormonal factors at insemination which may affect conception. J. Dairy Sci. 56, 873.

GWAZDAUSKAS, F.C., WILCOX, C.J. & THATCHER, W.W., 1975. Environmental and managemental factors affecting conception rate in a subtropical climate. J. Dairy Sci. 58, 88.

HAFEZ, E.S.E., 1952. Studies on the breeding season and reproduction of the ewe. J. agric. Sci. Camb. 42, 189.

HAFEZ, E.S.E., 1968. Reproduction of Sheep. In: Reproduction in Farm Animals. Lea & Febiger. Philadelphia.

HALL, J.G., BRANTON, C. & STONE, E.J., 1959. Oestrus, oestrous cycles, ovulation time, time of service and fertility of dairy cattle in Louisiana. J. Dairy Sci. 42, 1086.

HANSEL, W., 1966. Luteotrophic and luteolytic mechanisms in bovine corpora lutea. J. Reprod. Fert. Suppl. 1, 33.

HANSEL, W., CONCANNON, P.W. & LUKASZEWSKA, J.H, 1973. Corpora lutea of the large domestic animals. Biol. Reprod. 8, 222.

HANSEL, W. & CONVEY, E.M., 1983. Physiology of the oestrous cycle. J. Anim. Sci. 57 (Suppl. 2), 404.

HANSEL, W. & SNOOK, R.B., 1970. Pituitary ovarian relationships in the cow. J. Dairy Sci. 53, 945.

HANSEN, P.J., BAIK, D.H., RUTLEDGE, J.J. & HAUSER, E.R., 1982. Genotype x environmental interactions on reproductive traits of bovine females. II. Postpartum reproduction as influenced by genotype, dietary regimen, level of milk production and parity. J. Anim. Sci. 55, 1458.

HANSEN, P.J. & HAUSER, E.R., 1983. Genotype x environmental interactions on reproductive traits of bovine females. III. Seasonal variation in postpartum reproduction as influenced by genotype, suckling and dietary regimen. J. Anim. Sci. 56, 1362.

HANSEN, P.J., KAMWANJA, L.A. & HAUSER, E.R., 1982. The effect of photoperiod on serum concentrations of luteinizing and follicle stimulating hormones in prepubertal heifers following ovariectomy and oestradiol injection. Theriogenology 18, 551.

HARESIGN, W., FOXCROFT, G.R. & LAMMING, G.E., 1983. Control of ovulation in farm animals. J. Reprod. Fert. 69, 383.

HARRISON, L.M., HANSEN, T.R. & RANDEL, R.D., 1982. Evidence for seasonal and nutritional modification of ovarian and pituitary function in crossbred heifers and Brahman cows. J. Anim. Sci. 55, 649.

HARRISON, L.M. & RANDEL, R.D., 1981. Effect of season and monensin on the preovulatory luteinizing hormone surge in Brahman cows. J. Anim. Sci. 53 (Suppl. 1), 326.

HARWIN, G.O., 1974. Role of nutrition in beef cattle production. Fert. Soc. S. Afr. J. 2, 21.

HARWIN, 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.

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.

HARWIN, G.O. & LOMBARD, J.H., 1974. Intensification of the
beef-cow herd. S. Afr. J. Anim. Sci. 4, 247.

HARWIN, G.O. & THERON, E.P., 1975. Research on Radical Veld
Improvement. Proc. Grassld. Soc. Sth. Afr. 10, 159.

HEYNS, H., 1960a. The growth of the Afrikaner calf in relation
to the production and composition of the milk of its dam. I.
The production and composition of the milk. S. Afr. J. agric.
Sci. 3, 349.

HEYNS, H., 1960b. The growth of the Afrikaner calf in relation
to the production and composition of the milk of its dam. II.
The milk production of the dam and growth of the calf. S. Afr.
J. agric. Sci. 3, 517.

HILLEN, J.M. & RUPEL, J.W., 1960. Differential effect of
season on conception rate in Holstein and dairy cattle. J.
Dairy Sci. 43, 442.

HOBSON, W.C. & HANSEL, W., 1972. Plasma LH levels after
ovariectomy, corpus luteum removal and oestradiol
administration in cattle. Endocrinology 91, 185.

HOFFMAN, B., SCHAMS, D., BOPP, R., ENDER, M.L., GIMENEZ, T. &
KARG, H., 1974. Luteotrophic factors in the cow: Evidence for
LH rather than prolactin. J. Reprod. Fert. 40, 77.

HOHENBOKEN, W.D., HAUSER, E.R., CHAPMAN, A.B. & CUNDIFF, L.V.,
1973. Phenotypic correlations between dam traits expressed
during development and lactation and traits of progeny in
cattle. J. Anim. Sci. 37, 1.

HOLLNESS, D.H., HOPLEY, J.D.H. & HALE, D.H., 1978. The effects
of plane of nutrition, live weight, temporary weaning and
breed on the occurrence of oestrus in beef cows during the
post-partum period. Anim. Prod. 26, 47.

HOLLOWAY, J.W., BUTTS, W.T. & WORLEY, T.L., 1982. Utilization
of forage and milk energy by Angus calves grazing Fescue or
Fescue-legume pastures. J. Anim. Sci. 55, 1214.

HOLLOWAY, J.W., STEPHENS, D.F., WHITEMAN, J.V. & TOTUSEK, R.,
1975. Performance of 3-year-old Hereford, Hereford x Holstein
and Holstein cows on range and in drylot. J. Anim Sci. 40,
114.

HOLLOWAY, J.W., WORLEY, T.L. & BUTTS, W.T., 1983. Patterns of
milk intake as related to weaning traits of Angus calves
grazing Fescue-legume or Fescue pastures. Livest. Prod. Sci.
10, 351.

HOLMES, J.H.G., TAKKEN, A. & SEIFERT, G.W., 1968. Milk
production and calf growth rate in Hereford,
Africander-Shorthorn and Brahman-Shorthorn cattle in
Queensland. Proc. Austr. Soc. Anim. Prod. 7, 163.

HOWES, J.R., HENTGES, J.F., WARNICK, A.C. & CUHNA, T.J., 1958.
Yield and composition of milk from Brahman and Hereford
heifers fed two levels of protein and the correlated calf
growth. J. Anim. Sci. 17, 1222 (Abstr.).

HOWLAND, B.E., PALMER, W.M., SANFORD, L.M. & BEATON, D.B.,
1978. Oestrogen-induced LH and FSH release in ovariectomized
ewes: Effect of season. Can. J. Anim. Sci. 58, 547.

HUNTER, G.L., 1962. Observations on oestrus in Merinos. Proc.
S. Afr. Soc. Anim. Prod. 1, 67.

INGALLS, W.G., CONVEY, E.M. & HAFS, H.D., 1973. Bovine serum
LH , GH and prolactin during late pregnancy, parturition and
early lactation. Proc. Soc. exp. Biol. Med. 143, 161.

INGRAHAM, R.H., GILLETTE, D.D. & WAGNER, W.D., 1974.
Relationship of temperature and humidity to conception rate of
Holstein cows in subtropical climate. J. Dairy Sci. 57, 476.

INSKEEP, E.K., DAILEY, R.A. & RHODES, R.C., 1982. Some
considerations on the value of hormonal assays and a knowledge
of hormonal profiles to production of red meat animals. S.
Afr. J. Anim. Sci. 12, 85.

INSKEEP, E.K. & LISHMAN, A.W., 1978. Factors affecting
postpartum anoestrus in beef cattle. Anim. Reprod. Beltsville
Symp. agric. Res. 3, 277.

INSKEEP, E.K., LISHMAN, A.W., BUTCHER, R.L. & ALLISON, S.M.G.,
1977. Effect of short-term removal of the calf on release of
LH, ovulation and CL function following GnRh in beef cows. J.
Anim. Sci. 45 (Suppl. 1), 171 (Abstr.).

IRELAND, J.J. & ROCHE, J.F., 1982. Effect of progesterone on
basal LH and episodic LH and FSH secretion in heifers. J.
Reprod. Fert. 64, 295.

IRVIN, H.J., GARVERICK, H.A., ZAIED, A.A., KESLER, D.J., DAY,
B.N. & YOUNGQUIST, R.S., 1977. LH response to GnRh in
postpartum suckled beef cows. J. Anim. Sci. 45 (Suppl. 1), 172
(Abstr.).

IRVIN, H.J., RANDEL, R.D., HAENSLY, W.E. & SORENSEN, A.M.,
1978. Reproductive studies of Brahman cattle. III. Comparison
of weight, progesterone content, histological characteristics
and 3β-hydroxy-steroid dehydrogenase activity in corpora lutea
of Brahman, Hereford and Brahman x Hereford heifers.
Theriogenology 10, 417.

IRVIN, H.J., ZAIED, A.A., DAY, B.N. & GARVERICK, H.A., 1981.
GnRh induced LH release in suckled beef cows. I. The effects
of days postpartum and oestradiol-17β concentrations on the
release of LH following administration of GnRh. Theriogenology
15, 443.

JACOBS, J., 1983. Die uitdagings waarmee die Suid-Afrikaanse
rooivleisbedryf te kampe het. South Devon Focus 3, 3.

JEFFERY, H.B. & BERG, R.T., 1971. Evaluation of milk variables as measures of milk effect on preweaning performance of beef cattle. Can. J. Anim. Sci. 51, 21.

JEFFERY, H.B., BERG, R.T. & HARDIN, R.T., 1971a. Factors affecting preweaning performance in beef cattle. Can. J. Anim. Sci. 51, 561.

JEFFERY, H.B., BERG, R.T. & HARDIN, R.T., 1971b. Factors influencing milk yield of beef cattle. Can. J. Anim. Sci. 51, 551.

JOBLIN, A.D.H., 1969. Baby beef without concentrates - A feasibility study. Proc. N. Z. Soc. Anim. Prod. 29, 137.

JOHNSSON, I.D. & OBST, J.M., 1984. The effects of level of nutrition before and after 8 months of age on subsequent milk and calf production of beef heifers over three lactations. Anim. Prod. 38, 57.

JOHNSSON, I.D. & MORANT, S.V., 1984. Evidence of a negative relationship between heifer growth and first-calf weaning weight in commercial beef herds. Aust. J. exp. agric. & Anim. Husb. 24, 10.

JONES, R.J. & SANDLAND, R.L., 1974. The relation between animal gain and stocking rate: Derivation of the relation from the results of grazing trials. J. agric. Sci. Camb. 83, 335.

JORDAAN, J.C., 1984. Weistelsel bepaal vleisboer se wins of verlies. Landbwkbd 338, 20.

JOUBERT, D.M., 1954. The influence of winter nutritional depressions on the growth, reproduction and production of cattle. J. agric. Sci. Camb. 44, 5.

KAMWANJA, L.A. & HAUSER, E.R., 1983. Influence of season of birth and age on body weight and follicular growth in heifers. J. Anim. Sci. (Suppl. 1), 347 (Abstr.).

KARG, H. & SCHAMS, D., 1974. Prolactin release in cattle. J. Reprod. Fert. 39, 463.

KARSCH, F.J., GOODMAN, R.L. & LEGAN, S.J., 1980. Feedback basis of seasonal breeding: test of an hypothesis. J. Reprod. Fert. 58, 521.

KARSCH, F.J. & FOSTER, D.L., 1975. Sexual differentiation of the mechanism controlling the preovulatory discharge of luteinizing hormone in sheep. Endocrinology 97, 373.

KARSCH, F.J., LEGAN, S.J., HAUGER, R.L. & FOSTER, D.L., 1977. Negative feedback action of progesterone on tonic luteinizing hormone secretion in the ewe: dependance on the ovaries. Endocrinology 101, 800.

KENNAWAY, D.J. & GILMORE, T.A., 1984. Effects of melatonin implants in ewe lambs. J. Reprod. Fert. 70, 39.

KENNAWAY, D.J., OBST, T.M., DUNSTAN, E.A. & FRIESEN, H.G., 1981. Ultradian and seasonal rhythms in plasma gonadotrophins, prolactin, cortisol and testosterone in pinealectomised rams. Endocrinology 108, 639.

KILKENNY, J.B. & DENCH, J.A.L., 1981. The role of grassland in beef production. In: Grassland in the British economy. Ed. by J.L. Jollans. Centre for Agricultural strategy. University of Reading. Reading.

KLETT, R.H., MASON, T.R. & RIGGS, J.K., 1965. Milk production of beef cows and its relationship to the weaning weight of their calves. J. Anim. Sci. 24, 586 (Abstr.).

KOGER, M., REYNOLDS, W.L., MEADE, J.H., KIRK, W.G., PEACOCK, F.M. & KIDDER, R.W., 1962. Environment, sex and age of dam effects. J. Anim. Sci. 21, 973 (Abstr.).

KOONCE, K.L. & DILLARD, E.U., 1967. Some environmental effects on birth weight and gestation length in Hereford cattle. J. Anim. Sci. 26, 205.

KRESS, D.D. & ANDERSON, D.C., 1974. Milk production in Hereford cattle. J. Anim. Sci. 38, 1320 (Abstr.).

KRESS, D.D. & BURFENING, P.J., 1972. Weaning weight related to subsequent most probable producing ability in Hereford cows. J. Anim. Sci. 35, 327.

KRESS, D.D., HAUSER, E.R. & CHAPMAN, A.B., 1969. Efficiency of production and cow size in beef cattle. J. Anim. Sci. 29, 373.

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 x Holstein and Holstein females as influenced by level of winter supplementation. J. Anim. Sci. 37, 1222.

LABHSETWAR, A.P., TYLER, W.J. & CASIDA, L.E., 1963. Genetic and environmental factors affecting quiete ovulations in Holstein cattle. J. Dairy Sci. 46, 843.

LAMPKIN, K. & LAMPKIN, G.H., 1960. Studies on the production of beef from Zebu cattle in East Africa. II. Milk production in suckled cows and its effect on calf growth. J. agric. Sci. Camb., 55, 233.

LASLEY, J.F., DAY, B.N. & COMFORT, J.E., 1961. Some genetic aspects of gestation length and birth and weaning weights in Hereford cattle. J. Anim. Sci. 20, 737.

LASTER, D.B., GLIMP, H.A., CUNDIFF, L.V. & GREGORY, K.E., 1973. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. J. Anim. Sci. 36, 695.

LASTER, D.B., GLIMP, H.A. & GREGORY, K.E., 1973. Effects of early weaning on post-partum reproduction of cows. J. Anim. Sci. 36, 734.

LAWSON, J.E., 1981. Milk production and weight of cows of the Hereford and Highland breeds and their reciprocal crosses. Can. J. Anim. Sci. 61, 861.

LE DU, Y.L.P. & BAKER, R.D., 1978. A note on the effect of the level of milk consumption prior to weaning upon the silage intake and performance of weaned "suckled" calves. Anim. Prod. 27, 117.

LEGAN, S.J. & KARSCH, F.J., 1979. Neuroendocrine regulation of the oestrous cycle and seasonal breeding in the ewe. Biol. Reprod. 20, 74.

LE ROUX, J.D., 1951. Fertility standards of the cattle herds at the Mara Research Station. Fmg S. Afr. 26, 73.

LISHMAN, A.W., 1972. The influence of variations in the level of nutrition on reproduction in the ewe. Ph. D. Thesis, University of Natal.

LISHMAN, A.W., ALLISON, S.M.J., FOGWELL, R.L., BUTCHER, R.L. & INSKEEP, E.K., 1979. Follicular development and function of induced corpora lutea in underfed postpartum anoestrous beef cows. J. Anim. Sci. 48, 867.

LOMBARD, J.H., 1977. Market share and usage of red meat. The Meat Industry 26, 41.

LOMBARD, J.H., 1979. Opwindende uitdagings vir Vleisraad. Bylae tot Landbwkbd, 3 Aug. 1979, 6.

LOWMAN, B.G., EDWARDS, R.A., SOMERVILLE, S.H. & JOLLY, G.M., 1979. The effect of plane of nutrition in early lactation on the performance of beef cows. Anim. Prod. 29, 293.

LUITINGH, H.C., 1974. Certain aspects of the future development of the beef cattle industry. Fert. Soc. S. Afr. J. 2, 9.

LUITINGH, H.C. & RUDERT, C.P., 1981. Economic and biological properties in livestock production in the RSA. Fert. Soc. S. Afr. J. 1, 11.

LUSBY, K.S., STEPHENS, D.F. & TOTUSEK, R., 1976. Effects of milk intake by nursing calves on forage intake on range and creep intake and digestibility in drylot. J. Anim. Sci. 43, 1066.

MACMILLAN, K.L., 1983. Post-partum interval to oestrus in monozygous twin cows and possible effects of maternal bonding. N. Z. J. agric Res. 26, 451.

MADAN, M.L. & JOHNSON, H.D., 1973. Environmental heat effects on bovine luteinizing hormone. J. Dairy Sci. 56, 1420.

MADDOX, L.A., 1965. Nutrient requirements of the cow and calf. Texas Agr. Exp. Sta. Bull. 1044.

MAHADEVAN, P., 1951. The effect of environment and heredity on lactation. J. agric. Sci. Camb. 41, 80.

MANGUS, W.L. & BRINKS, J.S., 1971. Relationships between
direct and maternal effects on growth in Herefords. I.
Environmental factors during preweaning growth. J. Anim. Sci.
32, 17.

MARLOWE, T.J. & GAINES, J.A., 1958. The influence of age, sex
and season of birth of calf, and age of dam on preweaning
growth rate and type of sire of beef calves. J. Anim. Sci. 17,
706.

MARSHALL, D.A., PARKER, W.R. & DINKEL, C.A., 1976. Factors
affecting efficiency to weaning in Angus, Charolais and
reciprocal cross cows. J. Anim. Sci. 43, 1176.

MCNATTY, K.P., BALL, K., GIBB, M., HUDSON, N. & THURLEY, D.C.,
1982. Induction of cyclic ovarian activity in seasonally
anoestrous ewes with exogenous GnRh. J. Reprod. Fert. 64, 93.

MCNATTY, K.P., HUDSON, N., GIBB, M., BALL, K., FANNIN, J.,
KIEBOOM, L. & THURLEY, D.C., 1984. Effects of long-term
treatment with LH on induction of cyclical ovarian activity in
seasonally anoestrous ewes. J. Endocr. 100, 67.

MCNATTY, K.P., HUDSON, N.L., HENDERSON, K.M., LUN, S., HEATH,
D.A., GIBB, M., BALL, K., MCDIARMID, J.M. & THURLEY, D.C.,
1984. Changes in gonadotrophin secretion and ovarian antral
follicular activity in seasonally breeding sheep throughout
the year. J. Reprod. Fert. 70, 309.

MEISSNER, H.H. & NAUDE, R.T., 1982. Aksie: Beesvleisproduksie
tot die jaar 2003. S. Afr. J. Anim. Sci. 12, 187.

MELTON, A.A., RIGGS, J.K., NELSON, L.A. & CARTWRIGHT, T.C.,
1967. Milk production, composition and calf gains of Angus,
Charolais and Hereford cows. J. Anim. Sci. 26, 804.

MERCIER, E. & SALISBURY, G.W., 1947. Fertility level in
artificial breeding associated with season, hours of daylight
and the age of cattle. J. Dairy Sci. 30, 817.

MILLS, A.G., THATCHER, W.W., DUNLAP, S.E. & VINCENT, C.K.,
1972. Influence of postbreeding thermal stress on peripheral
plasma progestin concentrations in heifers. J. Dairy Sci. 55,
400 (Abstr.).

MONDRAGON, I., WILTON, J.W., ALLEN, O.B. & SONG, H., 1983.
Stage of lactation effects, repeatabilities and influences on
weaning weights of yield and composition of milk in beef
cattle. Can. J. Anim. Sci. 63, 751.

MONTGOMERY, G.W., 1982. Influence of suckling frequency and
bromocryptine treatment on the resumption of ovarian cycles in
post-partum beef cattle. Theriogenology, 17, 551.

MONTGOMERY, G.W., DAVIS, G.H. & HURREL, G.A., 1980. Interval
from calving to first oestrus in autumn- and spring-calving
herds in the same locality. Proc. N. Z. Soc. Anim. Prod. 40,
280.

MONTY, D.E. & WOLFF, L.K., 1974. Summer heat stress and reduced fertility in Holstein-Friesian cows in Arizona. Am. J. vet. Res. 35, 1495.

NEIDHART, R., PLASSE, D., WENIGER, J.H., VERDE, O., BELTRAN, J. & BENAVIDES, A., 1979. Milk yield of Brahman cows in a subtropical beef production system. J. Anim. Sci. 48, 1.

NEL, P., 1981. Verbruikersbesteding aan vleis en vleisprodukte. Elanco Feedlot Forum, 9th Sept., 1981.

NELSEN, T.C. & KRESS, D.D., 1981. Additive and multiplicative correction factors for sex and age of dam in beef cattle weaning weight. J. Anim. Sci. 53, 1217.

NELSON, L.A. & HUBER, D.A., 1971. Factors influencing dystocia in Hereford dams. J. Anim. Sci. 33, 1137 (Abstr.).

NEVILLE, W.E., 1962. Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J. Anim. Sci. 21, 315.

NEVILLE, W.E. & MCCORMICK, W.C., 1983. Comparison of stocking rate and performance of cows with calves vs dry cows on pasture. J. Anim. Sci. 57 (Suppl. 1), 9 (Abstr.).

NEVILLE, W.E., WARREN, E.P. & GRIFFEY, W.A., 1974. Estimates of age effects on milk production in Hereford cows. J. Anim. Sci. 38, 1.

NICOL, A.M., 1976. The influence of breed of calf on the milk production of beef cows. Proc. N. Z. Soc. Anim. Prod. 36, 93.

NISWENDER, G.D., REICHERT, L.E., MIDGLEY, A.R. & NALBANDOV, A.V., 1969. Radioimmunoassay for bovine and ovine luteinizing hormone. Endocrinology 84, 1166.

NOTTER, D.R., CUNDIFF, L.V., SMITH, G.M., LASTER, D.B. & GREGORY, K.E., 1978. Characterization of biological types of cattle. VII. Milk production in young cows and transmitted and maternal effects on preweaning growth of progeny. J. Anim. Sci. 46, 908.

NOTTER, D.R., SANDERS, J.O., DICKERSON, G.E., SMITH, G.M. & CARTWRIGHT, T.C., 1979a. Simulated efficiency of beef production for a midwestern cow-calf-feedlot management system. I. Milk production. J. Anim. Sci. 49, 70.

NOTTER, D.R., SANDERS, J.O., DICKERSON, G.E., SMITH, G.M. & CARTWRIGHT, T.C., 1979b. Simulated efficiency of beef production for a midwestern cow-calf-feedlot management system. II. Mature body size. J. Anim. Sci. 49, 83.

OXENREIDER, S.L., 1968. Effects of suckling and ovarian function on postpartum reproductive activity in beef cows. Amer. J. vet. Res. 29, 2099.

OXENREIDER, S.L. & WAGNER, W.C., 1971. Effect of lactation and energy intake on postpartum ovarian activity in the cow. J. Anim. Sci. 33, 1026.

PATERSON, A.G., HARWIN, G.O., EHRET, W.J., AVIS, W. & TWINE, H.E., 1983. Artificial insemination versus natural breeding in a multi-breed beef herd under intensive management. S. Afr. J. Anim. Sci. 13, 257.

PATERSON, A.G., VENTER, H.A.W. & HARWIN, G.O., 1980a. Preweaning growth of British, Bos indicus, Charolais and Dual Purpose type cattle under intensive pasture conditions. S. Afr. J. Anim. Sci. 10, 125.

PATERSON, A.G., VENTER, H.A.W. & HARWIN, G.O., 1980b. The effect of age of dam on weaning mass for five dam breed types in an intensively managed crossbred herd. S. Afr. J. Anim. Sci. 10, 135.

PELLETIER, J. & THIMONIER, J., 1973. Comparison of the induced preovulatory LH discharge in lactating and dry sheep during seasonal anoestrus. J. Reprod. Fert. 33, 311.

PERKINS, J.L. & KIDDER, H.E., 1963. Relation of uterine involution and postpartum interval to reproductive efficiency in beef cattle. J. Anim Sci. 22, 313.

PETERS, A.R., LAMMING, G.E. & FISHER, M.W., 1981. A comparison of plasma LH concentrations in milked and suckling post-partum cows. J. Reprod. Fert. 62, 567.

PETERS, A.R. & RILEY, G.M., 1982a. Is the cow a seasonal breeder? Brit. vet. J. 138, 533.

PETERS, A.R. & RILEY, G.M., 1982b. Milk progesterone profiles and factors affecting post partum ovarian activity in beef cows. Anim. Prod. 34, 145.

PFLANTZ, V.M., IRVIN, H.J., MORROW, R.E., GARVERICK, H.A. & DAY, B.N., 1979. Effects of GnRh and once-a-day suckling of beef cows. J. Anim. Sci. 49 (Suppl. 1), 110 (Abstr.).

PHILIPS, D., JOHNSSON, I.D. & COOPER, J.D., 1982. Early weaning of beef heifer replacements can improve subsequent milk production. Proc. Aust. Soc. Anim. Prod. 14, 596.

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

PLASSE, D., WARNICK, A.C. & KOGER, M., 1968. Reproductive behaviour of Bos indicus females in a subtropical environment. I. Puberty and ovulation frequency in Brahman and Brahman x British heifers. J. Anim. Sci. 27, 94.

PRESTON, T.R. & WILLIS, M.B., 1974. Intensive Beef Production. Second edition. Pergamon Press. Oxford.

RADFORD, H.M., NANCARROW, C.D. & MATTNER, P.E., 1978. Ovarian function in suckling and non-suckling beef cows. J. Reprod. Fert. 54, 49.

RAHE, C.H., OWENS, R.E., FLEEGER, H.L., NEWTON, H.J. & HARMS, P.G., 1980. Pattern of plasma luteinizing hormone in the cyclic cow: Dependance upon the period of the cycle. Endocrinology 107, 498.

RAMIREZ-GODINEZ, J.A., KIRACOFE, G.H., SCHALLES, R.R. & NISWENDER, G.D., 1982. Endocrine patterns in the postpartum beef cow associated with weaning: A comparison of the short and subsequent normal cycles. J. Anim. Sci. 55, 153.

RANDEL, R.D., 1976. LH and ovulation in Brahman, Brahman x Hereford and Hereford heifers. J. Anim. Sci. 43, 300 (Abstr.).

RANDEL, R.D., 1979. Increasing artificial insemination conception rates in Brahman cattle by injecting 1500 I.U. Human Chorionic Gonadotropin at insemination. J. Anim. Sci. 49 (Suppl. 1), 41 (Abstr.).

RANDEL, R.D., 1980. Total serum oestrogens before and after oestrus in Brahman, Brahman x Hereford and Hereford heifers. J. Anim. Sci. 51 (Suppl. 1), 2 (Abstr.).

RANDEL, R.D., 1981. Effects of once-daily suckling on postpartum interval and cow-calf performance of first-calf Brahman x Hereford heifers. J. Anim. Sci. 53, 755.

RANDEL, R.D. & MOSELEY, W.M., 1977. Serum luteinizing hormone surge and progesterone near oestrus in Brahman compared to Brahman x Hereford and Hereford heifers. J. Anim. Sci. 45 (Suppl. 1), 199 (Abstr.).

RANDEL, R.D., SHORT, R.E. & BELLOWS, R.A., 1976. Suckling effect on LH and progesterone in beef cows. J. Anim. Sci. 42, 267 (Abstr.).

RANDEL, R.D. & WELKER, G.A., 1976. Once daily suckling effect on cow-calf performance. J. Anim. Sci. 43, 301 (Abstr.).

RANDEL, R.D. & WELKER, G.A., 1977. Effect of energy intake and once daily suckling on postpartum interval in Brahman x Hereford heifers. Abstracts 69th Ann. Mtg. Amer. Soc. Anim. Sci. University of Wisc., 198 (Abstr. 495).

REEVES, J.J. & GASKINS, C.T., 1981. Effect of once-a-day nursing on rebreeding efficiency of beef cows. J. Anim. Sci. 53, 889.

REITER, R.J., 1980. Pineal mechanisms in seasonal reproduction. In: Endocrinology 1980. Elsevier/North Holland Biomedical Press. Oxford.

REYNECKE, J. & BONSMA, J.C., 1964. Milk production studies with beef cattle in the sub-tropics. I. Milk-fat and solids-non-fat of cows with summer or winter calves. Proc. S. Afr. Soc. Anim. Prod. 3, 184.

REYNOLDS, W.L., DE ROUEN, T.M. & BELLOWS, R.A., 1978. Relationships of milk yield of dam to early growth rate of straightbred and crossbred calves. J. Anim. Sci. 47, 584.

REYNOLDS, W.L., DE ROUEN, T.M., MEYERHOEFFER, D.C., WILTBANK, J.N. & TEMPLE, R.S., 1965. Birth weight and gestation length of beef cattle. J. Anim. Sci. 24, 851 (Abstr.).

RHODES, R.C., RANDEL, R.D. & HARMS, P.G., 1978. Reproductive studies of Brahman cattle. IV. Luteinizing hormone levels in ovariectomized Brahman, Brahman x Hereford and Hereford cows following a 20 mg dose of oestradiol-17 β. Theriogenology 10, 429.

RHODES, R.C., RANDEL, R.D. & LONG, C.R., 1982. Corpus luteum function in the bovine: In vivo and in vitro evidence for both a seasonal and breedtype effect. J. Anim. Sci. 55, 159.

RICHARDSON, F.D., OLIVER, J. & CLARKE, G.P.Y., 1977. Analysis of some factors which affect the productivity of beef cows and their calves in the marginal rainfall areas of Rhodesia. 2. The yield and composition of milk of suckling cows. Anim. Prod. 25, 359.

ROBISON, O.W., YUSUFF, M.K.M. & DILLARD, E.U., 1978. Milk production in Hereford cows. 1. Means and correlations. J. Anim. Sci. 47, 131.

ROCHE, J.F., 1974. Effect of short-term progesterone treatment on oestrous responses and fertility in heifers. J. Reprod. Fert. 40, 433.

ROCHE, J.F. & IRELAND, J.J., 1981. The differential effect of progesterone on concentrations of luteinizing hormone and follicle stimulating hormone in heifers. Endocrinology 108, 568.

ROCHE, J.F., KARSCH, F.J., FOSTER, D.L., TAKAGI, S. & DZIUK, P.J., 1970. Effect of pinealectomy on oestrus, ovulation and luteinizing hormone in ewes. Biol. Reprod. 2, 251.

ROSENBERG, M., FOLMAN, Y., HERZ, Z., FLAMENBAUM, I., BERMAN, A. & KAIM, M., 1982. Effect of climatic conditions on peripheral concentrations of LH, progesterone and oestradiol-17 β in high milk-yielding cows. J. Reprod. Fert. 66, 139.

ROSENBERG, M., HERZ, Z., DAVIDSON, M. & FOLMAN, Y., 1977. Seasonal variations in post-partum plasma progesterone levels and conception in primaparous and multiparous dairy cows. J. Reprod. Fert. 51, 363.

RUTLEDGE, J.J., ROBISON, O.W., AHLSCHWEDE, W.T. & LEGATES, J.E., 1971. Milk yield and its influence on 205-day weights of beef calves. J. Anim. Sci. 33, 563.

RZEPKOWSKI, R.A., IRELAND, J.J., FOGWELL, R.L., CHAPIN, L.T. & TUCKER, H.A., 1982. Serum luteinizing hormone, follicle stimulating hormone and prolactin response to photoperiod during the oestrous cycle of Holstein heifers. J. Anim. Sci. 55, 1125.

SAGEBIEL, J.A., KRAUSE, G.F., SIBBIT, B., LANGFORD, L., COMFORT, J.E., DYER, A.J. & LASLEY, J.F., 1969. Dystocia in reciprocally crossed Angus, Hereford and Charolais cattle. J. Anim. Sci. 29, 245.

SAIDUDDIN, S., RIESEN, J.W., GRAVES, W.E., TYLER, W.J. & CASIDA, L.E., 1967. Effect of suckling on the interval from parturition to first oestrus in dairy cows. J. Anim. Sci. 26, 950 (Abstr.).

SATTER, L.D. & BRINGE, A.N., 1969. Effect of abrupt ration changes on milk and blood components. J. Dairy Sci. 52, 1776.

SCHAEFFER, L.R. & WILTON, J.W., 1974. Age of dam, sex and environmental interaction affecting preweaning average daily gains of beef cattle. Can. J. Anim. Sci. 54, 183.

SCHALLENBERGER, E. & PETERSON, A.J., 1982. Effect of ovariectomy on tonic gonadotrophin secretion in cyclic and post-partum dairy cows. J. Reprod. Fert. 64, 47.

SCHAMS, D. & KARG, H., 1969. Radioimmunologische LH-Bestemmung in Blutserum vom Rind unter besondere Berucksichtigung des Brunstzyklus. Acta endocr. Copenh. 61, 96.

SCHANBACHER, B.C. & LUNSTRA, D.D., 1976. Seasonal changes in sexual activity and serum levels of LH and testosterone in Finnish Landrace and Suffolk rams. J. Anim. Sci. 43, 644.

SCHULTZE, A.B., 1965. Can big calves affect rebreeding performance? A. I. Digest 13, 8.

SCHWULST, F.J., SUMPTION, L.J., SWIGER, L.A. & ARTHAUD, V.H., 1966. Use of oxytocin for estimating milk production of beef cows. J. Anim. Sci. 25, 1045.

SELLERS, H.I., WILLHAM, R.L. & DE BACA, R.C., 1970. Effect of certain factors on weaning weight of beef calves. J. Anim. Sci. 31, 5.

SHARP, D.C., KOOISTRA, L. & GINTHER, O.J., 1975. Effects of artificial light on the oestrous cycle of the mare. J. Reprod. Fert. Suppl. 23, 241.

SHEFFEL, C.E., PRATT, B.R., FERREL, W.L. & INSKEEP, E.K., 1982. Induced corpora lutea in the postpartum beef cow. II. Effects of treatment with progestogen and gonadotropins. J. Anim. Sci. 54, 830.

SHORT, R.E., BELLOWS, R.A., MOODY, E.L. & HOWLAND, B.E., 1972. Effects of suckling and mastectomy on bovine postpartum reproduction. J. Anim. Sci. 34, 70.

SMEATON, D.C., WADAMS, T.K. & HOCKEY, H.U.P., 1982. The influence of an extra flush of pasture before and during mating on the performance of beef cows on hill country. Proc. N. Z. Soc. Anim. Prod. 42, 79.

SMITH, M.F., BURREL, W.C., SHIPP, L.D., SPROTT, L.R., SONGSTER, W.N. & WILTBANK, J.N., 1979. Hormone treatments and use of calf removal in postpartum beef cows. J. Anim. Sci. 48, 1285.

SMITH, M.F., LISHMAN, A.W., LEWIS, G.S., HARMS, P.G., ELLERSIECK, M.R., INSKEEP, E.K., WILTBANK, J.N. & AMOSS, M.S., 1983. Pituitary and ovarian responses to gonadotropin releasing hormone, calf removal and progestogen in anoestrous beef cows. J. Anim. Sci. 57, 418.

SMITH, J.F., TERVIT, H.R. & GOOLD, P.G., 1980. Synchronization of oestrus and ovulation in beef cows with progesterone releasing intravaginal devices (PRIDs): effect of duration of treatment and of temporary calf removal. Proc. Austr. Soc. Anim. Prod. 13, 309.

SMITH, L.E. & VINCENT, C.K., 1972. Effects of early weaning and exogenous hormone treatment on bovine postpartum reproduction. J. Anim. Sci. 35, 1228.

SNOOK, R.B., SAATMAN, R.R. & HANSEL, W., 1971. Serum progesterone and luteinizing hormone levels during the bovine oestrous cycle. Endocrinology 88, 678.

SOMERVILLE, S.H., LOWMAN, B.G., EDWARDS, R.A. & JOLLY, G., 1983. A study of the relationship between plane of nutrition during lactation and certain production characteristics in autumn-calving suckler cows. Anim. Prod. 37, 353.

SPRAGUE, E.A., HOPWOOD, M.L., NISWENDER, G.D. & WILTBANK, J.N., 1971. Progesterone and luteinizing hormone levels in peripheral blood of cycling beef cows. J. Anim. Sci. 33, 99.

STEENKAMP, J.D.G., 1979. A meat production strategy for Southern Africa. S. Afr. J. Anim. Sci. 9, 99.

STOTT, G.H. & WIERSMA, F., 1973. Climatic thermal stress, a cause of hormonal depression and low fertility in the bovine. Int. J. Biometeor. 17, 115.

STOTT, G.H. & WILLIAMS, R.J., 1962. Causes of low breeding efficiency in dairy cattle associated with seasonal high temperature. J. Dairy Sci. 45, 1369.

SUZUKI, O. & SATO, M., 1981. Effects of restricted suckling on growth of beef calves and postpartum reproductive performance of the dams. Bull. Nat. Grassl. Res. Inst. Jap. 20, 145.

SWEETMAN, W.J., 1950. Artificial breeding in Alaska and effect of extra light during short winter days. J. Dairy Sci. 33, 391.

SYMINGTON, R.B. & HALE, D.H., 1967. Methods to stimulate sexual activity in lactating Zebu cows. Rhod. Zamb. Mal. J. agric. Res. 5, 13.

TAINTON, N.M., 1981. Veld and pasture management in South Africa. Shuter & Shooter and University of Natal Press, Pietermaritzburg.

TAYLOR, A.J., 1949. The composition of kikuyu grass under intensive grazing and fertilizing. Dept. Agric. Bull. No. 203. Govt. Printer, Pretoria.

TERVIT, H.R., SMITH, J.F., GOOLD, P.G., JONES, K.R. & VANDIEN, J.J.D., 1982. Reproductive performance of beef cows following temporary removal of calves. Proc. N. Z. Soc. Anim. Prod. 42, 83.

THATCHER, W.W., 1974. Effects of season, climate and temperature on reproduction and lactation. J. Dairy Sci. 57, 360.

THERON, E.P., 1975. Potential for the radical improvement of the Highland Sourveld. Fert. Soc. S. Afr. J. 1, 73.

THERON, E.P. & CROSS, G.W., 1964. The yield potential and fertilizer requirements of perennial fodder crops grown on the Natal coast: Kikuyu at Umzinto. Project N-Ce 87/8. Final Rep. Dept. Agric., Natal Region.

THERON, E.P. & HARWIN, G.O., 1983. Redmeat production from grasslands. Arena 6, 7.

THIEBAULT, C., COUROT, M., MARTINET, L., MAULEON, P., DU MESNIL DU BUISSON, F., ORTAVANT, R., PELLETIER, J. & SIGNORET, J.P., 1966. Regulation of breeding season and oestrous cycles by light and external stimuli in some mammals. J. Anim. Sci. 25 (Suppl.), 119.

THOMAS, E.E., EASON, J.T. & TURNBULL, G.W., 1983. Dual benefits from creep grazing Tifleaf-L-pearlmillet. J. Anim. Sci. 57 (Suppl. 1), 299 (Abstr.).

THOMPSON, F.N., STUEDEMANN, J.A., CAUDLE, A.B., WILKINSON, S.R., WILLIAMS, D.J. & CIORDIA, H., 1983. Short oestrous cycle phenomenon in once a day suckled cows. J. Anim. Sci. 57 (Suppl. 1), 63 (Abstr.).

TODD, C., RIGGS, J.K. & SMITH, J.C., 1968. Milk yields and calf weights from Brahman, Hereford and crossbred cows in the Gulf Coast prairie. J. Anim. Sci. 27, 286 (Abstr.).

TOTUSEK, R., ARNETT, D.W., HOLLAND, G.L. & WHITEMAN, J.V., 1973. Relation of estimation method, sampling interval and milk composition to milk yield of beef cows and calf gain. J. Anim. Sci. 37, 153.

TOTUSEK, R., LUSBY, K.S. & STEPHENS, D.F., 1974. Three milk production levels in range cows. J. Anim. Sci. 38, 229 (Abstr.).

TRIGG, T.E. & TOPPS, J.H., 1981. Composition of bodyweight change during lactation in Hereford X British Friesian cows. J. agric. Sci. Camb. 97, 147.

TRIMBERGER, G.W. & HANSEL, W., 1955. Conception rate and ovarian function following oestrous control by progesterone injections in dairy cattle. J. Anim. Sci. 14, 224.

TROXEL, T.R. & KESLER, D.J., 1983. Progestin pretreatment enhances the function of corpora lutea induced by gonadotropin releasing hormone treatment in postpartum suckled beef cows. J. Anim. Sci. (Suppl. 1), 107 (Abstr.).

TROXEL, T.R., KESLER, D.J., NOBLE, R.C. & CARLIN, S.E., 1980. Ovulation and reproductive hormones following steroid pretreatment, calf removal and GnRh in postpartum suckled beef cows. J. Anim. Sci. 51, 652.

TUCKER, H.A., 1982. Seasonality in cattle. Theriogenology 17, 53.

VACCARO, R. & DILLARD, E.W., 1966. Relationship of dam's weight and weight changes to calf's growth rate in Hereford cattle. J. Anim. Sci. 25, 1063.

VAN DER WESTHUYSEN, J.M., 1972. Differences in progesterone synchronized oestrus and ovulation in three cattle breeds. S. Afr. J. Anim. Sci. 2, 91.

VAN MARLE, J., 1974. Intensiewe beesvleisproduksie. J. S. Afr. vet. Ass. 45, 41.

VAN MARLE, J., 1982. Omlyning van diereproduksiestrategieë. S. Afr. J. Anim. Sci. 12, 161.

VAN NIEKERK, A., 1982. Condition scoring as a guide to the nutritional status of the beef cow and its implications in reproductive performance. S. Afr. J. Anim. Sci. 12, 79.

VAN NIEKERK, A. & LOUW, B.P., 1982. Condition scoring of beef cattle. Bull. N14/82. Dept. Agric., Natal Region.

VANSTONE, E. & BRISTOW, M.D., 1960. Analysis of milk and milk products. In: Principles of Dairy Science. Cleaver-Hume Press Limited. London.

VENTER, H.A.W. & LUITINGH, H.C., 1980. 'n Beesvleisproduksiestrategie vir die Transvaalse bosveld en Noord-Kaap. S. Afr. J. Anim. Sci. 10, 311.

WAGNER, W.C. & HANSEL, W., 1969. Reproductive physiology of the postpartum cow. I. Clinical and histological findings. J. Reprod. Fert. 18, 493.

WALTERS, D.L., KALTENBACH, C.C., DUNN, T.G. & SHORT, R.E., 1982. Pituitary and ovarian function in postpartum beef cows. I. Effect of suckling on serum and follicular fluid hormones and follicular gonadotropin receptors. Biol. Reprod. 26, 640.

WALTERS, D.L., SHORT, R.E., CONVEY, E.M., STAIGMILLER, R.B., DUNN, T.G. & KALTENBACH, C.C., 1982. Pituitary and ovarian function in postpartum beef cows. III. Induction of oestrus, ovulation and luteal function with intermittent small-dose injections of GnRh. Biol. Reprod. 26, 655.

WALTERS, D.L., SMITH, M.F., HARMS, P.G. & WILTBANK, J.N., 1982. Effect of steroids and/or 48 hr calf removal on serum luteinizing hormone concentrations in anoestrous beef cows. Theriogenology 18, 349.

WARNICK, A.C., MEADE, J.H. & KOGER, M., 1960. Factors influencing pregnancy rate in Florida beef cattle. Fla. Agric. Exp. Sta. Bull. 623.

WARREN, J.A.R., 1972. Economic and technical aspects of milk production from pastures in Natal. 2. Milk production from Pennisetum clandestinum (Kikuyu) pasture during summer using different supplementary feed. Final Rep. Project N-Ce 123/2. Dept. Agric., Natal Region.

WATSON, R.H. & RADFORD, H.M., 1966. Seasonal variation in fertility in Merino ewes: The reproductive wastage associated with mating in winter, spring, summer or autumn. Aust. J. agric. Res. 17, 335.

WEBB, R., LAMMING, G.E., HAYNES, N.B., HAFS, H.D. & MANNS, J.G., 1977. Response of cyclic and post-partum suckled cows to injections of synthetic LH-Rh. J. Reprod. Fert. 50, 203.

WETTEMANN, R.P. & LUSBY, K.S., 1983. Reproductive response of beef cows to increased dietary energy and protein and short term calf separation. J. Anim. Sci. 57 (Suppl. 1), 28 (Abstr.).

WETTEMANN, R.P., TURMAN, E.J., WYATT, R.D. & TOTUSEK, R., 1978. Influence of suckling intensity on reproductive performance of range cows. J. Anim. Sci. 47, 342.

WHISNANT, C.S., KISER, T.E. & THOMPSON, F.N., 1983. Serum luteinizing hormone and cortisol concentrations in suckled and nonsuckled postpartum beef cows. J. Anim. Sci. 57 (Suppl. 1), 41 (Abstr.).

WILLIAMS, J.H., ANDERSON, D.C. & KRESS, D.D., 1979. Milk production in Hereford cattle. II. Physical measurements: Repeatabilities and relationships with milk production. J. Anim. Sci. 49, 1443.

WILLIAMS, G.L., KOTWICA, J., SLANGER, W.D., OLSON, D.K., TILTON, J.E. & JOHNSON, L.J., 1982. Effect of suckling on pituitary responsiveness to gonadotropin-releasing hormone throughout the early postpartum period of beef cows. J. Anim. Sci. 54, 594.

WILSON, L.L., GILLOOLY, J.E., RUGH, M.C., THOMPSON, C.W. & PURDY, H.R., 1969. Effect of energy intake, cow body size and calf sex on composition and yield of milk by Angus-Holstein cows and preweaning growth rate of progeny. J. Anim. Sci. 28, 789.

WILTBANK, J.N. & COOK, A.C., 1958. The comparitive reproductive performance of nursed cows and milked cows. J. Anim. Sci. 17, 640.

WILTBANK, J.N., ROWDEN, W.W., INGALLS, J.E., GREGORY, K.E. & KOCH, R.M., 1962. Effect of energy level on reproductive phenomena of mature Hereford cows. J. Anim. Sci. 21, 219.

WINCHESTER, C.F. & HOWE, P.E., 1955. Relative effects of continuous and interrupted growth in beef steers. USDA Tech. Bull. 1108.

WOLFF, L.K. & MONTY, D.E., 1974. Physiologic response to intense summer heat and its effect on the oestrous cycle of nonlactating and lactating Holstein-Friesian cows in Arizona. Amer. J. vet. Res. 35, 187.

WYATT, R.D., GOULD, M.B. & TOTUSEK, R., 1977. Effects of single vs simulated twin rearing on cow and calf performance. J. Anim. Sci. 45, 1409.

WYATT, R.D., GOULD, M.B., WHITEMAN, J.V. & TOTUSEK, R., 1977. Effect of milk level and biological type on calf growth and performance. J. Anim. Sci. 45, 1138.

YUTHASASTRAKOSOL, P., PALMER, W.M. & HOWLAND, B.E., 1975. Luteinizing hormone, oestrogen and progesterone levels in peripheral serum of anoestrous and cyclic ewes as determined by radioimmunoassay. J. Reprod Fert. 43, 57.

YUTHASASTRAKOSOL, P., PALMER, W.M. & HOWLAND, B.E., 1977. Release of LH in anoestrous and cyclic ewes. J. Reprod. Fert. 50, 319.