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

by

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DOCTOR OF PHILOSOPHY

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D 1984
ABSTRACT

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

The comparative performance of spring-calving beef cowherds comprising either Dual Purpose (Simmental) 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 conception rates, which averaged 65% over the three seasons. Simmental 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 conception 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 original work and have not been previously submitted by me in respect of a degree at any other university.

B. P. Louw
Pietermaritzburg
November, 1984
I wish to record my sincere thanks and appreciation to the following persons and institutions for their contribution to this thesis:

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The National Institute of Health, Bethesda, Maryland for the kind gift of NIH-LH-S16,

Dr H. Papkoff of the University of California, for the donation of purified LH used for iodination,

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My wife, Ina, for help with the data preparation, and together with my children Tabu, Marelize and Nanette, for continued encouragement and support.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>DH</td>
<td>density hydrometer</td>
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<tr>
<td>FCM</td>
<td>fat-corrected milk</td>
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<tr>
<td>FSH</td>
<td>follicle stimulating hormone</td>
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<tr>
<td>GnRh</td>
<td>gonadotropin releasing hormone</td>
</tr>
<tr>
<td>HCG</td>
<td>human chorionic gonadotropin</td>
</tr>
<tr>
<td>HPC</td>
<td>high protein concentrate</td>
</tr>
<tr>
<td>LH</td>
<td>luteinizing hormone</td>
</tr>
<tr>
<td>NPN</td>
<td>non-proteinic-nitrogen</td>
</tr>
<tr>
<td>PMSG</td>
<td>pregnant mare serum gonadotropin</td>
</tr>
<tr>
<td>RVI</td>
<td>radical veld improvement</td>
</tr>
<tr>
<td>SNF</td>
<td>solids-non-fat</td>
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</table>
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GENERAL DISCUSSION

SUMMARY

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GENERAL INTRODUCTION

An evaluation of future demands for beef in South Africa indicates continued seasonal surpluses 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
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 programmes 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
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 provided 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°32' and longitude 30°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%. Simmental 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>
<thead>
<tr>
<th>Stocking rate applied (cows &amp; calves/ha)</th>
<th>Number of cow/calf pairs per treatment</th>
<th>Area of kikuyu allocated per treatment (ha)</th>
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<tr>
<td>3.0</td>
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<td>1.87</td>
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<td>6.74</td>
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<td>3.56</td>
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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 Simmentaler 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.

<table>
<thead>
<tr>
<th>Stocking rate applied (cows &amp; calves/ha)</th>
<th>3.0</th>
<th>4.12</th>
<th>5.34</th>
<th>6.74</th>
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<tr>
<td>Number of cow/calf pairs (both breeds):</td>
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<tr>
<td>1980/81</td>
<td>8</td>
<td>11</td>
<td>10</td>
<td>13</td>
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<tr>
<td>1981/82</td>
<td>16</td>
<td>22</td>
<td>19</td>
<td>24</td>
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<tr>
<td>1982/83</td>
<td>16</td>
<td>22</td>
<td>19</td>
<td>24</td>
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<tr>
<td>Number of Simmentaler cow/calf pairs:</td>
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<tr>
<td>1980/81</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
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<tr>
<td>1981/82</td>
<td>9</td>
<td>13</td>
<td>10</td>
<td>10</td>
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<tr>
<td>1982/83</td>
<td>11</td>
<td>6</td>
<td>6</td>
<td>14</td>
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<tr>
<td>Number of Hereford-cross cow/calf pairs:</td>
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<tr>
<td>1980/81</td>
<td>5</td>
<td>8</td>
<td>7</td>
<td>8</td>
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<td>1981/82</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>14</td>
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<tr>
<td>1982/83</td>
<td>5</td>
<td>16</td>
<td>13</td>
<td>10</td>
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</table>
Table 3. Herd structures of groups allocated to the different stocking rates each season.

<table>
<thead>
<tr>
<th>Stocking rate applied (cows &amp; calves/ha)</th>
<th>3.0</th>
<th>4.12</th>
<th>5.34</th>
<th>6.74</th>
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<td>Number of cow/calf pairs (both breeds):</td>
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<td>1981/82</td>
<td>16</td>
<td>22</td>
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<td>1982/83</td>
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<td>22</td>
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<tr>
<td>Number of mature cows:</td>
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<tr>
<td>1980/81</td>
<td>8</td>
<td>11</td>
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<td>1981/82</td>
<td>11</td>
<td>15</td>
<td>13</td>
<td>18</td>
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<td>1982/83</td>
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<td>16</td>
<td>15</td>
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<tr>
<td>Number of first-calvers:</td>
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<tr>
<td>1980/81</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1981/82</td>
<td>5</td>
<td>7</td>
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<td>6</td>
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<tr>
<td>1982/83</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>5</td>
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<tr>
<td>Number of male calves:</td>
<td></td>
<td></td>
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<tr>
<td>1980/81</td>
<td>4</td>
<td>4</td>
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<td>1981/82</td>
<td>10</td>
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<td>1982/83</td>
<td>12</td>
<td>11</td>
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<td>12</td>
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<tr>
<td>Number of female calves:</td>
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<tr>
<td>1980/81</td>
<td>4</td>
<td>7</td>
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<td>1981/82</td>
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<td>1982/83</td>
<td>4</td>
<td>11</td>
<td>10</td>
<td>12</td>
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</table>
This reallocation 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% dicalcium phosphate
- 15% feed lime
- 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. An 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 =

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

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. Cumulative 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 or re-conception 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 condition 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
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 on 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.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stocking rate (cows &amp; calves/ha)</strong></td>
<td>3.0</td>
<td>4.12</td>
<td>5.34</td>
</tr>
<tr>
<td>Date animals placed on pasture</td>
<td>17 October 1980</td>
<td>20 November 1981</td>
<td>1 November 1982</td>
</tr>
<tr>
<td>Date calves weaned</td>
<td>2 July '81</td>
<td>18 June '81</td>
<td>30 April '81</td>
</tr>
<tr>
<td>Length of period between start of grazing and weaning (days)</td>
<td>258</td>
<td>244</td>
<td>195</td>
</tr>
<tr>
<td>Date when cows were removed from pasture</td>
<td>2 July '81</td>
<td>2 July '81</td>
<td>4 June '81</td>
</tr>
<tr>
<td>Length of period that cows remained on pasture (days)</td>
<td>258</td>
<td>258</td>
<td>230</td>
</tr>
<tr>
<td>(8.5)</td>
<td>(8.5)</td>
<td>(7.5)</td>
<td>(6.4)</td>
</tr>
<tr>
<td>Length of winter feeding period (days)*</td>
<td>123</td>
<td>123</td>
<td>151</td>
</tr>
</tbody>
</table>

* 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.

<table>
<thead>
<tr>
<th>Mean date on which cattle were placed on pasture</th>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>Mean date of weaning</th>
<th>Mean date on which cows were removed from pasture</th>
<th>Mean No. of months between the start of the grazing and:</th>
<th>Mean length of winter feeding period (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 November</td>
<td>3,0</td>
<td>19 June ± 13 days</td>
<td>29 June ± 22 days</td>
<td>7,5 ± 0,8</td>
<td>4,2 ± 0,7</td>
</tr>
<tr>
<td></td>
<td>4,12</td>
<td>5 June ± 18 days</td>
<td>14 June ± 25 days</td>
<td>7,1 ± 0,8</td>
<td>4,7 ± 1,0</td>
</tr>
<tr>
<td>± 17 days</td>
<td>5,34</td>
<td>20 April ± 33 days</td>
<td>7 May ± 41 days</td>
<td>5,5 ± 1,0</td>
<td>5,9 ± 1,5</td>
</tr>
<tr>
<td></td>
<td>6,74</td>
<td>17 April ± 32 days</td>
<td>22 April ± 29 days</td>
<td>5,5 ± 1,0</td>
<td>6,4 ± 0,9</td>
</tr>
</tbody>
</table>
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 and 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 $Y_1$ and $Y_2$ 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:

$$Y_1 = 171.7 - 15.8(X_1) - 0.2(X_2) + 0.21(X_4) \quad (R = 0.75; \ P < 0.05)$$

$$Y_2 = 185.4 - 17.2(X_1) - 0.2(X_2) + 0.2(X_4) \quad (R = 0.77; \ P < 0.05)$$

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 independent 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.*

<table>
<thead>
<tr>
<th>Dependant Variables</th>
<th>Independent variable(s)</th>
<th>Contribution of independent variables or combinations thereof to total variation in:</th>
<th>Significance of added independent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$Y_1(R^2 \times 100)$</td>
<td>$Y_2(R^2 \times 100)$</td>
</tr>
<tr>
<td>$Y_1$ (mass change between start of grazing and weaning)</td>
<td>Stocking rate ($X_1$)</td>
<td>40,3</td>
<td>42,0</td>
</tr>
<tr>
<td></td>
<td>Stocking rate ($X_1$) + Initial mass ($X_2$)</td>
<td>54,8</td>
<td>58,2</td>
</tr>
<tr>
<td>$Y_2$ (mass change between start of grazing and removal of cows from pasture)</td>
<td>Stocking rate ($X_1$) + Initial mass ($X_2$) + Season ($X_3$)</td>
<td>56,3</td>
<td>59,6</td>
</tr>
<tr>
<td></td>
<td>Stocking rate ($X_1$) + Initial mass ($X_2$) + Season ($X_3$) + Days postpartum ($X_4$)</td>
<td>57,5</td>
<td>-</td>
</tr>
</tbody>
</table>

Regression equations:

$Y_1 = 152.2 - 15.8(X_1) - 0.183(X_2) + 5.7(X_3) + 0.18(X_4)$  \[ R = 0.76; \ P < 0.05 \]

$Y_2 = 173.9 - 17.3(X_1) - 0.21(X_2) + 7.3(X_3)$  \[ R = 0.77; \ P < 0.05 \]

* 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 +/- 17 days).

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>3,0</th>
<th>4,12</th>
<th>5,34</th>
<th>6,74</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean initial mass (kg)</td>
<td>467,3</td>
<td>451,2</td>
<td>467,3</td>
<td>451,2</td>
</tr>
<tr>
<td>Mean date of weaning</td>
<td>19 June</td>
<td>19 June</td>
<td>5 June</td>
<td>5 June</td>
</tr>
<tr>
<td>Mean mass at weaning (kg)</td>
<td>506,7</td>
<td>493,9</td>
<td>489,0</td>
<td>476,2</td>
</tr>
<tr>
<td>Mean mass change between 2 Nov. and weaning (kg)</td>
<td>+39,4</td>
<td>+42,7</td>
<td>+21,7</td>
<td>+25,0</td>
</tr>
<tr>
<td>Mean date on which cows were removed from pasture (kg)</td>
<td>29 June</td>
<td>29 June</td>
<td>14 June</td>
<td>14 June</td>
</tr>
<tr>
<td>Mean mass when removed from pasture (kg)</td>
<td>502,2</td>
<td>489,8</td>
<td>482,9</td>
<td>470,5</td>
</tr>
<tr>
<td>Mean mass change between 2 Nov. and the date on which cows were removed from pasture (kg)</td>
<td>+34,9</td>
<td>+38,6</td>
<td>+15,6</td>
<td>+19,3</td>
</tr>
</tbody>
</table>
is diagrammatically illustrated in Fig. 5. It should be noted that the different regression lines presented for Simmental 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 Simmentals (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 Simmentals 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 Simmentals 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
Mass change between the start of the grazing period and weaning (kg)

Mass change between the start and end of the grazing period (kg)

Fig. 5. The relationship between stocking rate and mass change in Simmentaler(——) and Hereford-cross(-----) cows on pasture.
Fig. 6. Relative condition score changes in cows stocked at rates of 3, 0 (---), 4, 12 (--.--), 5, 34 (---0) and 6, 74 cows and calves/ha(0-0) 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. *

<table>
<thead>
<tr>
<th>Dependant variable</th>
<th>Independent variables</th>
<th>Contribution of independent variables or combinations thereof to total variation in Y (R^2 X100)</th>
<th>Significance of added independent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Y ) (Condition score change between start of grazing period and removal of cows from pasture)</td>
<td>Stocking rate (X1)</td>
<td>6,6</td>
<td>( P &lt; 0,05 )</td>
</tr>
<tr>
<td></td>
<td>Stocking rate (X1) + Breed (X2)</td>
<td>11,6</td>
<td>( P &lt; 0,05 )</td>
</tr>
<tr>
<td></td>
<td>Stocking rate (X1) + Breed (X2) + Initial score (X3)</td>
<td>16,8</td>
<td>( P &lt; 0,05 )</td>
</tr>
<tr>
<td></td>
<td>Stocking rate (X1) + Breed (X2) + Initial score (X3) + Days postpartum (X4)</td>
<td>20,4</td>
<td>( P &lt; 0,05 )</td>
</tr>
</tbody>
</table>

Regression equation:
\[
Y = 0,75 - 0,06 \ (X1) + 0,1 \ (X2) - 0,28 \ (X3) + 0,0027 \ (X4) \quad R = 0,45; \quad P < 0,05
\]

* 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.

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves /ha)</th>
<th>Breed</th>
<th>Mean initial score when cows placed on pasture</th>
<th>Mean score when cows removed from pasture</th>
<th>Mean score change on pasture</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>Simmentaler</td>
<td>2.89±0.29</td>
<td>2.79±0.29</td>
<td>-0.1±0.30</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>3.17±0.36</td>
<td>3.13±0.41</td>
<td>-0.04±0.30</td>
</tr>
<tr>
<td>4.12</td>
<td>Simmentaler</td>
<td>2.98±0.23</td>
<td>2.62±0.37</td>
<td>-0.36±0.37</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>3.11±0.24</td>
<td>2.92±0.32</td>
<td>-0.19±0.31</td>
</tr>
<tr>
<td>5.34</td>
<td>Simmentaler</td>
<td>3.02±0.22</td>
<td>2.86±0.22</td>
<td>-0.16±0.22</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>3.12±0.29</td>
<td>3.08±0.27</td>
<td>-0.05±0.19</td>
</tr>
<tr>
<td>6.74</td>
<td>Simmentaler</td>
<td>2.88±0.26</td>
<td>2.41±0.41</td>
<td>-0.47±0.33</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>3.10±0.29</td>
<td>2.78±0.34</td>
<td>-0.33±0.21</td>
</tr>
</tbody>
</table>
Table 10. The influence of stocking rate and breed on pooled reconception rates and intercalving periods over three seasons.

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>Breed</th>
<th>No. of cows mated</th>
<th>Cows conceived</th>
<th>Cows which failed to exhibit oestrus during the breeding season (%)</th>
<th>Intercalving period in cows which reconceived (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>3,0</td>
<td>Simmentaler</td>
<td>23</td>
<td>16</td>
<td>69,6</td>
<td>10,0</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>17</td>
<td>11</td>
<td>64,7</td>
<td>0,0</td>
</tr>
<tr>
<td>4,12</td>
<td>Simmentaler</td>
<td>22</td>
<td>15</td>
<td>68,2</td>
<td>4,5</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>33</td>
<td>21</td>
<td>63,6</td>
<td>3,0</td>
</tr>
<tr>
<td>5,34</td>
<td>Simmentaler</td>
<td>19</td>
<td>12</td>
<td>63,2</td>
<td>0,0</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>29</td>
<td>18</td>
<td>62,1</td>
<td>10,3</td>
</tr>
<tr>
<td>6,74</td>
<td>Simmentaler</td>
<td>28</td>
<td>19</td>
<td>67,9</td>
<td>10,3</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>32</td>
<td>18</td>
<td>56,3</td>
<td>15,6</td>
</tr>
<tr>
<td>Breed</td>
<td>Result following mating</td>
<td>Mean calving date</td>
<td>Mean bodymass</td>
<td>Mean bodymass change:</td>
<td>Mean condition score at the onset of the mating season</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------</td>
<td>-------------------</td>
<td>---------------</td>
<td>-----------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Within 14 days of calving (kg)</td>
<td>At the onset of the mating period (kg)</td>
<td>From calving until the onset of mating (kg)</td>
</tr>
<tr>
<td>Simmentaler</td>
<td>Calf</td>
<td>10 Sept. +20 days</td>
<td>479.8 ±59.8</td>
<td>482.6 ±62.6</td>
<td>+2.8 ±24.3</td>
</tr>
<tr>
<td></td>
<td>No calf</td>
<td>22 Sept. +25 days</td>
<td>484.3 ±56.3</td>
<td>485.6 ±52.1</td>
<td>+1.3 ±31.9</td>
</tr>
<tr>
<td>Hereford-cross</td>
<td>Calf</td>
<td>14 Sept. +21 days</td>
<td>467.0 ±51.3</td>
<td>471.1 ±56.7</td>
<td>+4.3 ±21.3</td>
</tr>
<tr>
<td></td>
<td>No calf</td>
<td>20 Sept. +23 days</td>
<td>462.3 ±56.9</td>
<td>471.1 ±57.6</td>
<td>+8.9 ±21.6</td>
</tr>
</tbody>
</table>

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 Simmentaler, 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. Simmental 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.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Calf sex</th>
<th>Mean birth mass (kg)</th>
<th>Birth mass as a percentage of post-calving mass in dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simmentaler</td>
<td>Male</td>
<td>35,5±0,7</td>
<td>7,65±0,15</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>32,7±0,8</td>
<td>7,13±0,16</td>
</tr>
<tr>
<td>Hereford-cross</td>
<td>Male</td>
<td>34,0±0,6</td>
<td>7,51±0,13</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>30,4±0,5</td>
<td>6,63±0,12</td>
</tr>
</tbody>
</table>

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

* P < 0,05
** P < 0,01
*** P < 0,001
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 independent variables ($X_1 \ldots X_6$) regressed against birth mass ($Y$), and the values assigned to these in the analysis, were:

$X_1$: Cow mass (obtained within 14 days of calving)
$X_2$: Calf sex (males = -1; females = 1)
$X_3$: Breed (Simmentaler = -1, Hereford-crosses = 1)
$X_4$: Season (1980/81 = 1, 1981/82 = 2, 1982/83 = 3)
$X_5$: Cow age (in years, or first-calvers = 1, mature cows = 2)
$X_6$: 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.

<table>
<thead>
<tr>
<th>Dependant variable</th>
<th>Independant variable(s)</th>
<th>Contribution of independant variables or combinations thereof to total variation in Y($R^2 \times 100$)</th>
<th>Significance of added independant variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth mass (Y)</td>
<td>Cow mass (X1)</td>
<td>17,4</td>
<td>P &lt; 0,001</td>
</tr>
<tr>
<td></td>
<td>Cow mass (X1) + Sex (X2)</td>
<td>32,0</td>
<td>P &lt; 0,001</td>
</tr>
<tr>
<td></td>
<td>Cow mass (X1) + Sex (X2) + Breed (X3)</td>
<td>33,9</td>
<td>P &lt; 0,05</td>
</tr>
<tr>
<td></td>
<td>Cow mass (X1) + Sex (X2) + Breed (X3) + Season (X4)</td>
<td>35,7</td>
<td>P &lt; 0,05</td>
</tr>
</tbody>
</table>

Regression equation:

\[ Y = 12,1 + 0,038 (X_1) - 2,1 (X_2) - 0,81 (X_3) + 0,99 (X_4) \quad R = 0,6; \quad P < 0,05 \]
Simmentalers

Hereford-crosses

1980/81

1981/82

1982/83

Mean sex-corrected calf mass (kg)

Days after 15 October

0 40 80 120 160 200 240 280

15 Oct. 4 March 22 July 15 Oct. 4 March 22

Date

Fig. 7. Mean sex-corrected mass changes in calves stocked at rates of 3,0 (---), 4,12 (---), 5,34 (-----) and 6,74 cows and calves/ha (----) 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. Simmental 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 ($X_2$) as an independent variable. The revised equation, which in effect predicts overall calf performance, based on the results obtained over three seasons, is:

$$Y_2 = 207.7 - 17.1(X_1) - 8.8(X_3) - 4.5(X_4) + 0.15(X_5)$$

($R = 0.77; P < 0.01$)

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.

<table>
<thead>
<tr>
<th>Dependant variable</th>
<th>Independant variable(s)</th>
<th>Contribution of independant variables or combinations thereof to total variation in:</th>
<th>Significance of added independant variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$Y_1 (R^2 \times 100)$</td>
<td>$Y_2 (R^2 \times 100)$</td>
</tr>
<tr>
<td>$Y_1$ (calf gain over a common period)</td>
<td>Stocking rate($X_1$)</td>
<td>20,0</td>
<td>48,1</td>
</tr>
<tr>
<td></td>
<td>Stocking rate($X_1$) + Season($X_2$)</td>
<td>50,4</td>
<td>58,0</td>
</tr>
<tr>
<td></td>
<td>Stocking rate($X_1$) + Season($X_2$) + Breed($X_3$)</td>
<td>64,9</td>
<td>68,3</td>
</tr>
<tr>
<td>$Y_2$ (calf gain between the start of the grazing period and weaning)</td>
<td>Stocking rate($X_1$) + Season($X_2$) + Breed($X_3$) + Sex($X_4$)</td>
<td>67,1</td>
<td>70,7</td>
</tr>
<tr>
<td></td>
<td>Stocking rate($X_1$) + Season($X_2$) + Breed($X_3$) + Sex($X_4$) + Initial mass($X_5$)</td>
<td>72,4</td>
<td>72,6</td>
</tr>
</tbody>
</table>

Regression equations:

$Y_1 = 204.8 - 10.1(X_1) - 26.2(X_2) - 9.4(X_3) - 3.0(X_4) + 0.37(X_5) \quad R = 0.85; \quad P < 0.001$

$Y_2 = 238.4 - 17.2(X_1) - 16.7(X_2) - 9.1(X_3) - 4.4(X_4) + 0.24(X_5) \quad R = 0.85; \quad P < 0.001$
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. Overall 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.

<table>
<thead>
<tr>
<th>Mean date on which grazing period commenced</th>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>Breed</th>
<th>Estimated calf mass at start of grazing period</th>
<th>Mean date of weaning</th>
<th>Estimated weaning mass</th>
<th>Estimated production of calf mass per hectare (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 November</td>
<td>3.0</td>
<td>Simm.</td>
<td>66.7</td>
<td>5 June</td>
<td>225.5</td>
<td>929.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Her.-X</td>
<td>62.3</td>
<td>18 days</td>
<td>201.1</td>
<td>828.5</td>
</tr>
<tr>
<td>+ 17 days</td>
<td>4.12</td>
<td>Simm.</td>
<td>66.7</td>
<td>5 June</td>
<td>225.5</td>
<td>929.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Her.-X</td>
<td>62.3</td>
<td>18 days</td>
<td>201.1</td>
<td>828.5</td>
</tr>
<tr>
<td></td>
<td>5.34</td>
<td>Simm.</td>
<td>66.7</td>
<td>20 April</td>
<td>204.5</td>
<td>1092.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Her.-X</td>
<td>62.3</td>
<td>33 days</td>
<td>180.0</td>
<td>961.2</td>
</tr>
<tr>
<td></td>
<td>6.74</td>
<td>Simm.</td>
<td>66.7</td>
<td>17 April</td>
<td>180.4</td>
<td>1215.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Her.-X</td>
<td>62.3</td>
<td>33 days</td>
<td>156.0</td>
<td>1051.4</td>
</tr>
</tbody>
</table>
Fig. 8. The relationship between stocking rate, mean 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 (1274 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.

<table>
<thead>
<tr>
<th>Pre-weaning stocking rate (cows &amp; calves /ha)</th>
<th>Breed</th>
<th>Post-weaning calf gain on kikuyu over a 88-day period between 14.3.83 and 10.6.83 (kg/day)</th>
</tr>
</thead>
</table>
| 5.34                                        | Simmentaler | 0.66 ± 0.13  
|                                             | Hereford-cross | 0.56 ± 0.09 |
| 6.74                                        | Simmentaler | 0.66 ± 0.09  
|                                             | Hereford-cross | 0.51 ± 0.05 |

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 body mass 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.

<table>
<thead>
<tr>
<th>Pre-weaning stocking rate (cows &amp; calves/ha)</th>
<th>Mean calf mass at weaning (kg)</th>
<th>Mean over 88 days of average daily maize silage intake per calf (kg)</th>
<th>Mean daily lick intake per calf (g)</th>
<th>Mean dry matter intake as a percentage of mean bodymass over feeding period (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>$254.3^{+4.9a}$</td>
<td>$15.1^{+1.3a}$</td>
<td>174</td>
<td>1.73</td>
</tr>
<tr>
<td>4.12</td>
<td>$229.9^{+40.4b}$</td>
<td>$13.9^{+1.3b}$</td>
<td>132</td>
<td>1.75</td>
</tr>
<tr>
<td>5.34</td>
<td>$221.0^{+37.9b}$</td>
<td>$13.6^{+1.2b}$</td>
<td>227</td>
<td>1.85</td>
</tr>
<tr>
<td>6.74</td>
<td>$201.5^{+36.3c}$</td>
<td>$13.5^{+1.2b}$</td>
<td>175</td>
<td>1.96</td>
</tr>
</tbody>
</table>

*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.

<table>
<thead>
<tr>
<th>Pre-weaning stocking rate (cows &amp; calves/ha)</th>
<th>Breed of calf</th>
<th>Mean mass at weaning (kg)</th>
<th>Mean post-weaning growth rate (kg/day)</th>
<th>Kg of dry matter (DM) consumed per kg of livemass gain (kg DM/kg gain)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>Simm.</td>
<td>275.1±32.1</td>
<td>0.65±0.3a</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Her.-X</td>
<td>227.5±46.8</td>
<td>0.59±0.3a</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>Simm.</td>
<td>250.6±26.7</td>
<td>0.36±0.3b</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>Her.-X</td>
<td>196.3±36.8</td>
<td>0.36±0.3b</td>
<td></td>
</tr>
<tr>
<td>5.34</td>
<td>Simm.</td>
<td>243.7±32.6</td>
<td>0.28±0.3b</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>Her.-X</td>
<td>192.7±22.1</td>
<td>0.27±0.3b</td>
<td></td>
</tr>
<tr>
<td>6.74</td>
<td>Simm.</td>
<td>230.0±31.3</td>
<td>0.24±0.3b</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>Her.-X</td>
<td>184.1±24.6</td>
<td>0.31±0.3b</td>
<td></td>
</tr>
</tbody>
</table>

a,b: Within the same column means with different superscripts differ significantly (P <0.05) from each other.
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.
Fig. 11. Mean daily yields of 4% fat-corrected milk produced by cows stocked at 3.0 (——), 4.12 (— —), 5.34 (———) and 6.74 cows and calves/ha (———) 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:

\[ \text{Persistency} = \frac{A - B}{C} \]

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.

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>Breed</th>
<th>Mean yield of PCM at weaning as a percentage of mean PCM yield at the start of the grazing period (%)</th>
<th>Mean persistency of lactation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,0</td>
<td>Simmental - + a</td>
<td>79,3 + 26,5 a</td>
<td>0,87 + 0,13 a</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross - + a</td>
<td>54,4 + 13,9 b</td>
<td>0,71 + 0,09 b</td>
</tr>
<tr>
<td>4,12</td>
<td>Simmental - + b</td>
<td>63,4 + 13,4 b</td>
<td>0,81 + 0,07 a</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross - + b</td>
<td>51,9 + 14,1 b</td>
<td>0,77 + 0,06 a</td>
</tr>
<tr>
<td>5,34</td>
<td>Simmental - + c</td>
<td>40,0 + 17,9 c</td>
<td>0,67 + 0,04 c</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross - + c</td>
<td>39,1 + 11,8 c</td>
<td>0,67 + 0,07 c</td>
</tr>
<tr>
<td>6,74</td>
<td>Simmental - + c</td>
<td>37,0 + 11,5 c</td>
<td>0,66 + 0,08 c</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross - + c</td>
<td>36,2 + 12,5 c</td>
<td>0,64 + 0,10 c</td>
</tr>
</tbody>
</table>

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.*

<table>
<thead>
<tr>
<th>Dependant variables</th>
<th>Independant variable(s)</th>
<th>Contribution of independant variables or combinations thereof to total variation in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1 (FCM yield; litres)</td>
<td>Initial FCM yield (X1)</td>
<td>Y1: 66.1, Y2: 71.4, Y3: 53.8, Y4: 65.7</td>
</tr>
<tr>
<td>Y2 (Lactose yield, kg)</td>
<td>Initial FCM yield (X1) + Breed (X2)</td>
<td>Y1: 71.4, Y2: 65.7, Y3: 65.9, Y4: 68.7</td>
</tr>
<tr>
<td>Y3 (Protein yield, kg)</td>
<td>Initial FCM yield (X1) + Breed (X2) + Calving day (X3)</td>
<td>Y1: 75.5, Y2: 67.7, Y3: 66.8, Y4: 70.6</td>
</tr>
<tr>
<td>Y4 (SNF yield, kg)</td>
<td>Initial FCM yield (X1) + Breed (X2) + Calving day (X3) + Stocking rate (X4)</td>
<td>Y1: 77.3, Y2: 70.3, Y3: 70.4, Y4: 73.3</td>
</tr>
</tbody>
</table>

Regression equations:

\[
Y_1 = 233.9 + 102.0(X_1) - 70.5(X_2) + 2.4(X_3) - 26.2(X_4) \quad R = 0.89; \quad P < 0.001
\]

\[
Y_2 = 16.51 + 4.37(X_1) - 4.97(X_2) + 0.08(X_3) - 1.42(X_4) \quad R = 0.84; \quad P < 0.001
\]

\[
Y_3 = 14.90 + 2.87(X_1) - 2.87(X_2) + 0.04(X_3) - 1.06(X_4) \quad R = 0.84; \quad P < 0.001
\]

\[
Y_4 = 29.43 + 7.61(X_1) - 7.95(X_2) + 0.13(X_3) - 2.39(X_4) \quad R = 0.86; \quad P < 0.001
\]

* 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 cumulative 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.

<table>
<thead>
<tr>
<th>Stocking rate (Cows &amp; calves/ha)</th>
<th>Breed</th>
<th>Daily yield of:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FCM (l)</td>
<td>Protein (g)</td>
<td>Lactose (g)</td>
<td>SNF (g)</td>
</tr>
<tr>
<td>3.0</td>
<td>Simmental</td>
<td>6.6</td>
<td>217.0</td>
<td>314.8</td>
<td>545.2</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>5.2</td>
<td>188.3</td>
<td>236.9</td>
<td>417.5</td>
</tr>
<tr>
<td>4.12</td>
<td>Simmental</td>
<td>6.4</td>
<td>210.6</td>
<td>305.9</td>
<td>530.2</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>5.1</td>
<td>163.8</td>
<td>228.0</td>
<td>402.4</td>
</tr>
<tr>
<td>5.34</td>
<td>Simmental</td>
<td>6.3</td>
<td>203.3</td>
<td>296.2</td>
<td>513.8</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>4.9</td>
<td>156.6</td>
<td>218.3</td>
<td>386.1</td>
</tr>
<tr>
<td>6.74</td>
<td>Simmental</td>
<td>6.1</td>
<td>195.0</td>
<td>284.9</td>
<td>495.0</td>
</tr>
<tr>
<td></td>
<td>Hereford-cross</td>
<td>4.7</td>
<td>148.3</td>
<td>207.0</td>
<td>367.2</td>
</tr>
</tbody>
</table>

* 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 Simmentales 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 3.7%, 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 Simmentales and 4.7% in the Hereford-crosses.

The inter-relationships between 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).*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Milk yield</th>
<th>FCM yield</th>
<th>Fat yield</th>
<th>Protein yield</th>
<th>Lactose yield</th>
<th>SNF yield</th>
<th>Fat %</th>
<th>Protein %</th>
<th>Lactose %</th>
<th>SNF %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield</td>
<td>0.94</td>
<td>0.86</td>
<td>0.91</td>
<td>0.99</td>
<td>0.99</td>
<td>0.04</td>
<td>-0.33</td>
<td>0.29</td>
<td>-0.04</td>
<td></td>
</tr>
<tr>
<td>FCM yield</td>
<td>0.98</td>
<td>0.98</td>
<td>0.89</td>
<td>0.93</td>
<td>0.94</td>
<td>0.37</td>
<td>-0.24</td>
<td>0.29</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Fat yield</td>
<td>0.94</td>
<td>0.99</td>
<td>0.83</td>
<td>0.85</td>
<td>0.87</td>
<td>0.53</td>
<td>-0.18</td>
<td>0.28</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Protein yield</td>
<td>0.95</td>
<td>0.95</td>
<td>0.93</td>
<td>0.89</td>
<td>0.93</td>
<td>0.15</td>
<td>0.08</td>
<td>0.22</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Lactose yield</td>
<td>0.99</td>
<td>0.97</td>
<td>0.94</td>
<td>0.96</td>
<td>0.99</td>
<td>0.04</td>
<td>-0.34</td>
<td>0.42</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>SNF yield</td>
<td>0.99</td>
<td>0.97</td>
<td>0.94</td>
<td>0.98</td>
<td>0.99</td>
<td>0.08</td>
<td>-0.24</td>
<td>0.37</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Fat %</td>
<td>-0.06</td>
<td>0.15</td>
<td>0.26</td>
<td>0.03</td>
<td>-0.05</td>
<td>-0.02</td>
<td>0.24</td>
<td>0.08</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Protein %</td>
<td>-0.37</td>
<td>-0.31</td>
<td>-0.27</td>
<td>-0.09</td>
<td>-0.29</td>
<td>-0.25</td>
<td>0.36</td>
<td>-0.15</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>Lactose %</td>
<td>0.24</td>
<td>0.25</td>
<td>0.24</td>
<td>0.31</td>
<td>0.37</td>
<td>0.34</td>
<td>0.03</td>
<td>0.13</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>SNF %</td>
<td>-0.24</td>
<td>-0.19</td>
<td>-0.15</td>
<td>-0.03</td>
<td>-0.11</td>
<td>-0.09</td>
<td>0.34</td>
<td>0.8</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>

* 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 Simmentaler bulls 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 Simmentaler bulls 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 Simmentaler bulls 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 Simmentaler bulls, 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.*

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

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.

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

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.*

<table>
<thead>
<tr>
<th>Dependant variable</th>
<th>Independant variable(s)</th>
<th>Contribution of independant variables or combinations thereof to total variation in milk conversion rate($R^2 \times 100$)</th>
<th>Significance of added independant variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y (milk conversion rate)</td>
<td>FCM yield(X1)</td>
<td>37.8</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td></td>
<td>FCM yield(X1)+Stocking rate(X2)</td>
<td>60.1</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td></td>
<td>FCM yield(X1)+Stocking rate(X2)+Breed(X3)</td>
<td>74.7</td>
<td>$P &lt; 0.001$</td>
</tr>
<tr>
<td></td>
<td>FCM yield(X1)+Stocking rate(X2)+Breed(X3)+Sex(X4)</td>
<td>76.7</td>
<td>$P &lt; 0.05$</td>
</tr>
</tbody>
</table>

Regression equation:

$$ f = -0.22 + 0.0052(X_1) + 0.501(X_2) + 0.63(X_3) + 0.23(X_4) \quad R = 0.88; \quad P < 0.001 $$

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 independent 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
GRAZING PERIOD CONSIDERED:

20.11.81 - 17.5.82 (Entire period)

20.11.81 - 17.2.82 (First half of period)

17.2.82 - 17.5.82 (Second half of period)

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 parameters for Simmental and Hereford-cross cows and calves stocked at four rates on kikuyu.

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>3,0</th>
<th>4,12</th>
<th>5,34</th>
<th>6,74</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calving date</td>
<td></td>
<td></td>
<td>22 September</td>
<td></td>
</tr>
<tr>
<td>Date onto pasture</td>
<td></td>
<td></td>
<td>2 November</td>
<td></td>
</tr>
<tr>
<td>Initial cow mass on 2 Nov. (kg)</td>
<td>467.3</td>
<td>451.2</td>
<td>467.3</td>
<td>451.2</td>
</tr>
<tr>
<td>Initial calf mass on 2 Nov. (kg)</td>
<td>66.7</td>
<td>62.3</td>
<td>66.7</td>
<td>62.3</td>
</tr>
<tr>
<td>Initial cow condition on 2 Nov.</td>
<td>2.89</td>
<td>3.17</td>
<td>2.98</td>
<td>3.11</td>
</tr>
<tr>
<td>Weaning date</td>
<td>19 June</td>
<td>19 June</td>
<td>5 June</td>
<td>5 June</td>
</tr>
<tr>
<td>Weaning mass of calves (kg)</td>
<td>244.8</td>
<td>220.4</td>
<td>225.5</td>
<td>201.1</td>
</tr>
<tr>
<td>Mass of cows at weaning (kg)</td>
<td>506.7</td>
<td>493.9</td>
<td>489.0</td>
<td>476.2</td>
</tr>
<tr>
<td>Cows removed from pasture:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>29 June</td>
<td>29 June</td>
<td>14 June</td>
<td>14 June</td>
</tr>
<tr>
<td>Mass</td>
<td>502.2</td>
<td>489.8</td>
<td>482.9</td>
<td>470.5</td>
</tr>
<tr>
<td>Condition score</td>
<td>2.79</td>
<td>3.13</td>
<td>2.62</td>
<td>2.92</td>
</tr>
<tr>
<td>Winter feed intake per cow:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize silage (tons)</td>
<td>3.6</td>
<td>3.53</td>
<td>4.0</td>
<td>3.92</td>
</tr>
<tr>
<td>NPN/mineral lick (kg)</td>
<td>37.8</td>
<td>37.8</td>
<td>42.3</td>
<td>42.3</td>
</tr>
<tr>
<td>HPC (kg)</td>
<td>16.4</td>
<td>16.4</td>
<td>16.4</td>
<td>16.4</td>
</tr>
<tr>
<td>Summer lick intake per cow (kg)</td>
<td>31.1</td>
<td>31.1</td>
<td>29.1</td>
<td>29.0</td>
</tr>
</tbody>
</table>
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 Simmental and Hereford cross cattle subjected to four stocking rates on pasture.

<table>
<thead>
<tr>
<th>Stocking rate (cows &amp; calves/ha)</th>
<th>3,0</th>
<th>4,12</th>
<th>5,34</th>
<th>6,74</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income per cow:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf weaning mass (kg)</td>
<td>244,8</td>
<td>220,4</td>
<td>225,5</td>
<td>201,1</td>
</tr>
<tr>
<td>Assumed price/kg calf livemass</td>
<td>115c</td>
<td>114c</td>
<td>114c</td>
<td>113c</td>
</tr>
<tr>
<td>Value of weaner (1)</td>
<td>R 281,5</td>
<td>R 251,3</td>
<td>R 257,1</td>
<td>R 227,2</td>
</tr>
<tr>
<td>8,3% X salvage value of cow at R 0,9/kg livemass (2)</td>
<td>R 37,8</td>
<td>R 36,9</td>
<td>R 36,5</td>
<td>R 35,6</td>
</tr>
<tr>
<td>Total income (1+2) = A</td>
<td>R 319,3</td>
<td>R 288,2</td>
<td>R 293,6</td>
<td>R 262,8</td>
</tr>
<tr>
<td><strong>Feed costs per cow:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer cost (Pasture &amp; lick)</td>
<td>R 108,4</td>
<td>R 108,4</td>
<td>R 82,4</td>
<td>R 82,4</td>
</tr>
<tr>
<td>Winter cost (Silage, HPC, lick)</td>
<td>R 115,3</td>
<td>R 104,4</td>
<td>R 134,8</td>
<td>R 119,4</td>
</tr>
<tr>
<td>Total cost = B</td>
<td>R 223,7</td>
<td>R 212,8</td>
<td>R 217,2</td>
<td>R 201,8</td>
</tr>
<tr>
<td><strong>Margin over feed cost:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per cow (A-B)</td>
<td>R 95,6</td>
<td>R 75,4</td>
<td>R 76,4</td>
<td>R 61,0</td>
</tr>
<tr>
<td>Per hectare</td>
<td>R 286,8</td>
<td>R 226,2</td>
<td>R 314,8</td>
<td>R 251,3</td>
</tr>
</tbody>
</table>
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.
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, Hulun & 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 cumulative 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 Simmental than in Hereford-cross cows, and in cows giving
birth to males than to females, since Simmental 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. Recombination 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 Simmentalers (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, Simmentalers 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 mil...
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
Improved cow condition towards the end of the suckling period has also been related to decreased lactational performance by Hohenbocken, 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; Hohenbocken 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 body mass 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 gauge 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 (Neville, 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 coefficients of approximately 0,5 were obtained for the milk yield : calf gain relationship on pasture, 0,59 (Simmental) 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., 1971; 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 fat 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 conducive 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 Simmentaler 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 *Bos indicus* than in *Bos taurus* types. In the present study the reconception rates in the Simmentalers tended to be higher than in the Hereford-crosses (which contained *Bos indicus* 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 conception. 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; Wetteeman 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 Simmentaler (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 $2 \times 2 \times 2$ 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>
<thead>
<tr>
<th>Breed</th>
<th>Days postpartum during which suckling intensity was varied</th>
<th>Suckling intensity</th>
<th>n</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>British-cross</td>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>2</td>
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<tr>
<td></td>
<td>60-75</td>
<td>Normal</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Drakensberger</td>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>5</td>
</tr>
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<td></td>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>6</td>
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<tr>
<td></td>
<td>60-75</td>
<td>Normal</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>
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 chromatography 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 parameters 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>
<thead>
<tr>
<th>Breed</th>
<th>Days postpartum treated</th>
<th>Suckling intensity</th>
<th>No. of cows which ovulated in response to GnRh</th>
<th>No. of cows which conceived to fixed-time inseminations</th>
<th>No. of cows which underwent &quot;short cycles&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
<td><strong>British-cross</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>2 (40%)</td>
<td>1 (20%)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>3 (60%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60-75</td>
<td>Normal</td>
<td>4</td>
<td>3 (75%)</td>
<td>1 (25%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td></td>
<td>Restricted</td>
<td>4</td>
<td>3 (75%)</td>
<td>2 (50%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td><strong>Drakensberger</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>3 (60%)</td>
<td>0</td>
<td>2 (40%)</td>
</tr>
<tr>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>4 (80%)</td>
<td>2 (40%)</td>
<td>1 (20%)</td>
</tr>
<tr>
<td>60-75</td>
<td>Normal</td>
<td>4</td>
<td>2 (50%)</td>
<td>1 (25%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>5 (100%)</td>
<td>3 (60%)</td>
<td>0</td>
</tr>
</tbody>
</table>
the ovaries approximately one week after the GnRih injection. In addition the pattern of progesterone secretion during the 21 days which followed the administration of GnRih 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 GnRih 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 GnRih 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 GnRih injection provide an indication of corpus luteum function. These profiles varied considerably between cows. Certain animals did not exhibit elevated progesterone levels at all, and rectal palpations confirmed that they had failed to ovulate in response to the GnRih. In other cows the progesterone concentrations increased markedly about six days after the GnRih injection and remained relatively high throughout, or decreased to reach baseline levels at 15 to 20 days after the GnRih 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
Plasma progesterone levels subsequent to the GnRh injection in British-cross cows.

* Donates cows which conceived to fixed-time inseminations.
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
Days postpartum treated:

- 35-50
- 60-75

Suckling intensity:

- Normal
- Restricted

**Fig. 17.** Mean plasma total oestrogen levels prior to the GnRh injection in Drakensberger (A) and British-cross cows (B).
Plasma LH (ng/ml) from start of variable suckling period:

Minutes after commencement of sampling:

-1 +5 +10

Fig. 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 among 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 on 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 Drakensberger 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.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Days postpartum treated</th>
<th>Suckling intensity</th>
<th>n</th>
<th>Mean Area under LH curve (mm²)</th>
<th>Mean Maximum LH level reached (ng/ml)</th>
<th>Mean duration of LH surge (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>British-cross</td>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>225,9±40,7</td>
<td>101,0±17,6</td>
<td>6,9±0,6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>202,4±27,5</td>
<td>88,7±12,0</td>
<td>6,2±0,3</td>
</tr>
<tr>
<td>60-75</td>
<td></td>
<td>Normal</td>
<td>4</td>
<td>124,6±20,3</td>
<td>60,7±6,7</td>
<td>6,5±0,0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>4</td>
<td>185,1±47,0</td>
<td>76,9±19,2</td>
<td>6,6±0,4</td>
</tr>
<tr>
<td>Drakensberger</td>
<td>35-50</td>
<td>Normal</td>
<td>5</td>
<td>197,5±19,7</td>
<td>88,8±12,9</td>
<td>6,9±0,4</td>
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<td>Restricted</td>
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<td>173,7±77,7</td>
<td>78,0±11,0</td>
<td>6,1±0,5</td>
</tr>
<tr>
<td>60-75</td>
<td></td>
<td>Normal</td>
<td>4</td>
<td>193,6±41,5</td>
<td>88,9±17,5</td>
<td>7,3±0,4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Restricted</td>
<td>5</td>
<td>163,8±37,1</td>
<td>72,2±16,7</td>
<td>5,7±1,0</td>
</tr>
</tbody>
</table>

* Levels < 10ng/ml
Fig. 22. LH response curves obtained in cows subsequent to the GnRh injection (levels obtained at the 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.

Body mass 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
The ovulatory response of the cows was not 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 Simmental 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 ± 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 LH 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 oestradiol, 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.
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 ovarioectomized 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 throughout 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 \(16.7 \pm 9.7^\circ C\), summer \(17.9 \pm 0.3^\circ C\) and autumn \(16.1 \pm 0.7^\circ C\) 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 \(11.1 \pm 0.7^\circ C\). The mean daily relative humidity during the spring \(78.9 \pm 3.4\%\), summer \(83.0 \pm 3.3\%\) and autumn \(75.6 \pm 2.2\%\) was also significantly higher than that measured during the winter sampling period \(63.9 \pm 3.3\%\). 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 \(2.26 \pm 0.07\ ng/ml\) were
Fig. 23. Changes in climatological parameters during the experimental period.
Fig. 24. Changes in body mass of cows during the experimental period.
Fig. 25. Mean daily tonic LH and progesterone levels in 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 with 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 parameters 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-gonadal 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, Karach, 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 & Karach, 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 independent 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; Karach & 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 (Karach, 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 quietly 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.
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 Drakensberger, 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 the
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 phenomenon 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 between 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 Simmental x Hereford cows. Furthermore, normally-suckled Drakensberger cows secreted more LH in response to GnRh than Simmental 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 Bos indicus breeding (Coetzee, 1983). Such studies should not be used as motivation to downgrade or discriminate against Bos indicus 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 Bos indicus 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 Bos indicus 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-PH" 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 phenomenon 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 et al. (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 originally 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 meaningful contribution to intensification in the high-potential areas is possible.
CHAPTER 1.

The comparative performance of spring-calving beef cowherds comprising either Dual Purpose (Simmental) 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 between 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 Simmentaler.

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 Simmentaler 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 Simmental 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 body mass 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 mm²) was significantly (P < 0.05) greater than that for cows sampled during summer (17.7 ± 0.6 mm²) and spring (17.4 ± 0.6 mm²).

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.


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