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EVALUATION OF THE PRODUCTIVITIES OF MAURE AND PEUL CATTLE BREEDS AT THE SAHELIAN STATION, NIONO, MALI

UNDERTAKEN BY

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA & L'INSTITUT D'ECONOMIE RURALE DU MALI

PUBLISHED BY
INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA. ADDIS ABABA

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P.O. BOX 5689 ADDIS ABABA ETHIOPIA

ABSTRACT

Productivity data on the Maure and Peul breeds and some of their crosses at the Sahelian Station, Niono, Mali from 1966 to 1975 were statistically analyzed. The traits studied included reproductivity, milk yield and composition, mortality, body weight, and various body measurements. The results were compared with those from other research stations in similar areas of Africa.

KEY WORDS

Sahelian zone, Mali, cattle productivity, Maure, Peul, crossbreeding.

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PREFACE

This report presents part of the results of almost ten years of research at the Station d'Elevage et de Recherches Zootechniques du Sahel, carried out under the leadership of Dr. N'Golo Traoré. The study is based on the performance parameters of Zebu cattle maintained under Sahelian conditions in the Republic of Mali. Such a considerable amount of data collected over a long period of time is relatively rare and thus of particular interest, providing information on the productivity of two typical African cattle breeds and allowing a tentative comparison with animal performance in other areas.

At the request of the Directorate of the Institute d'Economie Rurale du Mali, data recorded by the staff of the Station du Sahel were analysed by the International Livestock Centre for Africa (ILCA). No attempt has been made to interpret the results or to make suggestions or recommendations.

These results will assist the planning of future animal production programmes and will also allow comparison with similar information from elsewhere in Africa, though this was not the main objective of the study.

The cooperation illustrated by this joint publication follows an agreement signed in 1976 between the Malian Government and ILCA. This agreement includes a continuing research programme on livestock production systems centred mainly at the Station de Recherches Zootechniques du Sahel at Niono.

SUMMARY

Analyses were carried out on the productivities of the Maure and Peul breeds and some of their crosses in a semi-arid environment, at the Sahelian Station and Niono Ranch, Mali. The cattle were maintained from 1966 to 1975, primarily for milk and meat production. Supplementary feeding was practiced at virtually all stages.

Age at first calving averaged 43 months and showed a decrease of 2.5 months or 6 % per year, through management improvements, for animals born from 1966 to 1973. No breed differences were found, and with a heritability of 0.03, the expected decrease through genetic selection was only 2 days per generation, indicating that selection programmes for this trait would have little success.

The calving interval averaged 468 days and showed a decrease of 10 days, or 2.5 % per year, for animals born from 1966-1973. No breed differences were found, and the relatively low repeatability of 0.23 suggests that genetic selection would not be very effective. Lactation length represented 54 % of the calving interval.

Milked-out lactation yields averaged 563 kg and varied markedly between years. Annual milked-out yields averaged 457 kg. There was a positive association between lactation yield and lactation length, and between lactation yield and rainfall during the lactating period. Milk yields peaked at the 4-5th lactation, i.e. at about 9 years of age, and yield increased by 15 % from first to peak lactation. The Maure and the Maure x Peul were 15 % superior to the Peul in daily and annual milked-out yields, and repeatabilities of all yield measures were about 0.50. Approximately the same amount of milk was utilised by the calf as was milked-out. The Maure and Maure x Peul were 13 % superior to the Peul in annual total milk yield.

Butterfat measurements on 162 completed lactations in 1970-72 showed a fat level of 4.7 %, with no breed differences detected.

Mortality figures showed a 10 % abortion rate, and 26 % mortality to 3 years of all calves born. Disease was the largest single influence on mortality rates. No significant breed differences were found. A cow needed 2.8 calvings to produce a heifer that reached lactation in the herd, thus 56 % of females born were required as herd replacements ; and the generation interval was 7.2 years. The average cow production life was 6.4 years, giving a cow turnover rate of 15.6 %.

Growth rates showed a mean daily gain of 0.26 kg from birth to 30 months of age. Body weights at all stages increased by about 7.5 % per year. As the expected genetic gain was 1.3 % per year, this represented 17 % of the annual improvement achieved. Breed differences, detected only at the pre-weaning stages, suggested that Maure and Maure x Peul dams provided a 7 % superior maternal environment as compared with Peul dams. Heritabilities of 0.46 and 0.42 for 12- and 18-month weights suggest that body weight increases of 2 kg per year could be achieved through selection programmes at these ages. All breed types had low mature cow body weights, averaging 317 kg.

Three linear measurements -heart girth, height at withers, and scapulo-ischial length- were analysed and evaluated as estimators of body weights. Heart girth was found to be the most satisfactory, with mean deviations of 11 kg at 12 months and 14 kg at 24 months. These results suggested that for purposes such as selection, estimation of body weight from heart girth is no substitute for weighing.

Cow productivity estimates, combining the important traits of reproductive performance, milk production, pre-weaning calf growth, and cow and calf mortality, indicated that the average cow each year produced 418 kg milk ; 0.68 of a weaner calf weighing 54.5 kg ; and 47.4 kg of its own final live weight. In its 10-year lifetime, including 6.5 years in the milking herd, each cow produced 2717 kg milk ; 4.4 weaner calves weighing 354 kg ; and 308 kg of disposable cow body weight. The Maure proved 13 % superior to the Peul in cow productivity, and the Maure x Peul 2 % superior to the Maure.

An example is given of an attempt to compare results at Niono with those produced at other research stations in similar areas of Africa. Information has been built up on aspects of productivity of indigenous cattle at stations in various climatic zones, employing known grazing and supplementary feeding regimes. Initial results available have pinpointed many gaps in individual trait values that must be filled before productivity comparisons can be carried out, based on output of meat and milk per unit weight of cow per year.

PART 1

ORIGIN AND ANALYSIS OF DATA

Chapter 1

THE ANIMAL PRODUCTION SYSTEM AT NIONO, 1966–1975

1.1 Introduction

For ten years, 1966-1975, the Station d'Elevage et de Recherches Zootechniques du Sahel, à Niono (the Sahelian Station at Niono) maintained substantial herds of two indigenous breeds of Zebu cattle, the Maure and Peul, together with their crosses.

Figure 1. Geographical position of Niono.

The animals were kept for milk and meat production and for draught purposes. They were subject to improved management practices such as controlled breeding, supplementary feeding and veterinary care. Information was collected on traits relating to reproductive performance, milk production, body weight and mortality.

Figure 1 indicates the geographical position of Niono.

1.2 The Sahelian Station

The Sahelian station is composed of two distinct parts, the original "Sahel Station" and the "Niono Ranch", as indicated in Figure 2. The station is about 4 km north-east of Niono, covering an area of 750 ha. The western boundary of the ranch lies a further 10 km distant, and the ranch covers a total area of 11,000 ha.

Niono, situated at a height of 277 m, has a dry tropical climate characterised by a single wet season lasting four months, from June to September. Table 1 shows the monthly rainfall from 1966 to 1976.

Table 1. Monthly rainfall at Niono from 1966-1976 (mm)

Month	Year											
	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	Mean
January	-	-	-	-	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-	-	-	-	-
March	-	7	-	-	-	-	1	-	-	4	-	1
April	-	1	24	2	3	1	29	-	-	2	-	6
May	12	4	2	17	20	20	2	2	24	59	24	17
June	37	27	83	68	11	146	95	23	99	79	101	70
July	65	171	132	111	230	188	81	151	105	154	115	137
August	154	281	156	153	252	194	178	117	112	198	204	182
September	122	150	70	120	115	72	65	22	35	63	94	84
October	4	-	20	63	16	-	4	4	8	6	93	20
November	-	-	-	-	-	-	-	-	-	3	-	-
December	-	-	-	-	-	-	-	-	-	-	-	-
Total	394	641	487	534	647	620	455	318	383	568	631	516

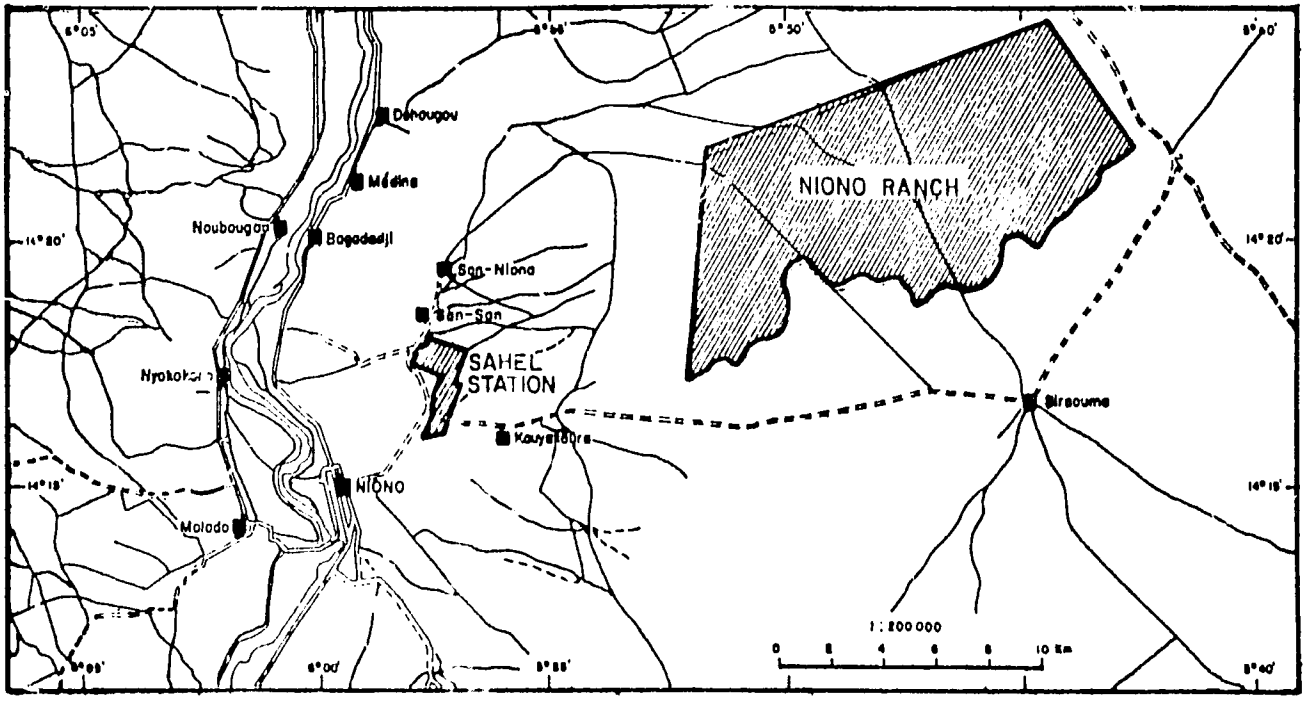

Figure 2. The Sahelian Station and Niono Ranch.

Temperature, evaporation, and sunshine data are available only from 1972, and data on these together with the number of days of rainfall for 1972 - 1975 are presented in Table 2.

Table 2. Monthly climatic data at Niono from 1972 - 1975.

Month	Temperature °C		Evaporation mm.	No. of hours sunshine	No. of days rainfall
	Mean min.	Mean max.			
January	12.2	30.0	243	286	-
February	14.6	33.5	265	272	-
March	18.8	35.5	345	266	.5
April	22.7	38.5	327	259	1.3
May	25.9	38.9	295	251	2.8
June	25.1	35.8	219	257	6.2
July	23.8	34.0	138	232	9.8
August	22.9	31.6	82	246	11.0
September	23.2	32.6	86	250	6.0
October	22.3	34.3	146	273	2.2
November	17.4	32.7	199	263	.2
December	14.1	32.1	210	290	-
Total/mean	20.3	34.1	2555	3145	40

Several detailed studies on vegetation types have been carried out in this area, e.g., Boudet and Leclerq (1970). These authors state that in the Niono region the vegetation reflects the overlapping of the Sahelian and Sudanian ecological zones with both steppe and savanna vegetation types. From south-east to north-west there is a sequence of vegetation types linked to flooding in the active delta, the bushlands in the inactive delta, the "Brousse tigrée", and finally the sand dune vegetation.

PLATE 1. Dry season vegetation in the Niono region.

PLATE 2. Peul work oxen.

Other authors (Togola, Cisse and Breman, 1974) have studied vegetation changes on the ranch from 1969 to 1974. Their comparison of the status of vegetation over this period indicates that four years of drought are responsible for the desert moving 70 to 100 km to the south in certain areas without any important human influence.

The operation of the work of the Niono station is carried out by four technical sections. The genetics and breeding section is responsible for genetic improvement and general livestock research. It records biometrical data and determines herd management. The nutrition and biochemistry section is responsible for nutrition and feeding studies and butterfat analysis. Research to date has been practical and oriented towards a better knowledge of tropical feeds and their use for meat and milk production. Many results have been published on the use of agro-industrial by-products. The veterinary section is responsible for the health of the herd. No programme of research in pathology has been started due to lack of finance and skilled personnel. The agrostology - agriculture section is responsible for studies on the natural rangelands and research on forage crops. Samples of local plants are grown and results have been obtained on the behaviour and utilization of some leguminous plants and graminaceae under normal and irrigated management.

1.3 Cattle

The two indigenous breeds maintained at Niono were the Maure and the Peul. Both are West African Zebu types : the Maure is classified as a short-horned subgroup of the Sahelian zebus, the Peul as a short-to medium-horned Sudanian subgroup. Little is known about their comparative performance. However Doutressoulle (1947), Joshi et al. (1957), Payne (1970) and IEMVT (1973) suggest that they are similar for most productive characters, although the Maure has a rather higher milk production than the Peul.

PLATE 3. Peel sire.

PLATE 4. Maure sire.

In 1963, a foundation herd of 150 cows and 2 bulls (1 Maure and 1 Peul) was established by purchasing animals from markets in the vicinity of Niono. The majority of replacements of both sexes were then produced from within the herd. The breeding objectives involved a programme of selection for productive traits within the two pure breeds. From the start, however, problems associated with the control of Peul bulls resulted in many Peul females being mated to Maure bulls, thus making a considerable number of Maure x Peul crosses available for evaluation.

1.4 Management Practices

1.4.1. Herd management

Figure 3 presents the summary of the general herd management scheme. In the breeding herds, a bull is run with each cow group during the day, with a 10-day gap between bull changes to allow accurate sire progeny records to be maintained. Cows to be mated to Maure and Peul sires are run in separate herds. At approximately the 7-month stage of gestation, cows are moved to the pregnant cow herd, where additional supplementation is provided.

Hand milking commences approximately 2 weeks after calving. The calf initiates milk let-down and is then tied to the cow's foreleg. After hand milking is completed, the calf is suckled. After weaning at 6 - 7 months, calves continue to initiate milk let-down. Cows are milked out twice daily (deviations from this are referred to in Chapter 2) and are not artificially dried off, but continue to be milked until naturally dry.

From birth to weaning, calves are maintained in calf pens, suckled twice daily, and supplied with supplementary feed and forage. From weaning to one year of age, calves are herded together for grazing during the day and penned at night. At one year they are separated by sex and sent to the heifer and bull-calf herds, where they remain for a further year. At this stage, on the basis of weight, appearance, and health, the best heifers are moved into the breeding herd.

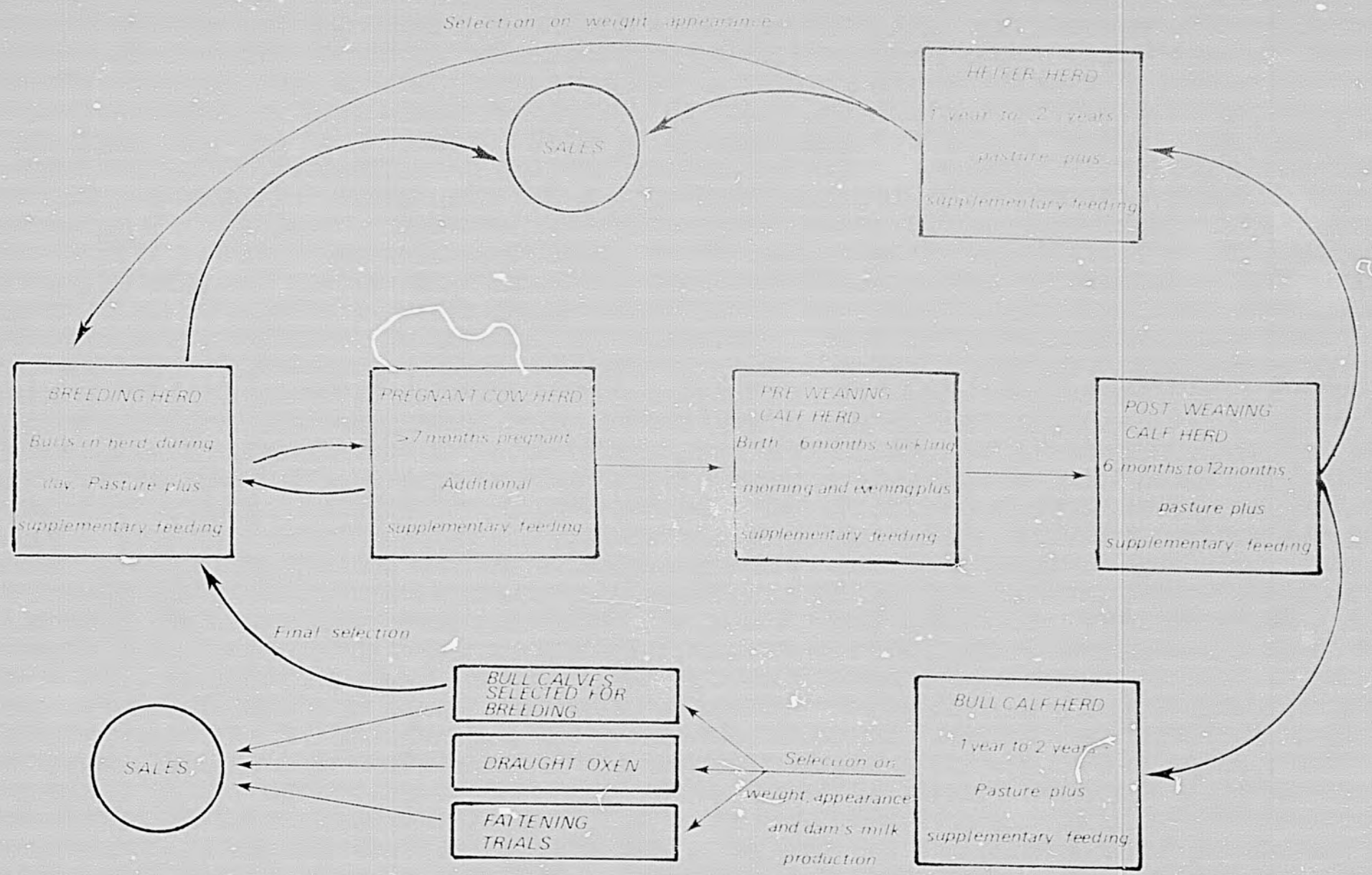

Figure 3. General herd scheme.

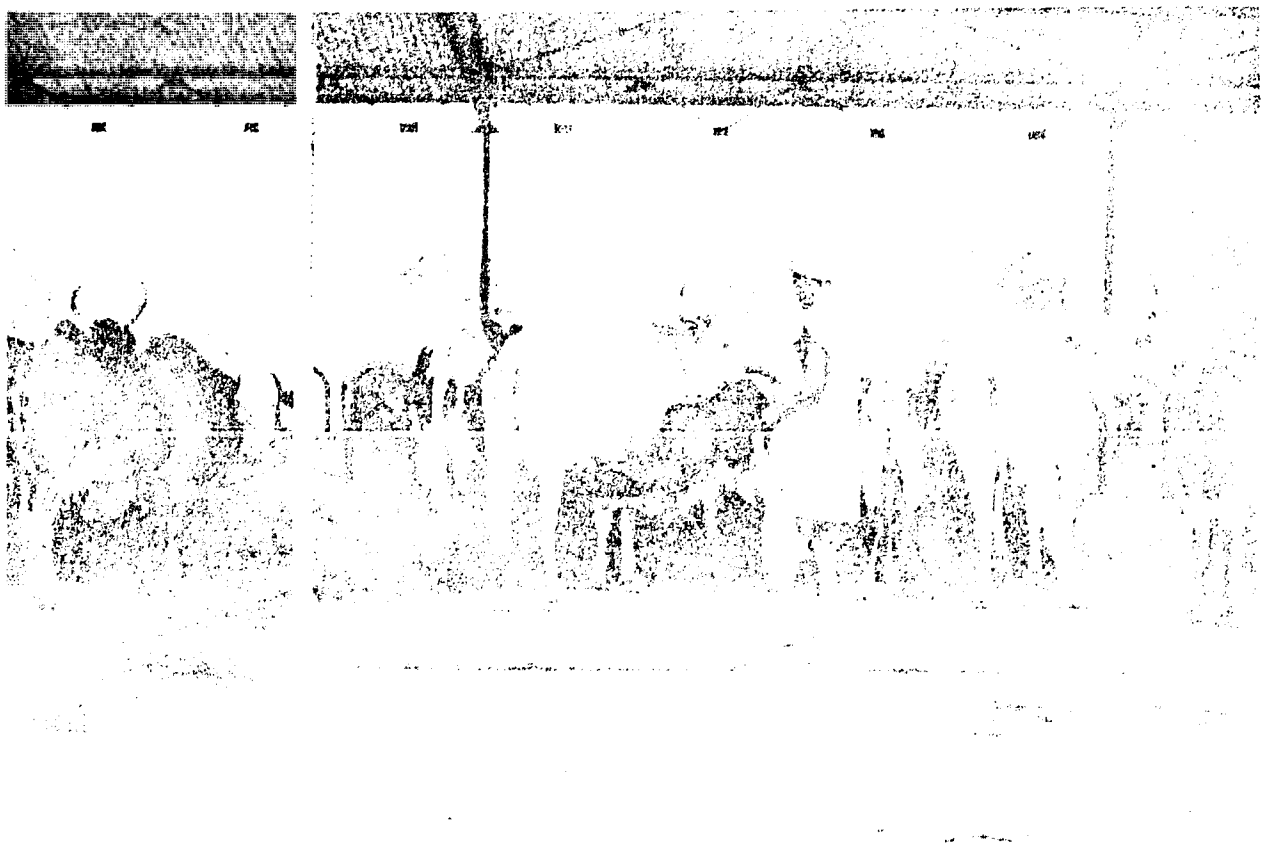

PLATE 5. Calf inducing milk let-down.

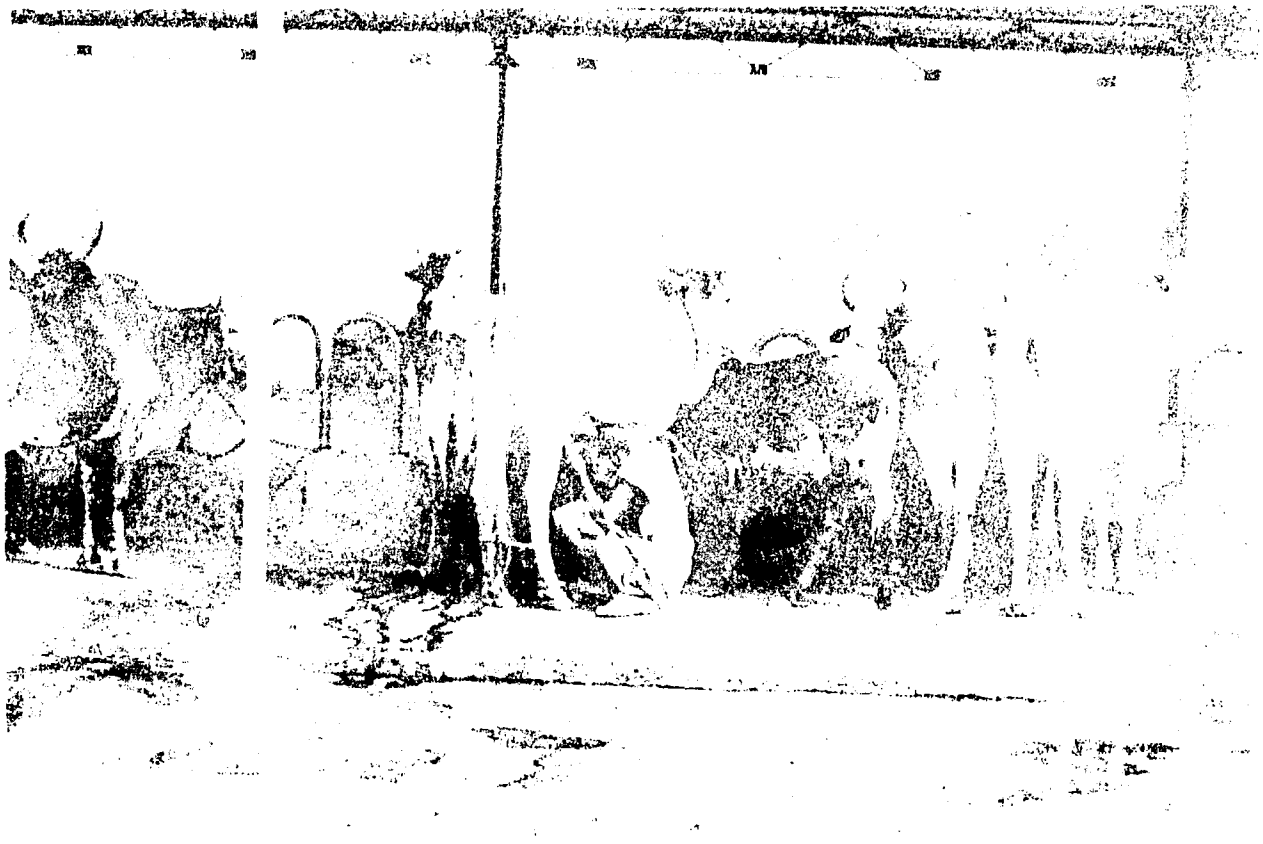

PLATE 6. Calf tied to cow's foreleg during hand milking.

PLATE 8. Preweaning calf pen.

The breeding bulls, both for Niono herd replacements and for sale (approximately 10 % of the herd), are selected at an annual meeting of specialists, who decide on the basis of the animal's growth, appearance, and dam's milking ability. The remainder of the males are castrated and go for draught oxen or for fattening.

Culling can take place at any time in the overall scheme, while the bulk of sales are made from the heifers, bull calves for breeding, draught oxen, and fattening and breeding herds.

1.4.2. Supplementary feeding

An outline of the broad supplementary feeding picture is presented in Table 3.

Table 3. Supplementary feeding system (daily).

Class of stock	Period of year			
	January-March	April-June	July-September	October-December
General situation for all classes of stock	Paddy fields can be grazed by animals	Critical period of year, grazing very limited	Grazing in good condition	Grazing reasonable, by-products available after harvest
Milking cows	Concentrates 2 kg Salt	Concentrates 2 kg Silage 5 kg Salt	Concentrates 2 kg Salt	Concentrates 2 kg Green forage or sugar cane 5 - 10 kg, salt
Pre-weaning calves	Concentrates 1 kg	Concentrates 1 kg	Concentrates 1 kg	Concentrates 1 kg
Post-weaning onward	Concentrates 2 kg	Concentrates 2 kg	Concentrates 1 kg	Concentrates 2 kg

It is appreciated that over the years from 1966, many problems of feed availability, transport, machinery, etc. have resulted in major deviations from this general pattern.

The four rather distinct quarters of the year, as far as natural pasture availability is concerned, are indicated in Table 3, where July to September is the most favourable time of year and April to June the critical period.

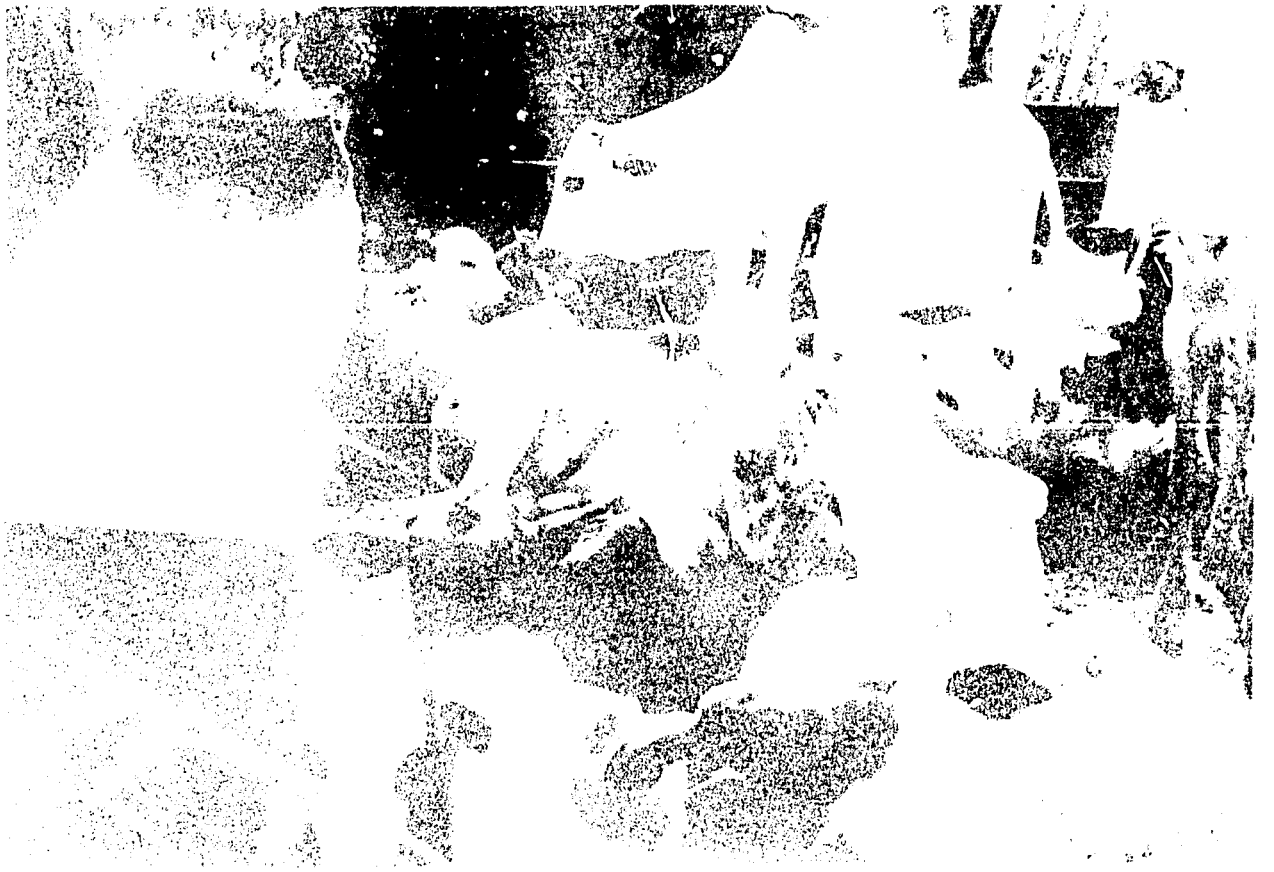

PLATE 9. Supplementation of young stock with cotton seed.

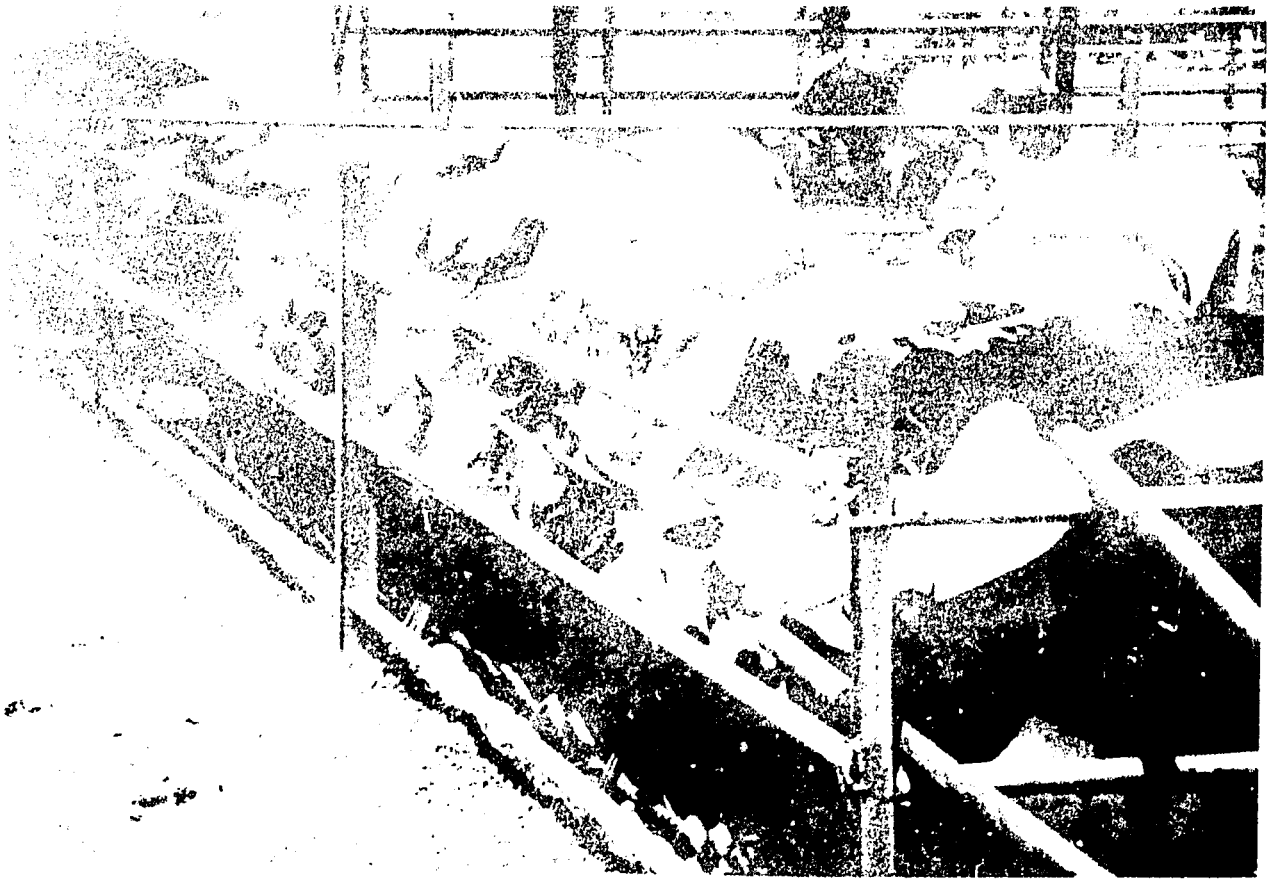

PLATE 10. Fattening trial.

For milking cows, the concentrate used until 1971 consisted of a sorghum, maize, oilcake, mineral mix, while from 1972 onward, this has basically been replaced by cotton seed. In general, milking cows at all stages receive approximately the same amount of concentrate. For pre-weaning calves, the concentrate was generally a sorghum, maize, oilcake, bloodmeal, mineral mix. For post-weaning calves, the concentrate was either similar to the pre-weaning mix, or a cotton seed and rice meal mixture.

1.4.3. Animal health programme

Routine vaccinations against rinderpest, pleuropneumonia, pasteurellosis, and blackleg take place twice a year. From 1966 onward, external parasites have been treated as required with a commercial preparation. The programme of control of internal parasites involves twice-yearly treatment with a product such as phenothiazine. Additionally, dosage against liver fluke takes place after each wet season.

Routine veterinary assistance is fairly readily available, and over part of the period, post-mortem records have been maintained.

1.5 Data Recording Procedures

The general recording procedures used are described here, while the problems of selection of accurate,unbiased data for analysis are discussed in Chapter 2.

Genealogical records : At birth the date, sire and dam numbers, breed, coat colour, sex, and weight of each calf are recorded. Calves are identified by their dam's number until weaning, after which they receive their own number, which remains with them for life.

Service records : A service record book is maintained, but the proportion of observed services is low.

Weight records : Calves are weighed weekly from birth to approximately one year, then monthly to approximately 30 months of age.

Linear measurements : Linear measurements are recorded weekly from birth to approximately one year, then monthly to approximately 30 months of age. The measurements taken are head length and width ; rump length and width ; height at withers ; height at chest ; height at rump ; scapulo-ischial

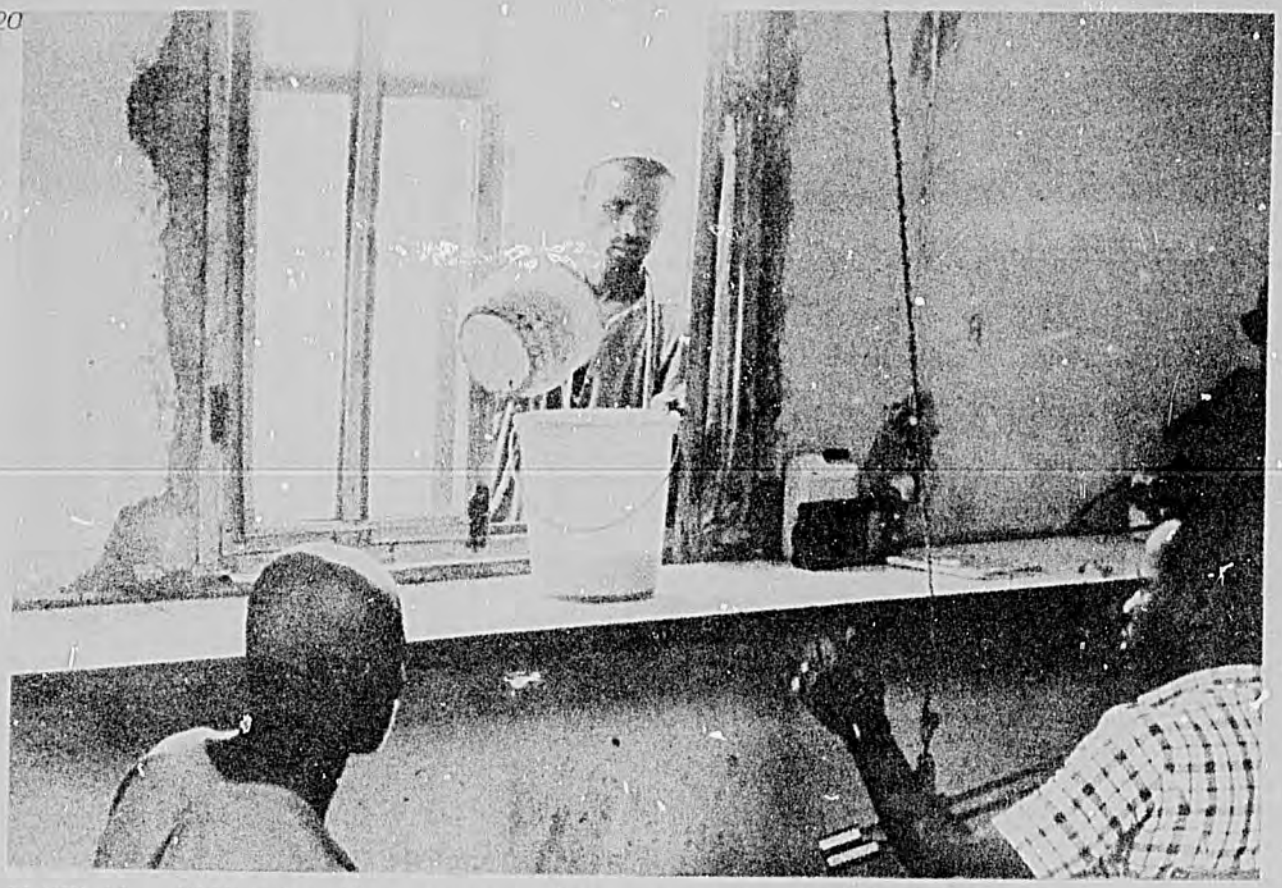

PLATE 11. Milk recording - cow number reported and milk delivered.

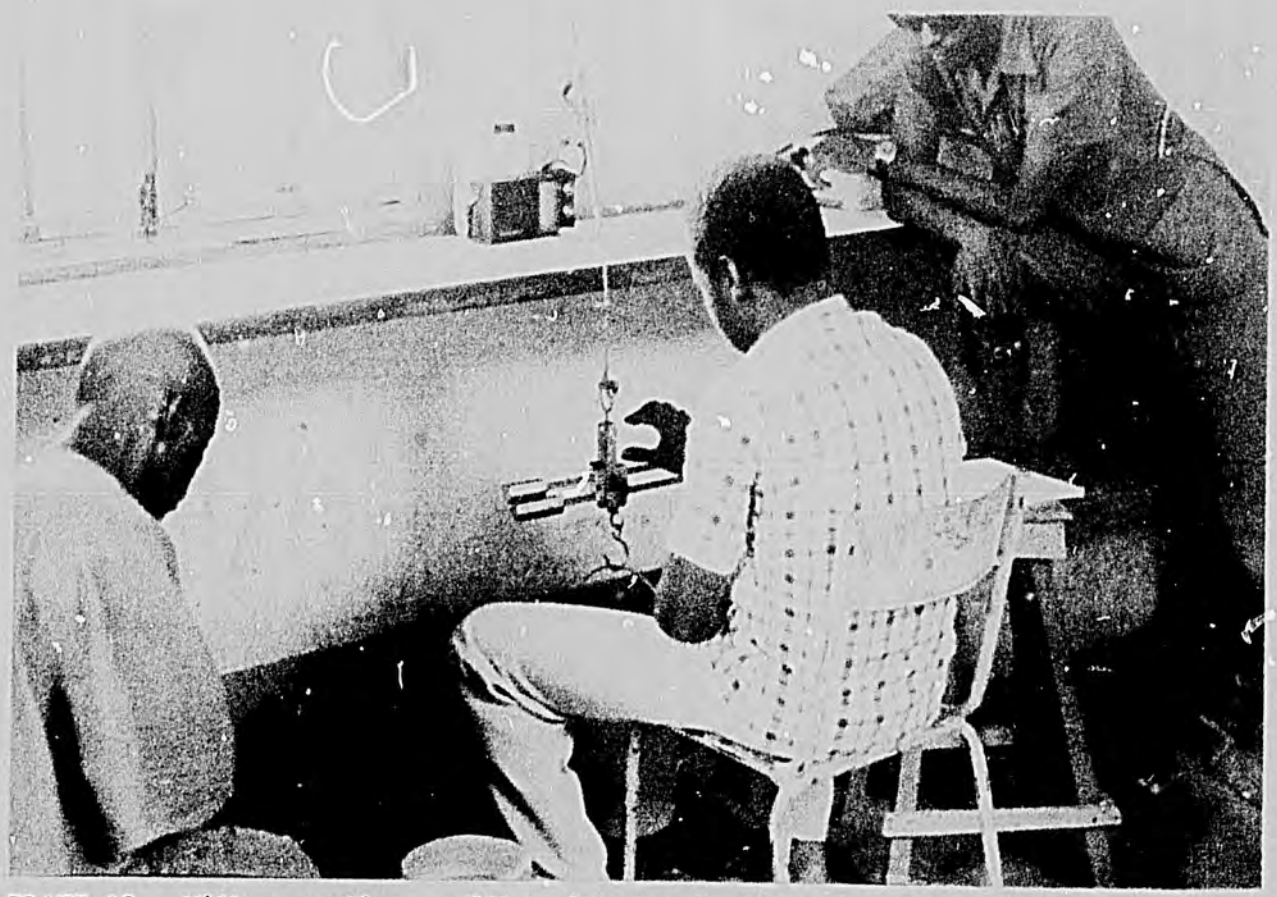

PLATE 12. Milk recording - milk weighed and recorded.

PLATE 13. Supplementation of milking cows.

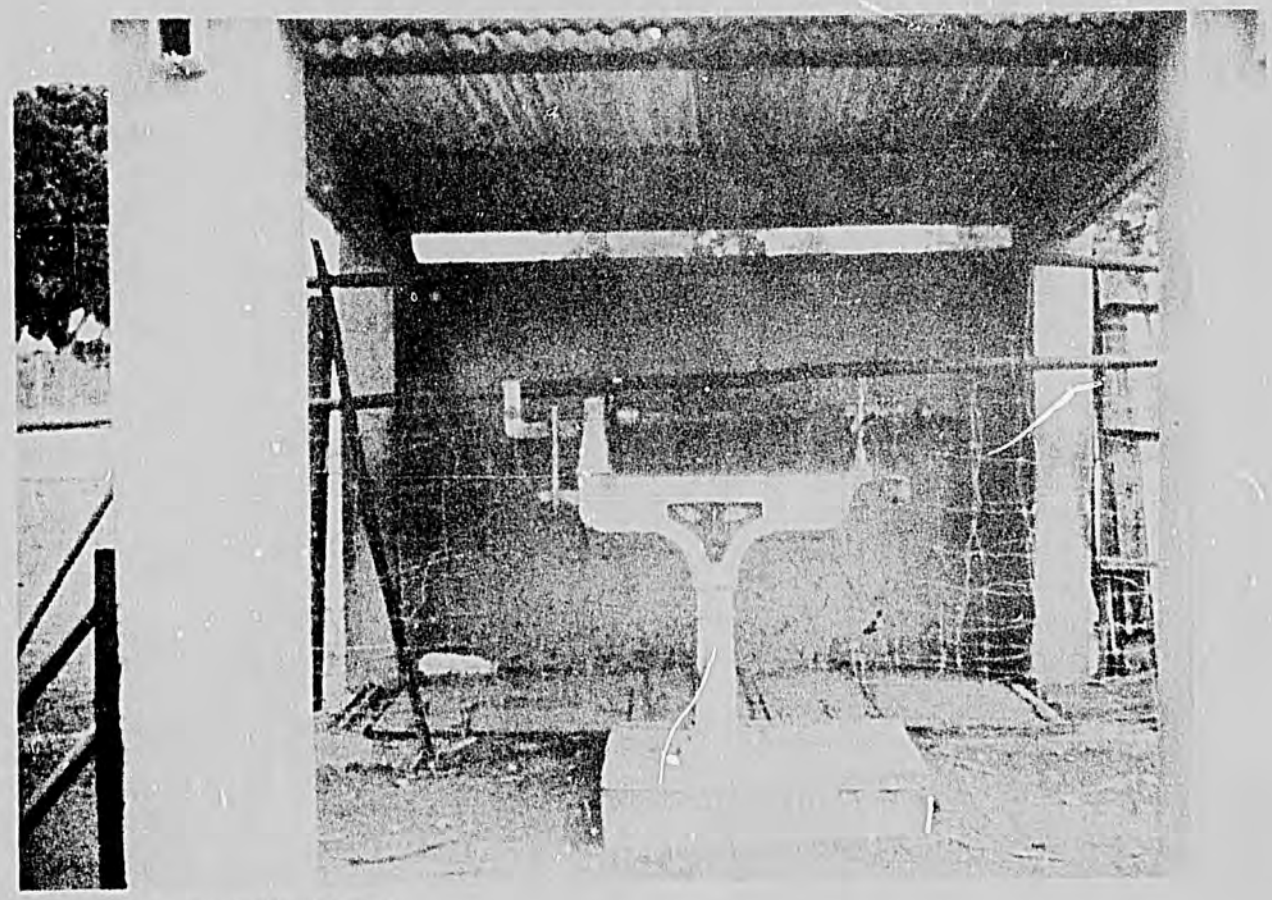

PLATE 14. Weighbridge.

length ; thoracic girth, and cannon bone girth.

Milk production records : From 1966 to 1971 all individual cow milked-out yields were recorded morning and evening. However, for a period of about one year milking was carried out only once per day, either morning or evening. From 1971 to 1973, yields were recorded morning and evening on one day, every two weeks. From 1974, individual daily yields were recorded again, but apparently only for selected cows ; while those cows that proved positive to a brucellosis test were transferred to the ranch, where milk recording facilities were not available.

Milk quality records : In theory, butterfat testing was carried out every two weeks, but the results were extremely fragmentary, due to recurring problems with laboratory supplies and equipment.

Supplementary feeding records : Produced monthly, thrice-monthly and annually, these records indicate the quantities of feeds distributed monthly to the different categories of animals.

Veterinary records : Vaccination records indicate the dates of all routine vaccinations ; treatment records note the individual treatment of each sick animal ; while post-mortem records from 1971 describe the post-mortem observations.

Climatic records : Daily rainfall was recorded over the whole period, while maximum and minimum temperatures, evaporation, and hours of sunshine are available from 1972 onward.

PLATE 15. Herd leaving for pasture after supplementation.

PLATE 16. Supplementation of dry cows.

PLATE 18. Watering facilities in the Niono region.

Chapter 2

PREPARATION OF DATA FOR ANALYSES

Reproductive performance : Individual records were built up for each cow, giving date of birth ; sire number ; sire breed ; dam number ; dam breed ; date of each calving ; sire number and sire breed for each calf ; and date when each milked-out lactation finished. On this record the age at first calving, length of each lactation, length of each calving interval, and length of each dry period were then calculated.

In the early years many cows were purchased, and birth dates were not available. Thus only 200 out of 404 cows had both birth and first calving dates, to allow age at first calving to be calculated. At least two separate calving dates per cow are required for calculation of calving interval, and 808 calving intervals were available from 1217 calving dates. Dates of abortions were not used in calculation of calving intervals. The calving intervals actually used in analyses were those that could be related to lactation milk yields and lengths, in order that the corresponding dry period lengths could be calculated.

Milked-out yield : Individual milked-out lactation records were built up from morning and evening yields covering 1966 to 1971, and from sampling at two-week intervals from 1971-1974. Five hundred and twenty-six lactations were available, 43 % built up from daily records, 57 % from bi-weekly records. All lactations accurately recorded were used, irrespective of length. Lactations not used were those that showed unexplained gaps in milk recording of over 2 months, early dead calves, cow sickness or death, periods where data were selected (e.g. from 1974 onward, when not all of the cows were recorded), and periods when some cows were maintained on the ranch.

Milked-out yield per day of lactation was calculated by dividing lactation yield by the corresponding lactation length in days. Annual yield was determined by dividing lactation yield by calving interval in days, multiplied by 365.

Calf-utilised and total yield : Total milk yield includes the quantity utilised by the calf. At Niono, calves were virtually dependent on milk for growth from birth to 3 months, and partially dependant on it for growth from 3 months to weaning which took place at approximately 6 months. Following the conversion factors discussed by Drewry, Brown, and Honea (1959), it was assumed that from birth to 3 months, 11.65 kg of milk are required for each kg of calf gain, while from 3 months to 6 months 8.55 kg are required. Thus these conversion factors were used on individual calf growth from birth to 3 months and 3 to 6 months, to estimate the calf-utilised yields over these periods. Four hundred and eighteen of the 526 milked-out records had data on calf gains over these periods, and these were used in analysis of calf-utilised and total milk yield.

Milk Composition : As noted in Section 1.5., many problems occurred in the measurement of butterfat, mainly associated with laboratory supplies and equipment. Butterfat was routinely measured at two-week intervals, but only 162 lactations had complete butterfat records. These were all used in the analysis.

Viability : Mortalities were grouped into 7 categories by year of birth and breed type. The categories were : abortion ; stillbirth and death on first day after birth ; pre-weaning, 1 day to 6 months ; post-weaning, 6 months to 1 year ; 1 year to 2 years ; heifers, 2 years to 3 years ; and adult cows. All available causes of death were obtained from monthly reports, treatment records, and autopsy records (from 1971 onward).

Body weights : Continuous weekly or monthly weight records were available from 1969 onward ; thus, records on all calves born from October 1968 onward were used. No data were available after September 1974 : on the basis of a brucellosis test, it was decided at that time to move animals to the ranch, where no weighbridge was available. Weights on 591 animals from birth to 6 months, 372 from birth to 18 months, and 243 from birth to 30 months were obtained, and these three groups were analysed separately.

Individual animal weights at 3, 6, 12, 18, 24 and 30 months were calculated from the weekly or monthly weights recorded immediately prior to and immediately after the date on which the animal reached that age, the actual weight for age being obtained by addition or subtraction of the number of days of live weight gain under or over measured.

Linear measurements : Linear measurements were carried out from 1969 onward. However, as the relationship between linear measurements and body weight appeared to be of much greater importance than linear measurements per se, only animals with both linear measurements and body weights to 24 months of age were considered.

Only 182 animals were available with complete records at the birth, 6-, 12-, and 24-month stages. The three most important linear measurements, i.e. height at withers, scapulo-ischial length, and heart girth, were evaluated.

Sire distribution for genetic analyses : Table 4 shows the monthly distribution of progeny births from each individual sire, from 1968 to 1974.

Table 4. Distribution of progeny births from 16 sires.

Sire	Year of birth of progeny						
	1968	1969	1970	1971	1972	1973	1974
Moussiko	++++++	++++++	++++++	++++++	++++++	++++++	++++++
Sonni	++++++						
Krémos		++++++	++++++	++++++			
Kogoni			++++++	++++++	++++++		++++++
289340		++++++					
Apollo				++++++	++++++	++++++	
Macina			++++++	++++++			
Sahel				++++++	++++++	++++++	++++++
Molodo				++++++			
Gueladjo					++++++	++++++	++++++
Samory						++++++	
Ambiance						++++++	++++++
1094						++++++	
Fama							++++++
Bablé							++++++
1107							++++++

Chapter 3

METHODS OF DATA ANALYSES

The choice of analytical methods used to determine environmental and genetic parameters depends on the data, the resources available and the preferences of the statistician. In the present work some environmental parameters were measured for further study in their own right and some were measured to account for variation arising from environmental factors in order that less biassed estimates of genetic parameters could be obtained. Unequal and disproportionate subclass numbers gave unbalanced factorial designs, for which conventional analyses of variance techniques were not applicable.

The basis used for analyses of those data having unequal and disproportionate subclass numbers was the method of fitting constants (least squares analysis) (Harvey, 1960). Application of this method to the different data layouts required that appropriate mathematical models be formulated in each case. Models used were linear, additive models that provided for estimation of the effects of several levels of different environmental and genetic factors on the variables being studied. The size of matrix that could be handled precluded accounting for individual interactions, these being summed into a pooled interaction term.

An outline of the steps that were carried out in the analysis of a trait, illustrating the type of models employed in the study and using body weight at a particular age as an example, is as follows.

<u>Step 1.</u> Least squares analyses were carried out, constants being fitted for year of birth, month of birth, sex, dam parturition number, breed type, and the sum of squares associated with each of the sources of variation calculated. Thus the model evaluated was :

$$Y_{ijklmn} = Mu + A_i + B_j + C_k + D_l + F_m + E_{ijklmn}$$

Where Y_{ijklmn} = the i j k l m n - th animal's record

Mu = the effect common to all animals

A_i = the effect of the i - th year of birth

B_j = the effect of the j - th month of birth

C_k = the effect of the k - th sex

D_l = the effect of the l - th parturition number of dam

F_m = the effect of the m - th breed type

E_{ijklmn} = the effect peculiar to the i j k l m n - th animal.

Pooled interaction sum of squares was obtained as the difference between the total reduction due to fitting all constants including Mu, and the five-way subclass sum of squares of uncorrected data. Residual sum of squares was obtained as the difference between the five-way subclass sum of squares of uncorrected data and the total sum of individual squared trait values. At this stage, environmental and breed effects and their significance were evaluated. Duncan's multiple range test (Duncan, 1955) was used to test the significance of differences between subclasses.

Step 2. The constants obtained for the environmental effects of year, month, sex, and parturition number were used to adjust the data. Within each breed of sire group, least squares analysis was carried out, constants being fitted for breed of dam, sire, and breed of dam by sire interaction. The model evaluated was :

$$Y_{ijk} = Mu + A_i + B_j + (AB)_{ij} + E_{ijk}$$

Where Y_{ijk} = the i j k - th animal's record

Mu = the effect common to all animals

A_i = the effect of the i - th breed of dam

B_j = the effect of the j - th sire

$(AB)_{ij}$ = the effect due to the interaction of the i - th breed of dam with j - th sire

E_{ijk} = the effect peculiar to the i j k - th animal.

Step 3. In determination of heritability estimates and genetic, phenotypic, and environmental correlations between traits, the constants obtained in Step 2 for breed of dam and breed of dam by sire interaction were used to adjust the data within breed of sire groups. Analyses of variance and co-variance were carried out within these groups, the within-breed of sire variance and covariance being separated into the between-sire variance and covariance and the within-sire variance and covariance. Results were then pooled over breed of sire groups by summing degrees of freedom, sums of squares, and sums of products.

The components of variance for between-sire (S_i and S_{ij}) and within-sire progeny groups (W_i and W_{ij}) were calculated from the pooled analyses of variance and covariance, e.g.

$S_i = (\sigma_b^2 - \sigma_w^2)/n_o$ and $W_i = \sigma_w^2$, where σ_b^2 is the mean square between sires, σ_w^2 the mean square within sires, and n_o the average number of progeny per sire.

Assuming a relationship of 0.25 among members of a sire group, the necessary variance and covariance components were :

Additive genetic variance $(A_i) = 4\ S_i$

Phenotypic variance $(P_i) = W_i + S_i$

Environmental variance $(E_i) = W_i - 3\ S_i$

The corresponding covariances were : $A_{ij} = 4\ S_{ij}$; $P_{ij} = W_{ij} + S_{ij}$; and $E_{ij} = W_{ij} - 3\ S_{ij}$.

The heritabilities and genetic, phenotypic, and environmental correlations were calculated from these as :

Heritability = A_i/P_i

Genetic correlation = $A_{ij} / \sqrt{(A_i \cdot A_j)}$

Phenotypic correlation = $P_{ij} / \sqrt{(P_i \cdot P_j)}$

Environmental correlation = $E_{ij} / \sqrt{(E_i \cdot E_j)}$

The standard errors of heritability estimates were obtained using the simplified formula of Robertson (1959).

$SE_{h^2} = (h^2 + \frac{4}{n_o}) \sqrt{\frac{2}{N}}$, where n_o is the average number of progeny per sire and N is the number of sires.

Some or all of these general steps were followed in the analyses of the various traits examined in this study.

In all analyses of variance tables, * and ** indicate significance at $P < 0.05$ and $P < 0.01$ respectively. In all tables, within-class row means followed by the same letters (a, b, etc.) do not differ significantly ($P < 0.05$) In some analyses, linear regressions have been used, not to predict parameters but to illustrate their trends over the periods studied.

PART 2

RESULTS

Chapter 4

REPRODUCTIVE PERFORMANCE

4.1 Introduction

Reproductive performance is the trait of outstanding importance in both beef and dairy cattle enterprises. In a beef cattle operation, if there is no calf, then there is no economic return. In a dairy operation the size of the calf crop is all-important for herd replacements, and the production of milk depends heavily on reproductive activity. In both types of enterprise, possible genetic improvement in virtually all traits of economic importance is closely tied to reproductive rate.

Differences in breeding efficiency are largely due to environment, although between breeds heredity plays some part in the variation of reproductive performance. Within breeds, however, heredity plays only a minor role in affecting variations in reproductive ability. The best cows are clearly those that have their first calf at an early age, have minimum calving intervals, and live a long time. Thus the most important measures of reproductive performance in the female are : age at first calving, length of calving interval, and length of cow productive life.

4.2 Age at first calving

4.2.1. Environmental and breed effects

The mean age at first calving was 43.04 ± 2.05 months, with a coefficient of variation of 15.5 %.

The analysis of variance given in Table 5 shows year of birth to have been the only significant effect on age at first calving.

Table 5. Analysis of variance of age at first calving.

Source	d.f.	Mean square
Year of birth	7	973**
Month of birth	5	38
Breed	4	29
Pooled interactions	86	47
Within subclasses	97	44

The estimated least squares means in Table 6 show that age at first calving ranged from 58.25 months for animals born in 1966 to 34.40 months for those born in 1973.

Table 6. Estimated least squares means for age at first calving.

Variable	No.	Mean age (months)
Overall mean	200	43.04
Year of birth		
1966	19	58.25 a
1967	22	51.16 b
1968	11	36.74 cd
1969	14	41.93 e
1970	24	41.85 e
1971	44	41.26 e
1972	44	38.73 de
1973	22	34.40 c
Month of birth		
January - February	50	44.00
March - April	26	43.26
May - June	22	43.24
July - August	15	42.28
September - October	37	43.95
November - December	50	41.51
Breed		
Maure	71	42.32
Peul	19	44.78
Maure x Peul	58	43.28
3/4 Maure	23	42.90
3/4 Peul	29	41.92

Causes of variation between years, in this environment and under this system, can basically fall into three main categories. Firstly, differences in annual rainfall affecting the pasture availability each year and this directly influencing animal performance ; secondly, differences resulting from changing and improving management techniques ; and thirdly, differences resulting from genetic improvement. The year means in Table 6 indicate an apparent reduction in age at first calving from early to later years.

To determine any linear trend in age at first calving from 1966 to 1973, the regressions of the least squares constants on year of birth (represented as 1 to 8) were calculated. The regression of age at first calving on years was - 2.57 months, significant at the 1 % level and indicating that age at first calving has decreased by 2.57 months per year over the 8-year period.

There was no evidence of any breed differences in age at first calving between the Maure and Peul breeds or their F_1 or backcross generations.

4.2.2. Genetic estimates

Complete sire and dam records were available for 155 females whose ages at first calving were known. The constants for year and month of birth were used to adjust the data within sire and dam breed groups, leaving only the variation between and within sires. The between- and within-sire components of variance were calculated within these breed groups and summed overall. Seventeen separate sire progeny groups with an average of 8.8 progeny each were available, representing 10 individual sires.

Table 7. Genetic estimates of age at first calving (days).

Statistic	Value
Between-sire d.f.	12
Within-sire d.f.	140
Between-sire components of variance	301
Within-sire components of variance	38,605
Standard deviation (σ_p)	197
Heritability (h^2)	0.03
Standard error h^2	0.12
Intensity of selection (i)	0.34
Expected genetic gain per generation ($i.\sigma p.h^2$)	2.0

Table 7 shows the genetic parameters. The heritability, estimated by the paternal half sib method was 0.03, not significantly different from zero. This low heritability, usually found for this parameter, coupled with the extremely low intensity of selection possible, due primarily to the rather high mortality rates discussed in Chapter 7, resulted in an expected genetic reduction in age at first calving, through selection, of only two days per generation.

4.3 Calving interval, length of lactation, and length of dry period

The calving interval is the period between two consecutive calvings, and can be subdivided into the lactating period and the dry period. The means, standard errors, and coefficients of variation for these three traits are laid out in Table 8. The percentage of the calving interval spent in lactation was 54 %.

Table 8. Mean values for calving interval, length of lactation, and length of dry period (days).

Trait	Mean length	SE	CV %
Calving interval	468	25	27
Length of lactation	254	16	31
Length of dry period	214	27	63

4.3.1. Environmental and breed effects

Analyses of variance, laid out in Table 9, show year of calving to have been the only significant effect on calving interval, while year and month of calving significantly affected length of lactation. There were no significant effects on length of dry period.

Table 9. Analyses of variance of calving interval, length of lactation, and length of dry period.

Source	d.f.	Mean squares x 10^{-2}		
		Calving interval	Length of lactation	Length of dry period
Year of calving	7	509**	183*	322
Month of calving	5	123	300**	85
Breed	2	43	43	80
Parturition number	3	262	41	193
Pooled interactions	197	153	67	149
Within subclasses	311	158	62	183

The estimated least squares means for years in Table 10 show that calving interval ranged from 561 to 423 days. Similarly the maximum length of lactation was 297 days, the minimum 226.

Table 10. Estimated least squares means for calving interval, length of lactation and length of dry period (days).

Variable	No.	Calving interval	Length of lactation	Length of dry period
Overall mean	526	468	254	214
Year of calving				
1966	27	561 a	297 a	271
1967	32	459 b	228 b	232
1968	25	472 b	277 ac	192
1969	48	457 b	226 b	231
1970	80	455 b	261 dc	194
1971	107	454 b	256 bcd	195
1972	94	462 b	246 bd	218
1973	113	423 b	240 bd	177
Month of calving				
January - February	108	480	278 a	202
March - April	72	479	260 ab	221
May - June	64	477	263 ab	214
July - August	51	462	258 ab	196
September - October	36	448	223 bc	226
November - December	145	461	241 bc	222
Breed				
Maure	225	470	249	222
Peul	216	474	258	216
Maure x Peul	85	460	255	203
Parturition number				
1	98	490	261	231
2 - 3	198	477	257	221
4 - 5	143	453	255	194
6 +	87	453	243	209

To determine any linear trend in calving interval and length of lactation from 1966 to 1973, the regressions of the least squares constants on year of calving (represented as 1 to 8) were calculated (Table 11).

Table 11. Regressions of the least squares constants for calving interval and length of lactation (days) on year of calving.

Trait	b	SEb	r
Calving interval	- 12.0	4.57	0.73**
Length of lactation	- 4.0	3.71	0.40

The regression of calving interval on years was -12 days, significant at the 1 % level and indicating that calving interval has decreased by 12 days per year over the 8-year period. The reduction in lactation length of 4 days per year over the 8 years was not significant.

The estimated least squares means for month of calving in Table 10 show that length of lactation ranged from a minimum of 223 days for lactations commencing in September - October, to a maximum of 278 days for lactations commencing in January - February. The effects of month of calving on length of lactation are likely to be connected with the stages in the wet and dry weather cycle covered by the lactations and fixed by the month of commencement. In order to determine any such trend, the correlations and regressions of the least squares means for month of calving on the total rainfall in the 254 days following that month of calving, which represents the mean length of lactation, were calculated. The highly significant correlation of 0.89, and regression of 0.09 days increase in length of lactation per mm of rainfall, indicate a marked rainfall effect on this trait.

There was no suggestion of any difference between the Maure, Peul and Maure x Peul breeds for these traits.

4.3.2. Repeatabilities

Table 12 lays out the analyses of variance within breed groups for the three reproductive performance traits, after adjustment for environmental effects ; and Table 13 indicates the repeatabilities.

Table 12. Analyses of variance for three reproductive performance traits (M.sqs. x 10^{-2}).

Cow breed	Source of variation	Calving interval		Length of lactation		Length of dry period	
		d.f.	M.sq.	d.f.	M.sq.	d.f.	M.sq.
Maure	Between cows	74	239	60	104	49	233
	Within cows	227	127	141	47	120	106
Peul	Between cows	64	299	50	126	44	259
	Within cows	236	96	140	38	122	124
Maure x Peul	Between cows	43	235	27	47	23	123
	Within cows	95	148	38	30	32	133
Combined	Between cows	181	259	137	101	116	221
	Within cows	558	117	319	41	274	117

Table 13. Repeatability of calving interval, length of lactation, and length of dry period.

Breed	Repeatability		
	Calving interval	Length of lactation	Length of dry period
Maure	0.18	0.27	0.26
Peul	0.31	0.38	0.23
Maure x Peul	0.16	0.19	- 0.04
Overall	0.23	0.31	0.21

The relatively low repeatabilities of calving interval and length of dry period, 0.23 and 0.21 respectively, suggest that selection would not be very effective in improving these traits. The slightly higher repeatability for length of lactation of 0.31 suggests that possibly some genetic improvement could be achieved by culling cows with short lactations.

4.4 Length of cow productive life

Statistics on length of cow productive life were built up using calving records of all cows that entered the breeding herd for the first time during the three years 1966-1968. Some of the early cows had previously calved, but their reproductive records were available. The data are laid out in Table 14.

Table 14. Statistics on length of cow productive life.

Statistic	Number
Sample years for cows entering breeding herd	3
Years of subsequent calving records	10.5
Cows entering breeding herd for first time	137
Subsequent calvings	648
Cows remaining active in herd in mid-1976	31
Correction for calvings expected after mid-1976	31
Calvings per cow in lifetime	5.0
Years per cow in breeding herd in lifetime	6.4
Mean annual turnover rate (%)	15.6
Age on completion of productive life (years)	10.0

The 137 females entering the breeding herd for the first time in 1966-1968 had 648 calvings up to mid-1976, when 31 still remained in the herd. Examination of these 31 animals suggested that they would subsequently produce an average of at least one further calf. Thus the 37 cows produced a total of 679 calves, representing a mean number of calvings per cow per lifetime of 5.0. Using the mean calving interval of 468 days, cows thus remained for an average of 468 x 5 days, or 6.4 years, in productive life. This complete replacement of the cow herd each 6.4 years represents a turnover rate of 15.6 %. When age at first calving is added to the productive life, the average cow age on completion of productive life is 10 years.

4.5 Discussion

As with most tropical milk breeds, the Maure, Peul, and their crosses produced their first calves at a late age, averaging 43 months. It is recognised that among indigenous breeds there is scope for reducing age at first calving through improved nutrition without significantly depressing subsequent lactation milk yields. The fact that age at first calving decreased by 2.57 months per year for animals born over the eight years from 1966 to 1973, i.e. approximately a 6 % improvement per year, shows that

a great deal has already been achieved at Niono in reducing age at first calving through improved management. The small expected genetic reduction in age at first calving of 2 days per generation illustrates that little can be achieved by selection within the indigenous breeds for improvement of this trait. Reduction of age at first calving is important for two reasons : firstly, to decrease the unproductive period of a cow's life ; and secondly, to reduce the generation interval, thereby increasing the opportunity for genetic improvement per unit of time in all other traits that respond to selection.

In indigenous cattle under good management, regularity of calving is a usual feature. Their freedom from reproductive disturbances is perhaps due in large measure to their relatively low milk yields. Again, under poor environmental conditions long calving intervals are often observed, which suggests that these variations are usually due to non-genetic causes. While the calving intervals at Niono are relatively long (averaging 468 days), again, as with age at first calving, the fact that the calving interval decreased by 10 days per year for animals calving over the 8 years from 1966-1973, i.e. an approximate 2.5 % improvement per year, shows that definite achievements were made in reducing calving interval through improved management. The relatively low repeatability of calving interval of .23, which indicates the absolute upper estimate of the fraction of total variance attributable to heredity, suggests that selection would not be very effective in improving this trait. This is in agreement with general findings that heritability of length of calving interval is low.

As far as length of lactation is concerned, the aim in general is to maximise the lactating portion of the calving interval, which at Niono represents only 54 %. The positive correlation between lactation length and lactation yield reported in Section 5.2.4 indicates that the longer lactation associated with increased rainfall during the lactation period could be of practical importance in deciding on optimum times of year for calving different proportions of the milking herd.

The average cow productive life of 6.4 years, giving a turnover rate of 15.6 %, is quite acceptable ; and the importance of this factor in relation to genetic improvement is discussed in Section 7.4.

Chapter 5

MILK YIELD

5.1 Introduction

As a fresh milk supply is essential, a fundamental area of past work has been the establishment of breeds of cattle that will live, thrive, and produce milk in different parts of Africa. Mahedevan (1966) has pointed out that Zebu cattle are generally poor milk producers, and that their level of production varies with the prevailing climatic and environmental conditions. He further considers that one of the more important reasons for the serious lack of accurate data on the milk yield of indigenous cattle in Africa is the difficulty of assessment of the cow yield when partial suckling of the calf is permitted. He favours using the calf purely to induce the let-down of milk, removing the calf as soon as milk flow commences, hand-milking as much as possible, and repeating the whole process if necessary until all the milk has been drawn.

The method of milking at Niono was the usual method employed when milk let-down is a problem. The dam was allowed to suckle the calf for about one minute prior to milking ; then as much as possible was milked by hand ; and afterward the calf was allowed to complete the operation by being suckled again. After weaning at approximately six months of age, the calf was still used to induce milk let-down.

Milked-out yield records were available on 526 lactations from 1966 - 1973. From 1968 - 1973, calf pre-weaning weights were available, and thus estimates of the amount of milk utilised by the calf could be obtained and added to the milked-out yield. Records were available on 418 milked-out and calf-utilised lactations.

5.2 Environmental effects on milked-out yields

Three measures of milked-out yield were available : lactation yield ; daily yield (per day of lactation) ; and annual yield (per day of calving interval x 365). The means and coefficients of variation for these measures are shown in Table 15.

Table 15. Mean values for milked-out yields.

Trait	Mean (kg)	SE	CV %
Lactation yield	563.4	59.1	52
Daily yield	2.17	0.15	34
Annual yield	456.7	47.3	52

Analyses of variance, laid out in Table 16, show year of calving and month of calving to have highly significant effects on all three measures, while parturition number has a highly significant effect on daily yield only.

Table 16. Analyses of variance of milked-out yields.

Source	d.f.	Mean squares		
		Lactation yield x 10^{-3}	Daily yield x 10^{-3}	Annual yield x 10^{-3}
Year of calving	7	726**	9448**	482**
Month of calving	5	384**	1997**	172**
Breed of cow	2	202	5306**	182**
Parturition	3	64	1731**	146
Pooled interactions	197	91	752*	61
Within subclasses	311	87	535	56

The estimated least squares means for all three measures of milked-out yield are shown i Table 17.

Table 17. Estimated least squares means for milked-out yields (kg).

Variable	No.	Lactation yield	Daily yield	Annual yield
Overall mean	526	563	2.17	457
Year of calving				
1966	27	542 abc	1.81 ab	391 ab
1967	32	431 d	1.83 ab	350 a
1968	25	628 c	2.34 c	503 c
1969	48	603 bc	2.62 d	501 c
1970	80	799 e	2.94 e	650 d
1971	107	554 abc	2.14 cf	459 bc
1972	94	445 ad	1.69 a	364 a
1973	113	506 abd	1.97 bf	435 abc
Month of calving				
January - February	108	622 a	2.22 ab	496 ab
March - April	72	614 a	2.34 a	506 b
May - June	64	632 a	2.36 a	485 ab
July - August	51	545 ab	2.10 b	449 abc
September - October	86	451 c	1.98 b	385 c
November - December	145	517 bc	2.01 b	420 ac
Breed				
Maure	225	586 a	2.30 a	471 a
Peul	216	522 a	1.96 b	413 b
Maure x Peul	85	583 a	2.24 a	486 a
Parturition number				
1	98	547	2.01 a	420
2 - 3	198	568	2.20 bc	452
4 - 5	143	599	2.33 c	512
6 +	87	540	2.14 ab	443

5.2.1. Effect of year of calving

Figure 4 illustrates the effect of year of calving on the three measures of milked-out yield, constructed from the least squares means presented in Table 17.

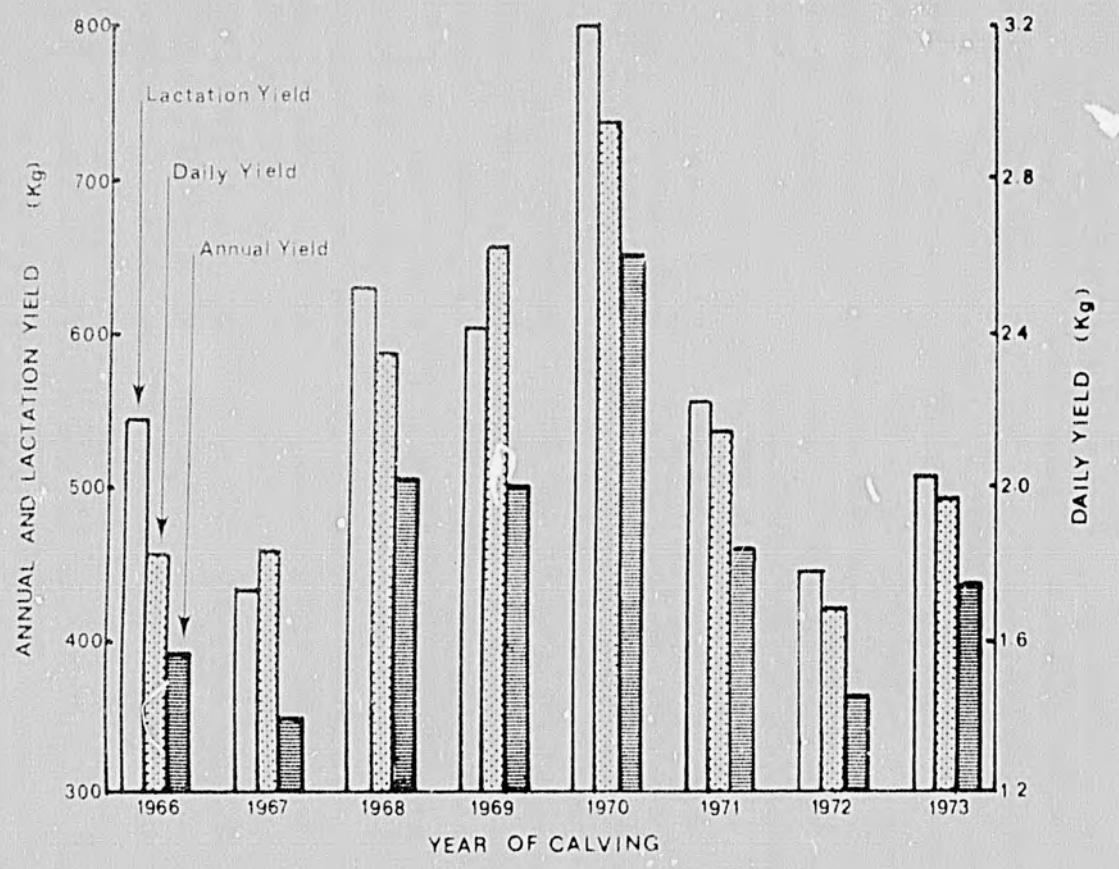

Figure 4. Effect of year of calving on milked-out yield.

Lactation yields ranged from 431 to 799 kg ; daily yields from 1.69 to 2.94 kg ; and annual yields from 350 to 650 kg. There was no significant correlation between annual rainfall and annual lactation yield. The results in Figure 4 did not suggest any linear trend in milked-out yield from 1966 to 1973, and non-significant regressions of milked-out yield on year of calving (represented as 1 to 8) confirmed this.

5.2.2. Effect of month of calving

Figure 5 illustrates the effect of month of calving on the three measures of milked-out yield, constructed from the least squares means presented in Table 17.

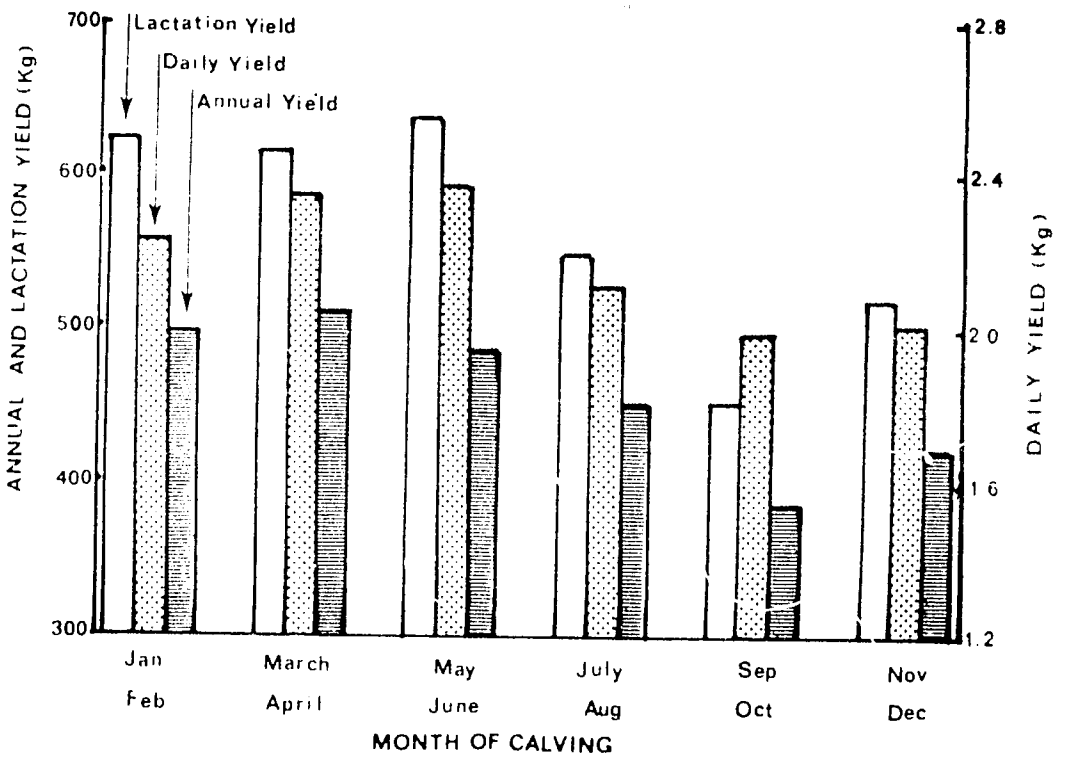

Figure 5. Effect of month of calving on milked-out yield.

Lactation yields, daily yields, and annual yields ranged from a minimum of 451 kg, 1.98 kg, and 385 kg respectively for lactations commencing in September - October, to 632 kg, 2.36 kg, and 506 kg for lactations commencing in May - June and March - April, respectively. The effects of month of calving on lactation yield and yield per day of lactation are likely to be connected with the stages in the wet and dry weather cycle covered by the lactations and fixed by the month of calving.

In order to determine any such trend, the correlations and regressions of the least squares means for month of calving on the total rainfall in the 254 days following that month of calving, which represents the mean length of lactation, were calculated. The highly significant correlations of 0.97 and 0.87, and regressions of 0.38 kg and 0.0008 kg increase in lactation and daily milked-out yield respectively, per mm of rainfall, indicate a marked rainfall effect on these two traits.

5.2.3. Effect of parturition number

Figure 6 illustrates the effect of parturition number on milked-out yield. Only the effect on daily yield during lactation was statistically significant. Milked-out yields peaked at the 4th - 5th parturition stage and decreased thereafter. Between 1st and 4th - 5th parturitions the milked-out yields increased by approximately 15 %.

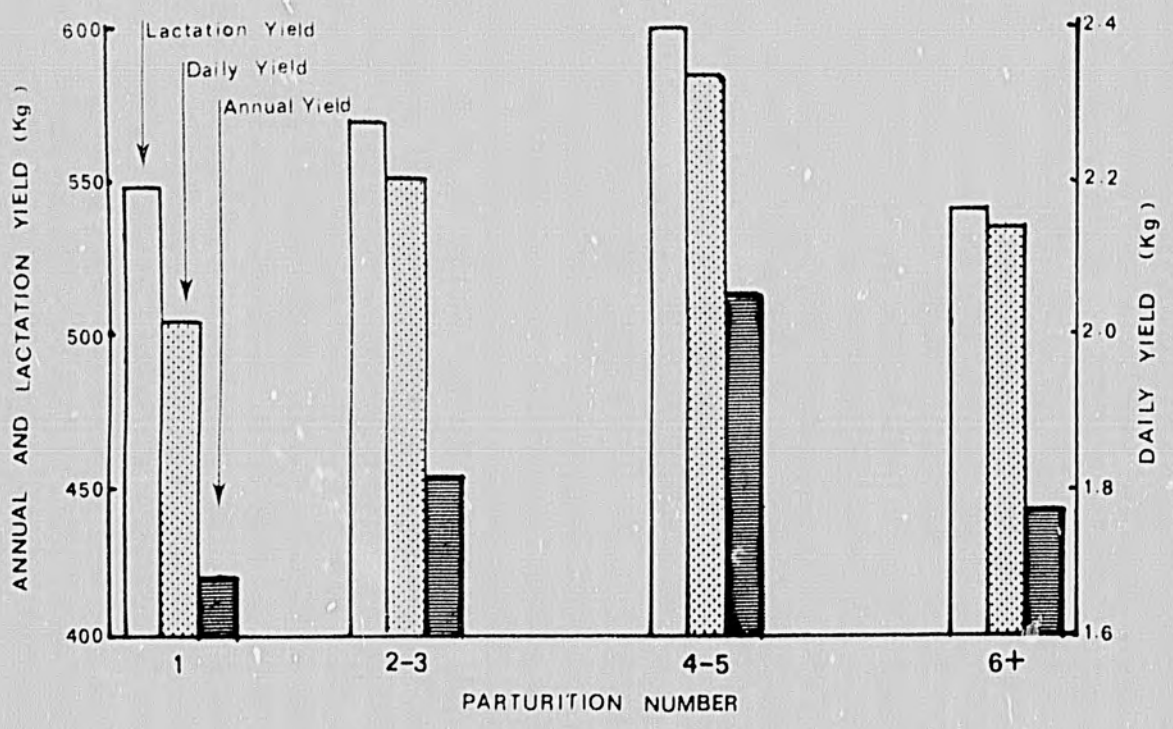

Figure 6. Effect of parturition number on milked-out yield.

5.2.4. Correlation between lactation yield and lactation length

Table 18 shows the intra-cow correlation and regression between lactation yield and lactation length.

Table 18. Intra-cow correlation and regression between lactation yield and lactation length.

Breed	No. of cows	No. of lactations	Correlation between lactation yield and lactation length	Regression of lactation yield on lactation length (kg)
Maure	61	202	.55**	1.16
Peul	51	191	.50**	0.87
Maure and Peul	28	66	.36**	0.57
Overall	140	459	.51**	0.98

There was a high overall correlation of 0.51 between the two traits and an increased lactation yield of 0.98 kg per additional day of lactation.

5.3 Breed effects on milked-out yields

Table 17 gives the Maure, Peul, and Maure x Peul breed means for the three measures of milked-out yield. There was no significant difference between the Maure and the Maure x Peul for any measure, but both were significantly superior to the Peul for daily and annual yield. Overall, the Maure and the Maure x Peul were 15 % superior to the Peul in milked-out yield.

5.4 Repeatabilities of milked-out yields

Table 19 shows the analyses of variance within breed groups for the three measures of milked-out yield after adjustment for environmental effects, and Table 20 indicates the repeatabilities.

Table 19. Analyses of variance for milked-out yields.

Cow breed	Source of variation	d.f.	Mean squares		
			Lactation milk yield x 10^{-2}	Yield per day of lactation x 10^{3}	Annual milk yield x 10^{-2}
Maure	Between cows	60	2061	1465	1332
	Within cows	141	488	368	330
Peul	Between cows	50	2056	1140	1007
	Within cows	140	308	243	258
Maure x Peul	Between cows	27	1444	1465	1073
	Within cows	38	231	277	229
Combined	Between cows	137	1938	1347	1162
	Within cows	319	378	302	287

Table 20. Repeatability of milked-out yields.

Breed	No. of cows	No. of records	Lactation milk yield	Yield per day of lactation	Annual milk yield
Maure	61	202	0.49	0.47	0.48
Peul	51	191	0.60	0.50	0.44
Maure x Peul	28	66	0.69	0.65	0.61
Overall	140	459	0.55	0.51	0.48

All three measures of milked-out yield have high repeatabilities. Lactation milk yield at 0.55 is the highest, and as expected when the lower repeatabilities of length of lactation and calving interval, 0.31 and 0.23 respectively, are recalled, yield per day and annual yield are slightly lower, at 0.51 and 0.48.

5.5 Calf-utilised and total milk yield

The milked-out, calf-utilised, and total milk yields, calculated as described in Chapter 3, are laid out in Table 21.

Table 21. Mean values for calf-utilised and total yields.

Trait		Mean (kg)	SE	CV (%)
Milked-out lactation yield	(A)	586.3	63.4	51
Milk utilised by calf from birth - 3 months	(B)	347.7	19.4	26
Milk utilised by calf from birth - weaning	(C)	589.2	31.4	25
A + C	(D)	1173.6	74.9	30
Annual milked-out yield	(E)	469.5	49.1	49
E + annual milk utilised by calf from birth to weaning	(F)	964.6	68.8	33

From Table 21, it is seen that the milked-out yield and the calf-utilised yield from birth to weaning are virtually equal. Sixty percent of the calf-utilised milk is produced in the first three months after parturition, and 40 % in the following three months. The best estimate of total milk production of the Maure and Peul and their crosses is thus 1174 kg per lactation, or 965 kg per year.

The analyses of variance laid out in Table 22 show the trends of environmental and breed effects on all measures of milk yield to be similar to those for milked-out yield previously illustrated in Table 16 and discussed in Sections 5.2 and 5.3.

Table 22. Analyses of variance of calf-utilised and total yields.

Source	d.f.	Mean squares x 10^{-3}					
		A	B	C	D	E	F
Year of calving	5	832**	279**	398**	385**	608**	552**
Month of calving	5	269*	49**	123**	273*	119*	121
Breed of cow	2	103	25	65	303	154	534**
Parturition number	3	85	26*	65*	230	211**	672**
Pooled interactions	165	84	9	22	122	57	98
Within subclasses	237	88	8	22	123	53	104

N.B. Explanations of codes A-F are listed on page 51.

A = Milked-out lactation yield

B = Milk utilised by calf from birth to 3 months

C = Milk utilised by calf from birth to weaning

D = A + C

E = Annual milked-out yield

F = E + annual milk utilised by calf from birth to weaning

Correlations and regressions involving milked-out and calf-utilised yields are given in Table 23.

Table 23. Correlations and regressions involving milked-out and calf-utilised yields.

Variables	r	b	d.f.
Milked-out yield and calf-utilised yield	.37	0.086	414
Year and milked-out yield	.55	- 36	5
Year and calf-utilised yield	.95**	50	5
Year and total yield	.34	15	5

The first line of Table 23 indicates a significant positive relationship between milked-out yield and calf-utilised yield, calf-utilised yield increasing by 0.086 kg for each kg increase in milked-out yield.

Again, as in Section 5.2.1, there is no suggestion of any linear trend in milked-out yield from 1968 - 1975 ; however, there appears to be a definite increase in calf-utilised yield over this period. This picture is confirmed in Table 23, where the regressions of the least squares constants for milked-out yield, calf-utilised yield, and total yield on year of calving (represented as 1 to 6) are laid out. The significant regression of calf-utilised yield on year was 50 kg, indicating that calf-utilised yield had increased by 50 kg per year over the 6-year period. The reduction in milked-out yield of 36 kg per year over this period was not significant.

5.6 Breed effects on total milk yield

Total milk production per lactation and per year by Maure, Peul, and Maure x Peul breed types is shown in Table 24.

Table 24. Effect of breed on total milk produced (kg).

Breed	Milked-out lactation yield plus milk utilised by calf from birth to weaning	Annual milked-out yield plus annual milk utilised by calf from birth to weaning
Maure	1206.0 a	1002.9 a
Peul	1117.8 a	887.6 b
Maure x Peul	1197.2 a	1003.4 a

There were no significant differences between the three breed types in total lactation yield, but the Maure and Maure x Peul had significantly higher total annual milk yields (13 %) than the Peul.

5.7 Repeatabilities of calf-utilised and total milk yield

Table 25 lays out the analyses of variance within breed groups for the calf-utilised and total milk yields, after adjustment for environmental effects ; and Table 26 indicates the repeatabilities.

Table 25. Analyses of variance for milked-out and calf utilised yields.

Cow breed	Source of variation	d.f.	Mean squares x 10^{-2}					
			A	B	C	D	E	F
Maure	Between cows	55	2155	80	219	2628	1428	1942
	Within cows	114	434	59	148	598	303	749
Peul	Between cows	44	2078	174	437	2858	1072	1705
	Within cows	94	313	68	163	559	237	602
Maure x Peul	Between cows	22	1004	124	326	1224	442	997
	Within cows	32	245	100	246	452	182	600
Combined	Between cows	121	1918	122	318	2456	1119	1684
	Within cows	240	361	68	167	563	261	671

N.B. Explanations of codes A - F are listed on page 51.

Table 26. Repeatabilities of calf-utilised and total yields.

Breed	No. of cows	No. of records	A	B	C	D	E	F
Maure	56	170	0.59	0.11	0.14	0.55	0.55	0.34
Peul	41	139	0.65	0.34	0.35	0.57	0.53	0.37
Maure x Peul	23	55	0.57	0.09	0.12	0.42	0.37	0.22
Overall	124	364	0.60	0.21	0.23	0.54	0.52	0.34

N.B. Explanations of codes A - F are listed on page 51.

The repeatabilities of calf-utilised yield are in all cases lower than those of milked-out yield, and thus of total yield.

5.8 Discussion

Discussing milk recording in developing countries, Lindstrom (1976) indicates that bi-monthly recording of yield, as practiced at Niono, permits high accuracy in the selection of individual cows for milk production. The milked-out yields at Niono fall into the low range and have the high coefficient of variation usually associated with tropical cattle. Generally in the tropics there is little evidence to suggest that this high variation in yield is associated with any increase in heritability. No heritability estimates for milked-out yields are available from Niono, but the repeatabilities of around 0.5 are not higher than generally reported.

Major year effects on lactation milked-out yield illustrate the importance of either comparing yields within years or adjusting data for year effects. Although year effects were so marked, there was no apparent connection between rainfall and lactation yields to suggest that pasture availability influenced milk production. Similarly there was no significant trend of increasing yields over the 8 years from 1966 to 1972 to suggest that either management or genetic selection had markedly affected milk production.

Month of calving had an important effect on milked-out yield : cows calving from January to June produced significantly higher yields than those calving from July to December. Thus, before comparing milk yields it is important to adjust for month of calving. The positive association between milk yield and rainfall during the lactation period, which is determined by the month of calving, again suggests that decisions on optimum times of year

for calving different proportions of the herd could be of practical importance.

Effect of parturition number showed that milked-out yields peaked at the 4 - 5th parturition, i.e. at about 9 years of age, which is later than usually reported for tropical cattle. The increase in milk yield from first to peak lactation of approximately 15 % follows the usual pattern for tropical cows.

As far as breed differences were concerned, both the Maure and the Maure x Peul were approximately 15 % superior to the Peul in daily and annual milked-out yield.

Approximately the same amount of milk was utilised by the calf from birth to weaning as was milked out, but the former measure showed a much lower variability. The marked increase per year of 50 kg calf-utilised milk from 1968 to 1973 is due to a management decision to allow the calf to obtain increasing amounts of milk.

As with milked-out yields, the Maure and the Maure x Peul were approximately 13% superior to the Peul in annual total milk yield.

Chapter 6

MILK COMPOSITION

6.1 Butterfat content

Twice-monthly butterfat measurements were available for 162 completed lactations only, between 1970 and 1972. The mean butterfat percent was 4.70, with a coefficient of variation of 17 %.

The analysis of variance laid out in Table 27 showed month of calving to have a significant effect and parturition number to have a highly significant effect on butterfat percent.

Table 27. Analysis of variance of butterfat percent.

Source	d.f.	Mean square x 10^2
Year of calving	2	93
Month of calving	5	162*
Breed	2	8
Parturition number	3	314*
Pooled interactions	58	62
Within subclasses	91	62

The estimated least squares means for butterfat percent are shown in Table 28.

Table 28. Estimated least squares means for butterfat percent.

Variable	No.	Butterfat percent
Overall mean	162	4.70
Year of calving		
1970	30	4.58
1971	101	4.57
1972	31	5.00
Month of calving		
January - February	41	4.36 a
March - April	17	5.22 b
May - June	6	4.74 a
July - August	10	4.63 a
September - October	35	4.59 a
November - December	53	4.67 a
Breed		
Maure	76	4.69
Peul	56	4.76
Maure x Peul	30	4.66
Parturition number		
1	37	5.17 a
2 - 3	46	4.77 b
4 - 5	38	4.46 b
6 +	41	4.42 b

There appears no obvious explanation for the significant month of calving effect. There was a steady decrease in fat content as parturition number increased, from 5.17 % in first lactation to 4.42 % in 6th and subsequent lactations. There was no suggestion of any breed effect on butterfat percent.

There is in the literature considerable evidence to show that fat percent and solids not fat percent decrease as parturition number increases to the fifth. Of the fractions making up the total solids content of milk, the solids not fat is of greater nutritional importance than the butterfat, as it contains the valuable protein. Mahadevan (1966) asks whether butterfat testing is really necessary in tropical dairy cattle, since human energy requirements can be met by other sources of food. Protein testing could be more relevant, but is unlikely to be widely practicable, since milk for protein testing must be brought in good condition to the laboratory.

There is in general a fairly good positive relationship between the level of fat and the level of solids not fat in milk. When large numbers of animals are involved, fat percent can be a good guide to solids not fat percent ; but selection of individual animals for solids not fat cannot be based on fat percent.

Chapter 7

VIABILITY

7.1 Mortality at different stages of the life cycle

Mortality data based on 1352 births or abortions over a 10.5 year period from 1966 to 1976 were available. Table 29 presents the percentage of mortality covering the different stages in the life cycle for each year of birth separately, calculated as described in Chapter 2.

Table 29. Percentage mortality at different stages from 1966 - 1976.

Year of birth	Number of parturitions and abortions	Percentage mortality						
		Abortions	Still-births & Day 1 deaths	Pre-weaning 1 day - 6 months	Post-weaning 6 - 12 months	1-2 yrs	Heifers 2yrs to maturity	Breeding cows (by year of death)
1966	69	1.4	1.5	6.0	1.6	0	3.2	-
1967	101	5.0	4.2	9.8	11.2	12.2	0	-
1968	82	7.3	2.6	12.2	36.9	14.6	5.7	-
1969	79	2.5	3.9	10.8	33.3	6.8	0	2.2
1970	105	3.8	2.0	10.1	13.5	15.6	6.2	5.4
1971	157	6.4	0.7	18.5	8.4	1.8	1.9	1.2
1972	125	8.0	1.7	6.2	2.8	1.0	2.0	2.9
1973	170	15.9	2.8	4.3	1.5	3.1	-	2.1
1974	188	19.7	4.0	8.2	0	3.0	-	3.7
1975	127	9.4	2.6	4.5	-	-	-	4.6
1976	149	14.1	2.3	12.8	-	-	-	1.3
Overall	1352	10.0	2.6	9.5	8.7	5.4	2.8	2.8

While abortions averaged 10.0 % per annum overall, during the 7 years from 1966 to 1972 they averaged only 5 %, but from 1973 to 1976 increased to 15 %. Brucellosis has been diagnosed as the major cause of abortions during this latter period. Stillbirths and first day deaths remained static throughout the period at 2.6 % per annum. High pre-weaning deaths averaging 9.5 % were boosted by an 18 % average mortality during the 1969 to 1971 rinderpest outbreaks. Similarly, high post-weaning deaths from 6 to 12 months of age of 8.7 % were boosted by a 20 % average mortality for these years. Deaths from

one to two years of age of 5.4 % were also affected by a 13 % average mortality for these three years. Mortality from 2 years to 3 years of age averaged 2.8 %.

The overall mortality to three years of age of all calves born, including stillbirths, was 26.0 %. If the 1969 - 1971 rinderpest influence had not been present, this mortality figure would have been reduced to approximately 19 %.

7.2 Causes of death

Proximity of a transhumance track on the east part of the ranch, traffic of animals due to the Niono market and common pastures for animals of the ranch and animals of Niono breeders - all these factors expose the station animals to different epizootics. The shortage of veterinary staff and the lack of a laboratory were serious handicaps to the precise diagnosis of all existing infections.

The post-mortem findings are grouped into six basic classes in Table 30.

Table 30. Post-mortem findings.

Group of post-mortem findings	Stage of death											
	Stillbirth + 1st day		Pre-weaning 1st day-6 m		Post-weaning 6-12 m		Post-weaning 12-24 m		2yr-3yr		Adult cows annually	
	N	%	N	%	N	%	N	%	N	%	N	%
Nutritional	-	-	26	21	8	10	4	7	-	-	4	11
Accidental	7	22	14	11	5	6	7	12	-	-	7	18
Parasitic	-	-	1	1	-	-	-	-	-	-	2	5
Reproductive	6	19	6	5	4	5	-	-	-	-	5	13
Disease	1	3	32	26	58	73	36	62	7	100	16	42
Unknown	18	56	45	36	5	6	11	19	-	-	4	11
Total	32	100	124	100	80	100	58	100	7	100	38	100

Forty-four percent of the post-mortem symptoms suggested disease problems with certain diagnosis; 12% were associated with nutritional problems; 12% with accidents; 6% with reproductive problems; 1% with parasitic problems; while 25% were of doubtful diagnosis or undiagnosed cases.

The major diseases identified are pleuropneumonia, rinderpest, rickettsiosis, blackleg, anthrax, pasteurellosis and some respiratory diseases. Nutritional problems reported included malnutrition, emaciation, digestive upsets and bloat. Accidental deaths were related to such causes as handling for vaccination, fracture, twisting of the intestine, heat stroke, and predators. Reproductive problems covered premature birth, mummified foetus, and dystocia. Parasitic problems were infrequently reported in post-mortem results, reflecting the management level and the regular treatment of young stock against parasites.

7.3 Breed mortality rates

Weighted comparisons of breed mortality were carried out within year of birth and summed over years (1966-1975). Insufficient data had been recorded to allow a breed comparison of abortions, and there were too few deaths in the 2 - 3 year period to allow any meaningful comparisons to be made. The overall 2 - 3 year mortality rate of 2.8 % was therefore used for all three breeds for this period and also in calculation of the total mortality from birth to three years. The breed comparisons are presented in Table 31 ; chi-squared tests showed no significant differences between breeds at any stage.

Table 31. Breed mortality rates.

Stage	Breed		
	Maure	Peul	Maure x Peul
Stillborn and first day	1.3	1.4	4.8
Pre-weaning (1 day - 6 m)	11.2	7.5	9.9
Post-weaning (6 m - 12 m)	6.5	11.9	7.8
1 - 2 years	5.3	5.9	5.0
2 - 3 years	2.8	2.8	2.8
Birth to 3 year total	24.6	26.5	27.0

7.4 Discussion of mortality rates in relation to genetic improvement

An appropriate definition of mortality rate in the context of genetic progress is the percentage of females that die before calving. Here it is approximately 26 %. The rearing proportion (Mahadevan,1966) is the proportion of births that produce a heifer that survives and is fertile. The rearing proportion here is about 0.36. This means that only once in 2.8 calvings does a cow produce a heifer calf that will reach lactation in the herd. The average length of reproductive life is 5 calvings : therefore, approximately 56 % of the females born are required as replacements to maintain herd size. High mortality rates are inconsistent with genetic progress, and when they can be reduced, a higher intensity of selection can be achieved.

Genetic improvement per unit of time is more important than per animal generation, and high mortality rates have a marked effect on generation interval. The average age at first calving is 43.04 months, and the average calving interval 15.38 months. To replace herself, a cow must calve 2.8 times ; thus, the average generation interval is 86.1 months or 7.2 years, within the normally reported range for tropical indigenous breeds.

Chapter 8

BODY WEIGHT

8.1 Environmental and breed effects at seven different ages

Weekly or monthly weight records were available for a total of 243 animals from birth to 30 months of age. Individual weights at the six stages from 3 to 30 months of age were calculated as indicated in Chapter 2. Analyses of variance, laid out in Table 32, showed year of birth, month of birth, sex, dam parturition number, and breed to have significant effects on body weight at different stages.

Table 32. Analyses of variance of weight at seven different ages using all records available to 30 months of age.

Source	d.f.	Mean squares						
		Birth	3m	6m	12m ($x10^{-1}$)	18m ($x10^{-1}$)	24m ($x10^{-1}$)	30m ($x10^{-1}$)
Year of birth	4	16	838**	1865**	1053**	1564**	816**	153
Month of birth	5	8	122*	1286**	250**	340**	224**	106
Sex	1	68**	360**	757**	186	1484**	5290**	11140**
Dam parturition number	3	31**	173*	193	64	20	30	5
Breed	5	2	179*	594**	61	82	78	116
Pooled interactions	157	13*	70	209	48	86*	82	132
Within subclasses	67	7	50	169	48	58	62	86

The estimated least squares means for body weight at seven different ages are shown in Table 33.

Table 33. Estimated least squares means for weight at seven different ages.

Variable	No.	Birth	3m	6m	12m	18m	24m	30m
Overall mean	243	20.5	49.6	78.6	125	176	218	261
Year of birth								
1968	23	20.1a	43.8a	67.5a	97a	161ab	195a	250
1969	31	20.0a	47.2b	78.1bc	126b	163a	211b	254
1970	57	20.3ab	45.5ab	73.2b	114c	152b	207b	262
1971	94	21.4b	51.7c	80.6c	126b	187c	229c	263
1972	38	20.6ab	59.8d	93.6d	161d	216d	245d	274
Month of birth								
January - February	48	21.2a	48.7a	76.5a	109a	169ab	213ab	256
March - April	33	20.6ab	48.8a	70.6a	117ab	169ab	209a	258
May - June	19	19.9b	48.2a	75.7a	138c	189c	232c	273
July - August	17	20.9ab	47.8a	76.6a	130cd	163a	205a	252
September - October	54	20.2ab	51.2ab	84.7b	125bd	175b	222bc	264
November - December	72	19.9b	52.7b	87.4b	130cd	129c	225c	262
Sex								
Female	119	19.9a	48.3a	76.8a	122a	168a	202a	239a
Male	124	21.0b	50.8b	80.4b	128b	184b	233b	283b
Dam parturition number								
1	53	19.3a	46.7a	75.6	120	173	215	260
2 - 3	71	20.8ab	50.7b	79.0	128	178	218	261
4 - 5	74	20.6ab	50.4b	80.1	126	176	221	260
6 +	45	21.1b	50.5b	79.6	125	176	217	262
Breed								
Maure	98	20.7	49.2ab	76.4ab	122	175	221	264
Peul	28	20.8	45.1c	72.8a	118	164	206	247
Maure x Peul (MP)	46	20.5	48.7a	74.2ab	125	178	217	262
3/4 Maure (M.MP)	19	20.3	49.3ab	80.0bc	124	177	220	266
3/4 Peul (P.MP)	32	20.4	52.4bd	82.9c	127	177	218	262
Maure.Peul x Maure.Peul (MP.MP)	20	20.0	52.8d	85.1c	133	183	223	263

Records to 18 months of age only were available for an additional 129 animals ; and analyses of weights from birth to 18 months were also carried out on the larger group of 372 animals. The environmental and breed effects on weight in this larger group were virtually identical to the results in Tables 32 and 33, and therefore the results of these additional analyses are not reproduced here.

Figure 7 illustrates the mean growth of all animals from birth to 30 months of age. The coefficients of variance of weight at birth, 3, 6, 12, 18, 24, and 30 months were 13 %, 14 %, 17 %, 18 %, 14 %, 11 %, and 11 % respectively.

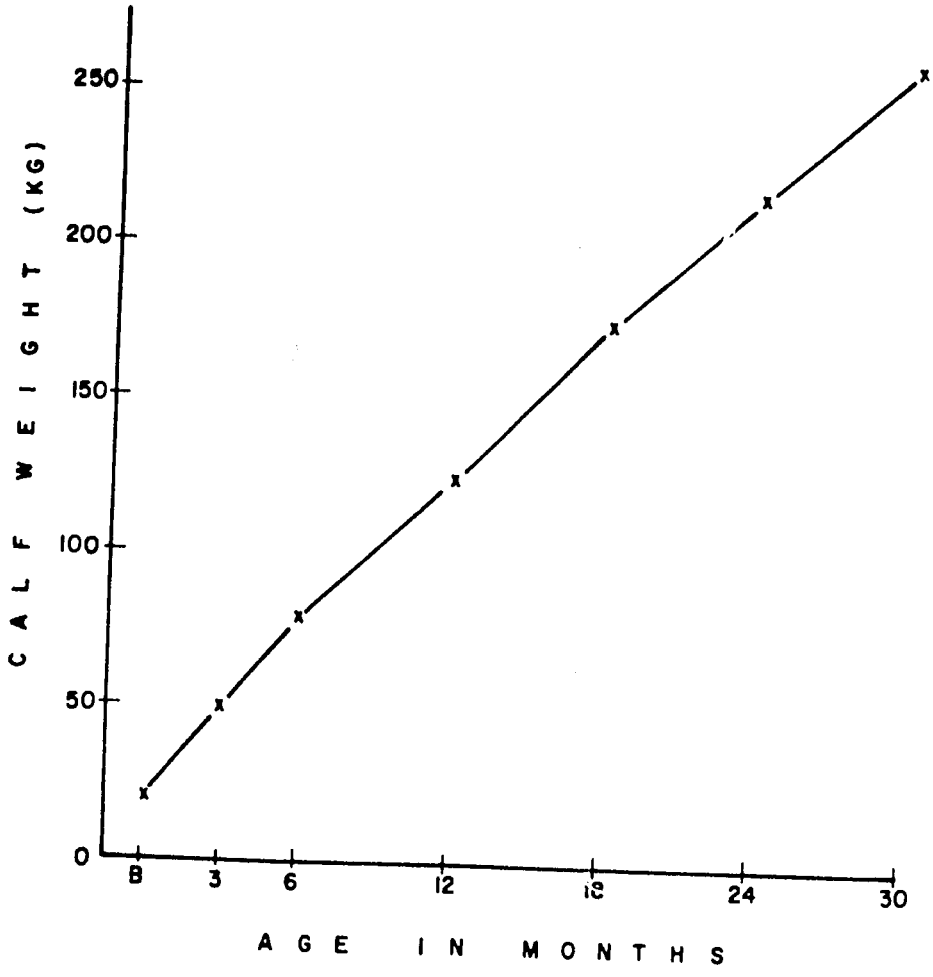

Figure 7. Mean body weights from birth to 30 months.

8.1.1. Year effect

Table 32 indicates that no significant year differences existed for birth or 30-month weight, but there were significant year effects for weight at all other stages. The maximum year difference at birth, 3, 6, 12, 18, 24, and 30 months represented 7 %, 32 %, 33 %, 51 %, 36 %, 23 %, and 9 % respectively of the mean weights.

Causes of variation between years in this environment and under this system can be grouped in three main categories. Firstly, differences in annual rainfall affecting the pasture availability each year, and this directly influencing growth rates ; secondly, differences resulting from changing and improving management techniques ; and thirdly, differences resulting from genetic improvement.

Correlations between growth covering several combinations of twelve-month periods from birth to 30 months, and rainfall within these twelve-month periods were calculated, but no significant relationships between growth and rainfall were found.

To determine any linear trends in body weights from 1968 births to 1972 births, the regressions of the least squares constants on year of birth (represented as 1 to 5) were calculated (Table 34).

Table 34. Regressions of the least squares constants for weight on year of birth (kg).

Trait	b	SEb	r
Birth weight	0.24	0.12	0.67
3-month weight	3.65	0.84	0.90**
6-month weight	5.47	1.35	0.89**
12-month weight	12.80	3.54	0.86*
18-month weight	13.40	4.46	0.82*
24-month weight	11.80	1.85	0.95**
30-month weight	5.70	0.64	0.97**

The regressions were significant at all stages after birth, and indicate that weight for age increased at each stage by the amounts listed in Table 34, per year over the 5-year period.

Weight differences at the different stages that could have resulted from genetic improvement are presented in Section 8.2.

8.1.2. Effect of month of birth

Table 32 indicates that the effects associated with month of birth were significant at all stages except birth and 30 months. Figure 8 shows the weights of animals in each of the six 2-month periods of birth, corrected for all other environmental and genetic effects evaluated. The maximum month of birth difference at birth, 3, 6, 12, 18, 24, and 30 months represented 5 %, 10 %, 21 %, 23 %, 15 %, 12 %, and 8 % respectively of the mean weights.

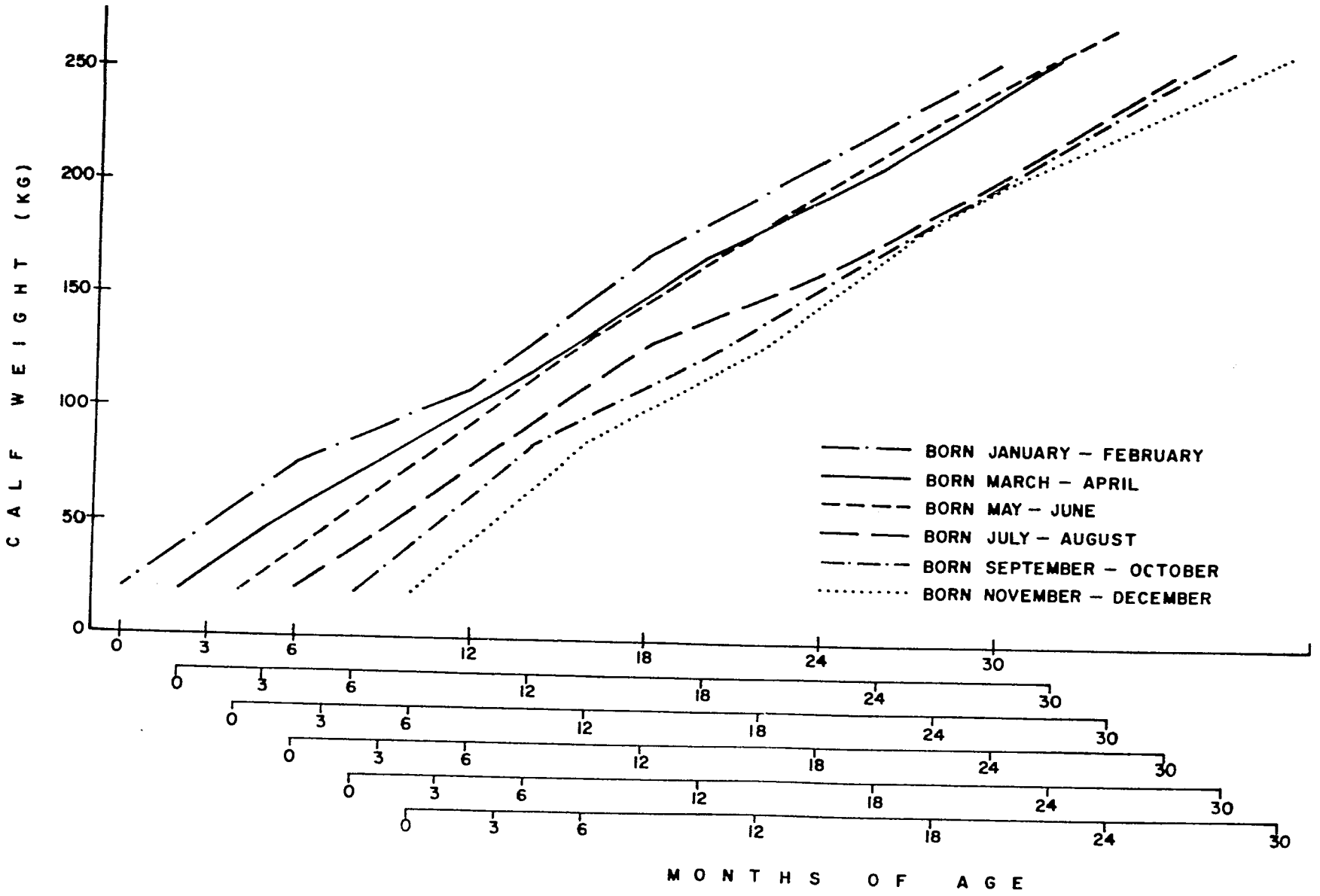

Figure 8. Effect of month of birth on body weight.

The effects of month of birth on later body weights are usually related to the stage in the wet and dry weather cycle at which an animal reaches a given age ; and relative rankings of month of birth groups might be expected to change from stage to stage. However, Figure 8 indicates that at 18 months and all subsequent ages, animals born in May - June ranked first ; September - October and November - December born ranked next ; January - February and March - April born ranked next ; and July - August born ranked last.

8.1.3. Effect of sex

Table 32 indicates that the effect of sex was significant at all stages except 12 months, males being heavier than females. The sex differences at birth, 3, 6, 12, 18, 24, and 30 months represented 5 %, 5 %, 5 %, 5 %, 9 %, 14 %, and 17 % respectively of mean body weights.

8.1.4. Effect of dam parturition number

Table 32 indicates that the effect associated with dam parturition number was significant at the birth and 3-month stages only. Table 33 shows that at both these stages, heifers had significantly lighter calves than all other cows.

8.1.5. Effect of breed

Table 32 indicates that breed effects were significant at the 3- and 6-month pre-weaning stages only. Table 33 shows that at these two stages the Peul was significantly poorer than several of the crossbred types, these crosses all being suckled by Maure x Peul dams. This breed effect, at the pre-weaning stage only, suggests that it is the maternal abilities of the breeds, as represented by early calf weights, that is being reflected, rather than genetic differences in growth rate. Thus in Chapter 9, the maternal abilities of the breed types, as represented by calf pre-weaning weights, are looked at in more detail, using all available records : a total of 591 cow/calf pairs.

8.2 Genetic, environmental and phenotypic correlations; heritabilities; and expected genetic gains at different ages

Body weight data to 18 months of age were available for a much larger number of animals than were data to 30 months. Since selection decisions must be implemented by 2 years of age, 18 months appears a suitable stage for body weight evaluation. Complete sire and dam records were available for 347 animals, the progeny of 10 different sires. Analyses were carried out on birth, 6-, 12-, and 18-month weights as described in Chapter 3. The pooled analyses of variance and covariance are presented in Table 35.

Table 35. Analyses of variance and covariance for birth, 6-, 12-, and 18-month weights (kg).

Trait	Mean squares or covariances	
	Between sires (7 d.f.)	Within sires (337 d.f.)
Birth wt. (X1)	44.6	9.6
6m wt. (X2)	1248.2	190.7
12m wt. (X3)	2490.4	474.3
18m wt. (X4)	3159.2	663.3
X1 X2	- 7.6	9.9
X1 X3	- 29.8	12.8
X1 X4	8.2	14.0
X2 X3	1713.0	227.6
X2 X4	1786.9	221.2
X3 X4	2608.2	440.6

The components of variance and covariance for between and within sires were calculated from the pooled analyses of variance, and from those, assuming a relationship of 0.25 among members of a sire group, the genetic, phenotypic, and environmental variances and covariances were obtained. These are laid out in Table 36.

Table 36. Genetic, environmental, and phenotypic variance and covariance of birth, 6-, 12-, and 18-month weights.

Trait		X1	X2	X3	X4
X1	V_G	4.31	- 2.16	- 5.25	- 0.71
	V_E	6.39	9.36	16.73	14.52
	V_P	10.70	7.20	11.47	13.81
X2	V_G		130.36	183.11	193.00
	V_E		92.88	90.22	76.45
	V_P		223.24	273.33	269.44
X3	V_G			248.52	267.20
	V_E			287.90	240.18
	V_P			536.41	507.38
X4	V_G				307.67
	V_E				432.54
	V_P				740.20

n_o = 32.45

Estimates of the genetic, environmental and phenotypic correlations between the weights were obtained by dividing the covariances in Table 36 by the square root of the product of their corresponding variances. These estimates are given in Table 37.

Table 37. Genetic, environmental, and phenotypic correlations between birth, 6-, 12-, and 18- month weights.

Trait	Correlation	6m wt.	12m wt.	18m wt.
Birth	Gen.	- 0.09	- 0.16	- 0.02
	Env.	0.38	0.39	0.28
	Phen.	0.15	0.15	0.16
6m wt.	Gen.		1.02	0.96
	Env.		0.55	0.38
	Phen.		0.79	0.66
12m wt.	Gen.			0.97
	Env.			0.68
	Phen.			0.81

The phenotypic, genetic, and environmental correlations between weights at different ages given in Table 37 were positive and fairly large, except for those involving birth weight. As measured at Niono, birth weight was of no value for predicting later body weights.

Table 38 shows the heritabilities and expected genetic gains in 12- and 18-month weights. A larger body of data are available for birth, 3- and 6-month weights, and the genetic parameters for these stages are discussed in Section 9.4.

Table 38. Genetic estimates of 12- and 18-month weights.

Statistic	12 m	18 m
Standard deviation (σ_p)	23.16	27.21
Heritability (h^2)	0.46	0.42
Standard error h^2 (σ_{h^2})	0.26	0.24
Intensity of selection (i)	1.34	1.34
Expected genetic gain per generation (kg) (i. σ_p. h^2)	14.28	15.31
Generation interval (years)	7.2	7.2
Expected genetic gain per year	1.98	2.13

The heritabilities of 12- and 18-month weights, 0.46 and 0.42, just fail to reach significance. The top 5 % of males and 56 % of females are required for breeding purposes : thus the mean intensity of selection is 1.34, and expected genetic gains per generation are 14.28 and 15.31 kg for 12- and 18-month weights respectively. The generation interval of 7.2 years discussed in Section 7.4 results in expected genetic gains of 1.98 and 2.13 kg per year for 12- and 18-month weights respectively.

The more limited data from Table 33, when analysed in the same manner, gave heritability estimates of 0.64 ± 0.38 and 0.46 ± 0.30 for 24- and 30-month weights respectively. The expected genetic gains thus were 3.33 kg and 2.92 kg per year for weight at these two ages.

8.3 Cow weights

All 242 cows available in the breeding herds were weighed in October 1976. There were no significant effects associated with breed type or parturition number when body weights were compared using weighted differences within herd, breed, and parturition class subgroups. The subclass means are laid out in Table 39. Overall, the average weight of breeding cows in the herd was 317 kg.

Table 39. Cow body weight.

Variable	No.	Mean (kg)
Overall mean	242	317
Breed		
Maure	122	322
Peul	56	302
Maure x Peul	64	326
Parturition number		
1	86	310
2	73	318
3	43	321
4	40	317

8.4 Discussion

The growth curve from birth to 30 months illustrated in Figure 7 was virtually a straight line, with no significant differences in growth rate occurring during the different periods measured. The mean overall daily live weight gain was 0.26 kg. This would indicate that with growing stock, the supplementary feeding regime described in Section 1.4.2 was extremely successful in smoothing out the effects of differing pasture availabilities.

Major year effects on body weights at most stages illustrate the importance of comparing weights within years or adjusting data for year effects. Although year effects were so marked, there was no apparent connection between rainfall and growth within periods to suggest that pasture availability influenced growth. This additionally indicates that the supplementary feeding regime smoothed out pasture availability effects.

The fact that body weights at all stages after birth increased by an average of 7.5 % per year over the five years from 1968-1972 shows that very definite achievements were made in increasing body weights through improved management, feeding, and breeding techniques. The expected genetic gains, averaged over all stages, of 1.3 % per year illustrate that over the period only 17 % of the improvement achieved each year could have been through breeding, with 83 % through management and feeding.

When climatic conditions affect pasture availability, month of birth effects on later body weights are usually related to the stage in the wet and dry weather cycle in which an animal reaches a particular age. Under these conditions, relative rankings of month-of-birth groups change from stage to stage. The absence of this change of relative rankings is a further indication of the ameliorisation of pasture availability effects by the supplementary feeding programme.

The lower pre-weaning weights of calves from heifers indicate the importance of correction of data for dam parturition number at these stages.

The fact that breed differences were detected only at the pre-weaning stages suggests that the Peul is a poorer milk producer than the Maure and their crossbreeds, but that growth rates thereafter are similar. This theme is developed further in Chapter 9.

The heritabilities of 12- and 18-month weights, 0.46 and 0.42, agree well with the reported range for these traits. The positive genetic gains of around 2 kg per year suggest that the operation of an efficient selection programme for weight at 12-18 months would be well worthwhile.

Cow body weight data indicate that both breeds and their F1 cross are of similar low weight, averaging 317 kg.

Chapter 9

MATERNAL ABILITY

9.1 Introduction

As discussed in Section 8.1.5, significant breed effects on calf weights, at the pre-weaning stage only, suggested that these differences in early weights reflected breed maternal abilities rather than genetic differences between breeds in growth rate. Thus it was considered essential to look at maternal abilities in as much detail as possible. Complete pre-weaning performance data were available on a total of 591 calves, over a seven-year period, and these were used to further evaluate maternal ability, based on calf weights to weaning.

9.2 Environmental effects

Analyses of variance laid out in Table 40 show the significance of both environmental and breed effects on calf pre-weaning weights. Environmental effects at birth, 3, and 6 months are very similar to those presented in Table 32, with, additionally, year of birth having an effect on birth weight, and cow parturition number an effect on 6-month weight.

Table 40. Analyses of variance of pre-weaning weights using all records available to weaning stage.

Source	d.f.	Mean squares		
		Birth	3 m	6 m
Year of birth	5	57**	3425**	5642**
Month of birth	5	10	298**	1391**
Sex	1	382**	1791**	4044**
Dam parturition number	3	123**	856**	1631**
Breed	5	13	344**	724**
Pooled interactions	379	12	60	236
Within subclasses	191	10	89	204

The estimated least squares means for pre-weaning body weight are shown in Table 41.

Table 41. Estimated least squares means for pre-weaning weights.

Variable	No.	BW	3 m	6 m
Overall mean	591	20.2	52.0	80.4
Year of birth				
1968	32	18.8a	42.7a	65.8a
1969	67	18.9a	45.6a	73.8b
1970	89	20.0b	44.6a	71.6b
1971	120	21.1c	51.4b	79.9c
1972	106	21.2c	58.6c	88.6d
1973	129	20.8bc	59.9c	91.5d
1974	48	20.3bc	61.4c	91.6d
Month of birth				
January - February	132	20.4	52.6ab	80.9ab
March - April	105	19.9	52.6ab	78.3ac
May - June	50	19.7	50.7ac	77.4ac
July - August	54	20.6	48.9c	76.3c
September - October	93	20.4	52.6ab	82.7b
November - December	157	20.0	54.7b	86.8d
Sex				
Female	289	19.3a	50.2a	77.7a
Male	302	21.0b	53.8b	83.1b
Dam parturition number				
1	123	18.7a	48.0a	75.0a
2 - 3	199	20.4b	52.9b	80.7b
4 - 5	145	20.5b	53.0b	82.5b
6 +	124	21.1c	54.2b	83.4b
Breed				
Maure (M.M)	231	20.7	53.6ab	82.3ab
Peul (P.P)	89	20.1	48.7c	76.0c
Maure.Peul (M.P)	94	20.1	51.2ac	77.7cd
3/4 Maure (M.MP)	52	20.1	51.5ab	80.1acd
3/4 Peul (P.MP)	89	20.0	52.7ab	81.5abd
Maure.Peul x Maure.Peul (MP.MP)	36	19.8	54.3b	84.8b

Significant linear trends were previously found for 3- and 6-month weights over the years 1968 - 1972. Therefore the regressions of the least squares constants for birth, 3-month and 6-month weights on year of birth were again calculated using this much larger body of data, which also covered an additional two years. The results are presented in Table 42.

Table 42. Regressions of the constants for early calf weights on year of birth.

Trait	b	SEb	r	d.f.
Birth weight	0.34	0.14	0.74*	6
3-month weight	3.53	0.45	0.96**	6
6-month weight	4.64	0.59	0.96**	6

The regressions in Table 42 were significant at all three stages, and indicate that weight has increased at each stage by the amounts listed per year, over the seven-year period.

9.3 Breed effects

Table 43 brings together the breed of calf effects on pre-weaning weights shown in Table 41, and presents them under breed of dam groups.

Table 43. Maternal ability of Maure, Maure x Peul, and Peul dams based on early calf weights.

Breed of dam	Number	Early calf weights (kg)			Percentage advantage over Peul	
		Birth	3 m	6 m	3 m	6 m
Maure	231	20.7	53.6a	82.3a	+ 7	+ 7
Maure x Peul	177	20.0	52.8a	82.1a	+ 6	+ 7
Peul	183	20.1	50.0b	76.9b	0	0

As measured by pre-weaning weights, both Maure and Maure x Peul dams provide a maternal environment 7 % superior to that provided by Peul dams.

9.4 Heritability and expected genetic gain

Complete sire and dam records were available for 553 of the 591 animals. Sixteen separate sire progeny groups were represented. Analyses were carried out on birth, 3-, and 6-month weights as described in Chapter 3.

Table 44 shows the genetic parameters. The heritabilities of birth and 6-month weights, 0.31 and 0.32, are significant. The top 5 % of males and 56 % of females are required for breeding purposes, thus the mean intensity of selection is 1.34 ; and expected genetic gains per generation are 1.4 kg, 1.5 kg, and 6.2 kg for birth, 3-month, and 6-month weights respectively. The generation interval of 7.2 years discussed in Section 7.4 results in expected genetic gains of 0.19, 0.21, and 0.86 kg per year for birth, 3-month, and 6-month weights respectively.

Table 44. Genetic estimates of early calf weights.

Statistic	Birth	3 m	6 m
Between-sire degrees of freedom	13	13	13
Within-sire degrees of freedom	537	537	537
Between-sire components of variance	0.84	2.30	16.78
Within-sire components of variance	9.96	62.18	190.86
Standard deviation (σp)	3.29	8.03	14.41
Heritability (h^2)	0.31	0.14	0.32
Standard error h^2 (σh^2)	0.15	0.09	0.16
Intensity of selection (i)	1.34	1.34	1.34
Expected genetic gain per generation (kg) (i. σp. h^2)	1.37	1.51	6.18
Generation interval (years)	7.2	7.2	7.2
Expected genetic gain per year (kg)	0.19	0.21	0.86

Chapter 10

LINEAR MEASUREMENTS

10.1 Environmental and breed effects from birth to 24 months of age

Three linear measurements -height at withers, scapulo-ischial length, and heart girth- together with body weight were available for a total of 182 animals from birth to two years of age. Analyses of variance, laid out in Table 45, showed year of birth and month of birth to affect all linear measures and weight at all stages ; dam parturition number to affect height at birth and 6 months ; sex to affect all linear measures and weight at 24 months; and breed to affect height and weight at 6 months. The general situation is thus that environmental and breed effects on linear measurements closely resembled their effects on body weight.

The estimated least squares means for height, length, girth and weight at birth, 6, 12, and 24 months are given in Table 46.

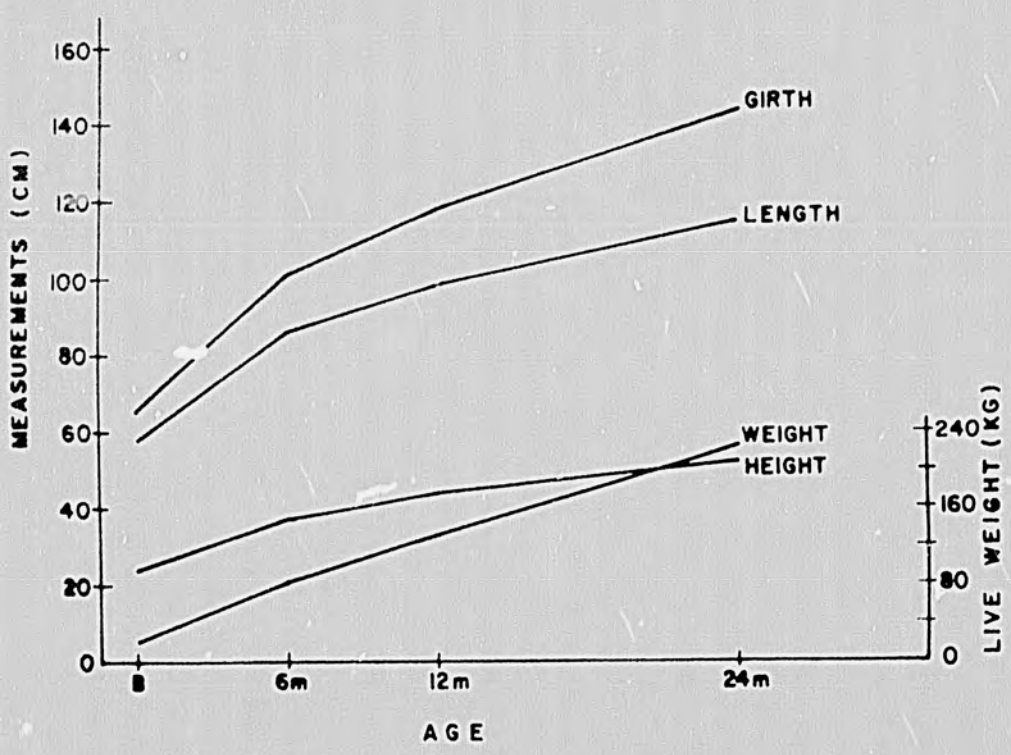

Figure 9. Mean changes in linear measurements and weight.

Table 45. Analyses of variance of weight and linear measurements at four different ages.

Source	d.f.	Mean square, weight				Mean square, height			
		Birth	6 m x 10-1	12 m x 10-1	24 m x 10-1	Birth x 10	6 m	12 m	24 m
Year of birth	2	48*	127**	1227**	375**	39	18	126**	31*
Month of birth	5	29*	95**	141*	168	18	16	16	14
Dam parturition number	3	41*	39	27	36	117*	25*	7	10
Breed	5	10	49**	62	86	28	23*	11	13
Sex	1	44*	32	12	3475**	91	31	6	180**
Residual	165	13	22	56	79	42	9	10	9

Table 45. (continued).

Source	d.f.	Mean square, length				Mean square, girth			
		Birth	6 m	12 m	24 m	Birth	6 m	12 m	24 m
Year of birth	2	334**	52	550**	139**	1	153*	1430**	588**
Month of birth	5	92**	32	26	60	35	157**	285**	128
Dam parturition number	3	48	67	51	39	42	44	10	34
Breed	5	7	36	52	10	3	92	31	61
Sex	1	56	36	21	535**	10	36	18	1392**
Residual	165	19	37	40	31	21	46	77	59

Table 46. Estimated least squares means for weights and linear measurements at four different ages.

Variable	Number	Weight (kg)				Height (cm)				Length (cm)				Girth (cm)			
		Birth	6 m	12 m	24 m	Birth	6 m	12 m	24 m	Birth	6 m	12 m	24 m	Birth	6 m	12 m	24 m
Overall mean	182	20.3	81.6	131.4	223.0	24.3	37.3	44.0	52.4	57.8	86.2	98.2	114.3	65.4	100.4	118.3	143.4
Year of birth																	
1970	48	20.5a	74.4a	112.0a	208.5a	24.8	36.6	41.8a	51.3a	62.1a	85.8	93.6a	111.5	65.5	97.8a	111.5a	137.8a
1971	90	21.3a	80.4b	124.7b	227.0b	24.2	36.9	43.5b	53.1b	57.2b	85.3	97.3b	115.0	65.5	100.0a	116.1b	145.5b
1972	44	19.1b	89.9c	157.7c	233.4b	23.9	38.3	47.7c	52.9b	54.1c	87.6	103.7c	116.4	65.1	103.3b	127.3c	146.8b
Month of birth																	
January - Febru	47	22.0a	83.8ab	121.0a	228.3	27.7	37.1	43.0	52.4	61.0a	86.8	97.1	115.1	67.1	101.6ab	114.7a	144.9
March - April	26	21.3ab	74.1c	122.9a	220.6	24.4	36.4	45.1	51.9	58.2b	84.3	97.3	113.3	64.9	98.0ac	114.9a	141.3
May - June	15	19.0c	76.7ac	142.5b	229.9	24.3	37.5	44.4	54.0	55.5c	85.1	98.4	117.3	63.6	96.9c	121.2bc	146.2
July - August	14	19.7bc	76.8ac	130.8ab	202.9	23.9	36.1	45.0	51.6	58.5b	87.5	99.5	114.1	66.0	100.0ac	118.8abc	139.6
September - October	36	20.3abc	88.6b	132.9ab	226.3	24.1	38.1	44.0	51.8	57.3bc	87.0	97.5	112.4	64.9	101.7ab	117.1ab	142.8
November - December	44	19.5bc	89.3b	138.6b	229.8	24.3	38.4	44.7	52.8	56.2bc	86.8	99.3	113.7	65.6	104.0b	123.2c	145.4
Dam parturition no.																	
1	45	19.2a	76.8	127.5	222.6	23.6a	36.4a	43.5	52.1	56.2	84.6	96.8	113.3	63.9	99.1	117.8	143.3
2 - 3	46	21.1b	83.1	132.1	218.8	24.6b	38.9a	44.5	51.9	58.0	85.5	98.1	113.5	62.2	99.8	118.[illegible]	142.0
4 - 5	45	19.7ab	83.5	133.6	226.7	24.2ab	37.6ab	44.2	52.7	58.1	87.8	99.7	115.7	65.3	100.9	119.1	144.5
6 +	46	21.2b	82.9	132.5	223.8	24.8b	38.3b	43.8	53.0	58.8	87.0	98.2	114.7	66.1	101.6	118.2	143.6
Breed																	
Maure	67	20.8	79.4ab	126.4	222.8	24.3	36.8ab	43.5	52.5	57.6	85.8	96.6	113.9	65.4	99.9	117.9	143.7
Peul	23	20.8	76.5a	127.6	207.8	23.7	35.9a	43.5	50.6	58.1	86.7	99.5	113.1	65.5	97.2	116.0	139.4
Maure x Peul	28	19.9	77.4a	132.3	225.7	23.9	36.4ab	43.8	52.5	56.8	84.3	96.9	115.0	64.9	98.4	119.0	144.6
3/4 Maure	15	20.2	82.3ab	131.3	220.9	24.7	39.4c	43.7	52.8	58.5	88.8	98.4	115.2	66.5	103.4	118.5	144.4
3/4 Peul	26	20.8	86.5b	131.7	223.2	24.5	37.3ab	44.4	53.1	57.5	86.0	97.7	114.4	65.1	100.8	118.4	143.0
MP x MP	23	19.2	87.3b	139.4	227.5	24.6	37.9bc	45.1	53.0	58.1	85.8	99.9	114.3	65.5	102.6	120.0	145.1
Sex																	
Female	98	19.8a	80.2	130.6	208.6a	24.1	36.8	43.8	51.4a	57.2	85.8	98.5a	112.5	65.1	99.9	118.6	140.5a
Male	84	20.8b	83.0	132.3	237.4b	24.5	37.7	44.2	53.4b	58.4	86.7	97.8b	116.1	65.6	100.8	118.0	146.2b

Figure 9 illustrates the mean changes in linear measurements and weight of all animals from birth to 24 months of age. The coefficients of variation of each of the three linear measurements at birth, 6, 12, and 24 months were 8 %, 7 %, 7 %, and 5 % respectively, while those of weight were 18 %, 18 %, 18 %, and 13 % respectively.

10.2 Correlations and regressions between weight and linear measurements

Table 47 presents the correlations and regressions between weight, height, length, and girth, and the index constructed from "length x girth^2". Virtually all correlations and regressions were significant within all 6 breed types.

Figure 10 illustrates the overall change in weight per unit change in each of the three linear measurements and the index at birth, 6, 12, and 24 months of age.

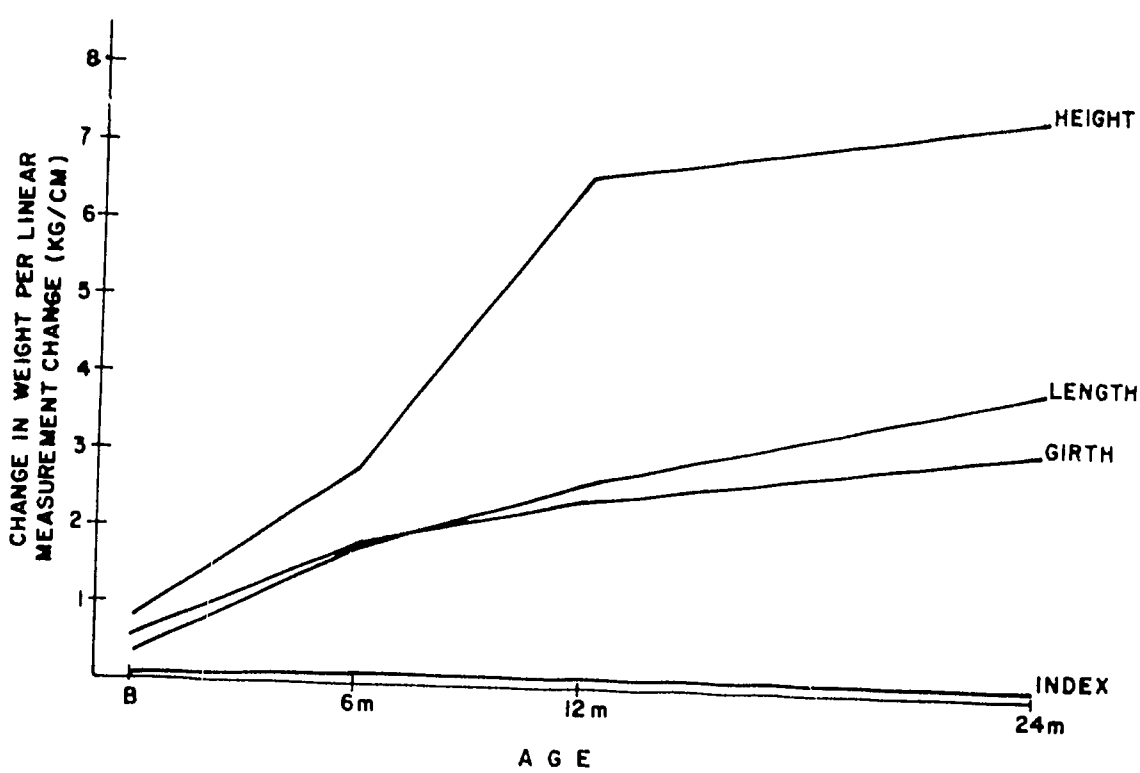

Figure 10. Change in weight per unit change in linear measurements and index.

Table 47. Correlations and regressions between linear measurements and weight.

Stage	Breed	No.	Correlation between weight and :				Regression of weight on :			
			Height	Length	Girth	Index	Height	Length	Girth	Index
Birth	1	67	0.54**	0.52**	0.65**	0.61**	0.94	0.44	0.49	0.05
	2	23	0.23	0.37	0.66**	0.60**	0.32	0.26	0.68	0.05
	3	28	0.58**	0.21	0.60**	0.51**	1.02	0.17	0.53	0.04
	4	15	0.31	0.53**	0.73**	0.71**	0.73	0.44	0.57	0.05
	5	26	0.53**	0.28	0.45**	0.46**	1.41	0.29	0.47	0.05
	6	23	0.58**	0.60**	0.69**	0.66**	0.96	0.47	0.43	0.04
	All	182	0.42**	0.43**	0.64	0.61**	0.79	0.35	0.52	0.05
6 m	1	67	0.63**	0.58**	0.71**	0.74**	3.34	1.38	1.45	0.06
	2	23	0.45*	0.67**	0.88**	0.86**	2.03	1.32	1.97	0.08
	3	28	0.53**	0.40*	0.56**	0.61**	1.84	0.63	0.76	0.04
	4	15	0.58**	0.81**	0.81**	0.85**	2.00	2.17	1.78	0.07
	5	26	0.82**	0.88**	0.90**	0.92**	6.84	3.04	2.86	0.11
	6	23	0.79**	0.70**	0.84**	0.84**	3.91	1.66	1.73	0.07
	All	182	0.61**	0.70**	0.79	0.82	2.81	1.75	1.76	0.08
12 m	1	67	0.63**	0.60**	0.73**	0.76**	3.53	2.21	1.66	0.06
	2	23	0.84**	0.73**	0.89**	0.89**	6.86	1.91	2.17	0.06
	3	28	0.78**	0.67**	0.77**	0.82**	5.39	2.39	2.77	0.09
	4	15	0.91**	0.90**	0.89**	0.93**	8.89	4.96	3.03	0.10
	5	26	0.75**	0.51**	0.89**	0.85**	7.76	2.11	2.50	0.08
	6	23	0.76**	0.67**	0.82**	0.80**	6.26	2.68	2.15	0.07
	All	182	0.79**	0.68**	0.84**	0.85	6.58	2.64	2.39	0.08
24 m	1	67	0.74**	0.69**	0.79**	0.85**	7.54	4.04	3.23	0.08
	2	23	0.72**	0.60**	0.85**	0.88**	6.77	2.28	2.65	0.07
	3	28	0.73**	0.77**	0.87**	0.89**	7.66	3.64	3.35	0.07
	4	15	0.77**	0.85**	0.92**	0.93**	8.29	4.84	3.11	0.07
	5	26	0.73**	0.67**	0.73**	0.78**	6.94	4.14	3.20	0.08
	6	23	0.71**	0.81**	0.86**	0.92**	7.09	4.70	3.29	0.08
	All	182	0.74**	0.74**	0.84**	0.88**	7.43	3.96	3.14	0.08

1 = Maure ; 2 = Peul ; 3 = M.P ; 4 = $\frac{3}{4}$ M ; 5 = $\frac{3}{4}$ P ; 6 = MP.MP

10.3 Use of linear measurements

On several occasions (see, for example, Ross, 1958), heart girth has been found to be the most satisfactory single measurement for estimating body weight. The results laid out in Table 47 suggest the index "length x girth^2" to be marginally superior to heart girth, but this index requires twice the measurements. Therefore in this present evaluation of the use of linear measurements for estimation of body weight at 12 and 24 months of age, heart girth has been selected as the most practical single measurement.

The overall regression equations for calculation of 12- and 24-month weights obtained from the data in Table 47 are :

12-month weight : $y = -151.8 + 2.39\ x$

24-month weight : $y = -226.5 - 3.14\ x$

The difference in the estimated weight and the actual weight recorded was calculated as a percentage of the actual weight for the 182 animals at 12 and 24 months of age. The number of animals whose weights were estimated to within two, five, and ten percent at each stage are presented in Table 48, along with the mean deviations and standard errors.

Table 48. Frequency of percentage differences in actual/estimated weights at 12 and 24 months.

Age	Frequency				Mean deviation (kg)	SE of deviation
	<2 %	2-5%	5-10%	>10 %		
12 m	37	30	43	72	10.9	1.04
24 m	42	50	56	34	13.8	1.34

At 12 months of age the estimated weight came within two per cent of the actual weight in 20% of the cattle (37 out of 182); to within five per cent in 37% of the cattle (37 + 30 out of 182); and to within ten per cent in 60% of the cattle (37 + 30 + 43 out of 182). At 24 months of age, the corresponding values were 23%, 51%, and 81%.

Estimation of weight from heart girth measurement in the field would therefore appear to be a reasonable method for purposes such as calculation of drug dosages dependent on body weight or indication of marketing weights. However, the results suggest that for more precise operations such as selection on body weight, heart girth measurement is not a satisfactory substitute for accurate body weight determination by weighing.

Chapter 11

PRODUCTIVITY

11.1 Cow productivity

Table 49 indicates the annual cow productivity at Niono for the period from first calving onwards, in terms of milked-out yield, number and weight of weaner calves, and proportion of final disposable cow body weight. This last parameter is the average cull cow weight divided by the number of years in the breeding herd.

Table 49. Annual cow productivity.

Productivity measure	Annual prod. of all cows completing a prod. year	Losses due to :			Annual prod. of all cows in herd
		Stillbirths + Day 1 deaths	Cow deaths	Pre-weaning deaths	
Milked-out yield (kg)	457	12	6	21	418
Number of weaner calves	0.78	0.02	0.01	0.07	0.68
Weight of weaner calf (kg)	62.7	1.6	0.9	5.7	54.5
Proportion of final available cow weight (kg)	48.8	-	1.4	-	47.4

The productivity measures in Table 49 take into account the important traits of reproductive performance, milk production, pre-weaning calf growth, and cow and calf mortality. Each year in the production herd the average cow produced 418 kg milk ; 0.68 of a weaner calf weighing 54.5 kg ; and 47.4 kg of its own final disposable live weight. In its 10-year lifetime, including 6.5 years in the milking herd, the average cow thus produced 2717 kg milk ; 4.4 weaner calves weighing 354 kg ; and 308 kg of final disposable cow body weight.

11.2 Breed productivities

A comparison of breed productivities in terms of annual cow production is laid out in Table 50.

Table 50. Breed of cow productivities.

Productivity	Annual prod. of all cows completing a prod. year	Losses due to :			Annual prod. of all cows in herd
		Stillbirths + Day 1 deaths	Cow deaths	Pre-weaning deaths	
Milked-out yield (kg)					
Maure	471	6	7	51	407
Peul	413	20	5	38	349
Maure x Peul	486	7	7	53+	420
Number of weaner calves					
Maure	0.78	0.01	0.01	0.08	0.67
Peul	0.77	0.04	0.01	0.07	0.65
Maure x Peul	0.79	0.01	0.01	0.06	0.69
Weight of weaner calf (kg)					
Maure	63.9	0.8	0.9	7.0	55.2
Peul	59.2	2.8	0.8	5.5	50.1
Maure x Peul	65.2	0.9	0.9	7.1	56.3
Prop. of final cow weight (kg)					
Maure	49.5	-	1.4	-	48.1
Peul	46.5	-	1.3	-	45.2
Maure x Peul	50.2	-	1.4	-	48.8

+ Data for Maure used, due to lack of data for progeny of M.P cows.

Table 50 shows the Maure to be superior to the Peul in all cow productive measures ; 16 % higher in milked-out yield ; 3 % higher in number of weaner calves ; 10 % higher in weight of weaner calf ; and 6 % higher in final disposable cow weight. When these measures are weighted by their approximate economic values, the Maure proves 13 % superior to the Peul in terms of overall cow productivity, while the Maure x Peul is 2 % superior to the Maure.

PART 3

COMPARISON WITH RELATED DATA

Chapter 12

SIMILAR PRODUCTION SYSTEMS IN ENVIRONMENTS COMPARABLE TO THAT OF NIONO

12.1 Introduction

A major problem of animal production in Africa is how to make maximum use of research results produced in isolation. An example of this is afforded by the Report of the First FAO Expert Consultation on Research on Trypanotolerance and Breeding of Trypanotolerant Animals (FAO, 1976), which concluded that although considerable work was still being undertaken on the productivities of trypanotolerant cattle types, little objective information had become available. For this reason it was stressed that the emphasis should be on comparisons between animals in a given environment, rather than on measures of absolute value.

The building up of accurate animal production information is expensive and takes time. Thus the gathering and comparison of data produced in isolation throughout Africa is of utmost importance.

It is not easy to accurately compare the productive performances of the Maure, the Peul, and their crossbreds at the Sahelian Station, Niono, with data available from other regions of Africa, since climate, production aims, feeding, and management systems differ so widely.

The initial approach in attempting comparisons was to build up a record of stations in Africa where indigenous Zebu and Sanga cattle were, or had been, maintained under conditions similar to those of the system at Niono for beef, milk, and draught purposes.

12.2 Climate

Assessment of the climatic conditions at each research station was carried out under the headings of annual rainfall, number of wet seasons, and altitude. Annual rainfall is the predominant influence on quantity, seasonal distribution, and ecological composition of the natural vegetation, in addition to being the major factor in rain-fed fodder crop production. Distinctions must be made between areas with one or two wet seasons per year. Even a short second wet season can greatly benefit the natural grazing conditions, in comparison to similar rainfall levels occurring only once per year. Not only altitude but also the micro-climate and ecology affect the physiology of the animal.

Table 51 shows the climatic data for Niono and 16 research stations throughout Africa where some results were available for approximate comparisons.

Table 52 indicates the four climatic zones to which the stations were assigned, using the Niono climatic data as the baseline.

Table 52. Climatic zones for comparison with Niono.

Zone	Mean annual rainfall (mm)	No. of wet seasons	Altitude (m)
I (NIONO)	500 - 600	1	low (0 - 600)
I a	350 - 500	1	low
I b	600 - 800	1	low
II	800 - 1200	1	low
III a	500 - 600	1	medium (900 - 1500)
III b	500 - 600	2	high (> 1500)
IV a	1300 - 1500	1	medium
IV b	800 - 1500	2	medium

Figure 11 indicates on the map of Africa south of the Sahara the extent of the different climatic zones and the positions of the 17 research stations.

Table 51. Climatic data for 17 research stations.

Station	Country	Rainfall (mm)				Altitude (m)	Temperature (°C)			Vegetation zone	Type of Station
		Annual		No. of seasons	Months						
		Mean	Years				Mean annual	Mean max.	Mean min.		
Niono	Mali	515	1966-76	1	May-October	277	27.2	34.1	20.2	Sahelo-sudanian	Station d'élevage et de Recherches Zootechniques du Sahel
Dahra-Djoloff	Senegal	397	1961-74	1	June-October	300	28.0a			Sahelian	Centre de Recherches Zootechniques
Toukounous	Niger	443	1954-66	1	May-October	500a	26.6b	35.1b	18.0b	Sahelian	Station d'Elevage du Zebu Azaouak
Ghazala Gawazat	Sudan	400-500		1	June-October	500a				Sahelian savannah	Animal and range research centre
Buiassa	Nigeria	630b		1	May-October	600a	28.0a	35.0a	20.5a	Sudanian savannah	Livestock investigation and breeding centre
Dugondaji	Nigeria	630b		1	May-October	600a	28.0a	35.0a	20.5a	Sudanian savannah	Livestock investigation and breeding centre
Bornu	Nigeria	635-660b		1	May-September	350-400a	27.0b	35.0b	19.0b	Sudanian savannah	Livestock investigation and breeding centre
Dalori	Nigeria	635-660b		1	May-September	350-400a	27.0b	35.0b	19.0b	Sudanian savannah	Livestock investigation and breeding centre
Shika	Nigeria	1090b		1	April-October	400a	25.0a	31.5a	18.5a	Northern Guinean	Agricultural research station
Birnin Kudu	Nigeria	800-1000a		1	April-October	600a	26.5a	32.5a	18.5a	Northern Guinean	Livestock investigation and breeding centre
Kabomo	Nigeria	800-1000a		1	April-October	600a	26.5a	32.5a	18.5a	Northern Guinean	Livestock investigation and breeding centre
APRU network	Botswana	519	1969-75	1	September - April	900-1200	21.5	29.5	13.0	Bush savannah	Network of 13 breeding stations
Naivasha	Kenya	573	1972-73	2	March-June/ October-December	1600	18.5	28.0	8.0	Bush savannah	National animal husbandry research station
Vom	Nigeria	1300-1500a		1	March-October	1280	22.0a	28.6b	17.0b	Open savannah	Livestock investigation centre (Fed. Dep. Vet. Res.)
Mbarara	Uganda	864b		2	March-June/ September-November	1430	21.0			Woodland savannah	Stock farm
Entebbe	Uganda	1520b		2	March-June/ September-November	1130	21.0			Lakeshore savannah	Livestock experimental station
Serere	Uganda	1380		2	March-June/ September-November	1100	23.0	29.0	17.0	Woodland savannah	Research station

a = estimation from topographic/climatic maps
b = approximate figure

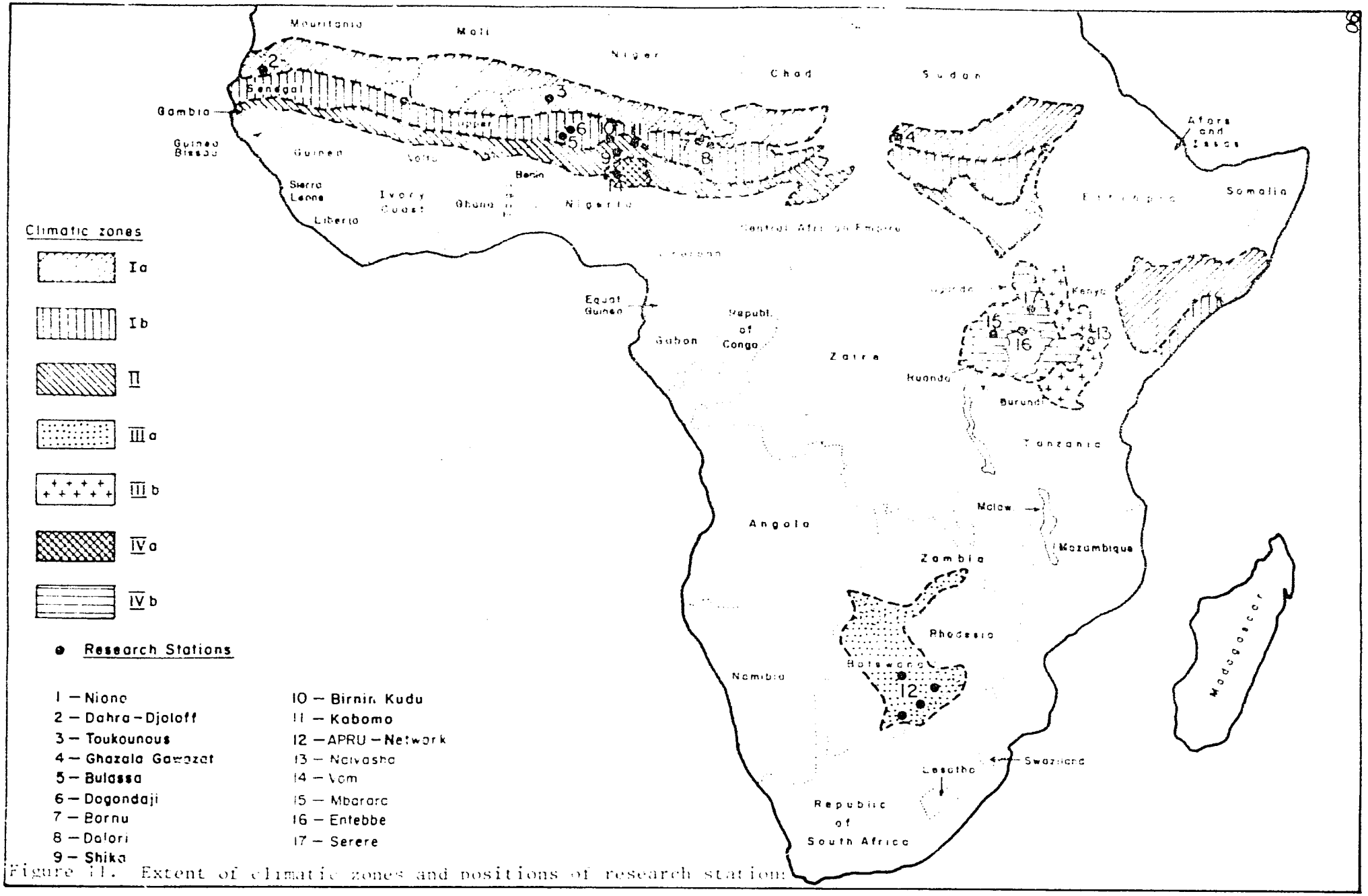

Figure 11. Extent of climatic zones and positions of research stations

12.3 Grazing and supplementary feeding

The grazing management and supplementary feeding system can have a very marked effect on productivity; thus a detailed assessment must be made of the system employed. The grazing and supplementary feeding systems used at the 17 stations are summarised in seven broad groups in Table 53.

Table 53. Grazing and supplementary feeding systems practiced at the 17 research stations in wet and dry seasons.

Group	Natural grazing		Roughage supplementation		Concentrate supplementation		Milk availability		
	Wet	Dry	Wet	Dry	Wet	Dry	Suckling all dam's milk	Bucket fed	Suckling after dam hand-milked
A	xx	xx	-	-	-	-			
B)	xx	xx	-	-	-	x			
B)	xx	x	-	x	-	-			
C	xx	x	-	x	-	x			
D	xx	x	-	x	x	x			
E							x	-	-
F							-	x	-
G							-	-	x

On the 17 research stations under consideration, grazing on fenced pastures was generally available all the year round, with varying degrees of roughage and concentrate supplementation. Three basic methods of supplying milk to young calves were utilised.

12.4 Available comparative data

Table 54 summarises the comparative production data available from the research stations throughout the different climatic zones. The documentation centre of the International Livestock Centre for Africa (ILCA) is still in the process of being built up, and thus a considerable amount of information relevant to this first specialist study in the field of cattle productivity has not yet been obtained. However, as ILCA's information storage and retrieval unit develops, this problem will be gradually overcome.

Table 54. Summary of sources of comparative information.

Climatic zone	Country	Research station	Reprod. perfor.		Milk production				Weight development							Cow wt	Mortality	
			Age at first calving	Calving interv.	Lact. yield	Lact. leng.	Daily lact. yield	Annual yield	Pre-weaning B	3m	6m	Post-weaning 12m	18m	24m	30m		Pre-weaning	Post-weaning
I	Mali	Niono	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
I a	Senegal	Dahra-Djoloff	+	+					+	+	+	+	+	+	+	+	+	+
I a	Niger	Toukounous		+	+	+	+	+	+	+	+	+	+	+	+	+		
I a	Sudan	Ghazala Gawazat		+					+		+	+				+		
I b	Nigeria	Bulassa	+	+					+	+	+	+	+	+	+			
I b	Nigeria	Dogondaji	+	+					+	+	+	+	+	+	+			
I b	Nigeria	Bornu Ranch	+	+					+	+	+	+	+	+	+			
I b	Nigeria	Dalori	+	+					+	+	+	+	+	+	+			
II	Nigeria	Shika	+	+	+	+	+	+	+	+	+	+	+	+	+			
II	Nigeria	Birnin Kudu	+	+					+	+	+	+	+	+	+			
II	Nigeria	Kabomo	+	+					+	+	+	+	+	+	+			
III a	Botswana	APRU netw.		+					+		+		+				Up to 2 years of age	
III b	Kenya	Naivasha		+					+	+	+	+	+	+	+	+		
IV a	Nigeria	Vom	+	+	+	+	+	+	+									
IV b	Uganda	Mbarara	+	+	+	+	+	+	+			+		+				
IV b	Uganda	Entebbe	+	+	+	+	+	+										
IV b	Uganda	Serere	+	+	+	+	+	+									Probably up to 1 year of age	

Additionally, many vital gaps in information available through reports and publications necessitate communication with individual stations. Thus the aim of Chapter 13 in this first specialist study is more to illustrate the approach than to attempt an overall comparison of production results at Niono with those from other research stations in Africa : the latter will be undertaken when the follow-up programme with individual stations has been completed.

Chapter 13

NIONO RESULTS IN RELATION TO THOSE FROM COMPARABLE SOURCES

As noted in Section 12.4, there are many gaps in the assessment of productivities on the 16 comparative research stations that remain to be filled by individual communications. Completion of this task is necessary before a precise picture of total output (meat, milk) per unit weight of cow per year in the different climatic zones, as related to the grazing and supplementary feeding systems employed, can be built up.

Tables 55-60 show the presently available comparisons of the important traits of age at first calving, calving interval, milk production, pre-weaning weights, and cow body weight. Only brief comments on each of these traits, plus mortality and productivity, can be presented at this time.

Age at first calving : In comparison with data received from the other stations, age at first calving at Niono appears reasonable ; and when the significant annual improvement is considered, there would seem to be little problem with this trait. However, the supplementary feeding regime is above average.

Calving interval : The calving interval at Niono appears rather long in comparison with intervals at the other stations, especially as the supplementary feeding regime is above average. However, the lactation stress may be greater since Niono cows are hand-milked and also suckle their calves. The significant reduction achieved each year is encouraging.

Milk production : The total annual yield (milked-out plus calf-utilised) appears satisfactory when compared to the yields at other stations, but regular improvement in yield has not been achieved every year.

Pre-weaning weights : Pre-weaning weights are below average. The fact that daily live weight gain is no higher than at any post-weaning stage suggests that the amount of milk received by the calf after hand-milking is completed limits pre-weaning growth. Significant improvement in pre-weaning weights was achieved each year, and the possibility of further improvement through selection is good.

Post-weaning weights : Post-weaning growth rates were good, but weight for age remained below average, still affected by poor pre-weaning growth. Significant improvement in post-weaning growth was achieved each year, and the possibility of further improvement through selection is good.

Cow body weight : At Niono, cow body weight tended to be slightly lower than at the other stations represented.

Mortality : Only one station, Dahra-Djoloff, has information covering total annual herd mortality over a number of years : 6.21 % is reported. The equivalent value at Niono is 7.04 %.

Productivity : Before productivity comparisons can be meaningfully constructed, the many gaps covering individual trait values illustrated in Table 54 must be filled. Comparisons can then be carried out, based on output of meat and milk per unit weight of cow per year, in relation to the supplementary feeding and grazing systems employed.

Table 55. Age at first calving.

Station	Country	Climatic zone	Breed	Investigation purpose	Feeding managem. system	Period of data collection	Age at first calving records n	x	s.e.	h^2	Signif. env. effects	Signif. breed effects	Ref.
Niono	Mali	I	Maure	Beef,			71	42.3			Year of		
			Peul	milk,	D	1966/73	19	44.8	2.1	0.03	birth		
			M x P	draught			58	43.3		± 0.12			
Dahra-Djoloff	Senegal	I a	Gobra	Beef	C	1955/70	534	45.5	0.8				
			Gobra	Beef	D	1970	24	31.1	1.5		Feed		6
			Gobra	Beef	C	1970	24	39.8	1.8		system		
Bulassa	Nigeria	I b	Sokoto Gudali	Milk	C	1968/70 v	34	43.4	7.7x				24
Dogondaji	Nigeria	I b	Sokoto Gudali	Beef	C	1968/70 v	75	40.8	9.8x				24
Bornu	Nigeria	I b	Wadara	Beef	B	1965/70 v	34	45.4	6.6x				22
Dalori	Nigeria	I b	Wadara	Milk	B	1965/70 v	103	52.4	7.6x				22
Shika	Nigeria	II	White Fulani	Milk	B	1959/72	433	41.8	10.1x				25
Birnin Kudu	Nigeria	II	White Fulani	Milk	C	1965 v	52	42	11 x				23
Kabomo	Nigeria	II	White Fulani	Beef	C	1965 v	46	42	8.5x				23
Vom	Nigeria	IV a	White Fulani	Milk	C	1946/56	64	45.5	0.8				
			White Fulani	Milk	C	1968/69	11	47					9
Mbarara	Uganda	IV b	Ankole	Milk	C	1956/61	43	51.3	1.2				
			Small E.A.Zebu	Milk	C	1956/61	39	51.7	1.5				16
Entebbe	Uganda	IV b	Nganda	Milk	B	1947/56		42.0	0.5	0.08 ± 0.25			11
Serere	Uganda	IV b	Small E.A.Zebu	Milk	Prob. A or B	1943/63		42.7	0.6	- 0.03 ± 0.23			18, 19

v : exact period not known, estimations

x : standard deviation

Table 56. Calving interval.

Station	Country	Climatic zone	Breed	Investigation purpose	Feeding managem. system	Period of data collection	Calving interval records n°	$\bar{x}$	s.e.	h^2	Signif. env. effects	Signif. breed effects	Ref.
Niono	Mali	I	Maure	Beef, milk, draught	D/G	1966/73	225	470	25	r=.23	Year of calving		
			Peul				216	474					
			M x P				85	460					
Dahra-Djoloff	Senegal	I a	Gobra	Beef	C/E	1955/70	1257	473	8				6
			Gobra	Beef	D/E	1970	23	378	35				
			Gobra	Beef	C/E	1970	23	409	41				
Toukounous	Niger	I a	Azaouak	Milk	B or C/E	1962/66	683	535x					3
Ghazala Gawazat	Sudan	I a	Western Baggara	Beef	A/E	1959/60	148	615					14
Bulassa	Nigeria	I b	Sokoto Gudali	Milk	C/F	1968/70 v	9[illegible]	496	16				24
Dogondaji	Nigeria	I b	Sokoto Gudali	Beef	C/E	1968/70 v	132	439	11				24
Bornu	Nigeria	I b	Wadara	Beef	B/E	1965/70 v	309	533	9				22
Dalori	Nigeria	I b	Wadara	Milk	B or C/F	1965/70 v	103	444	8				22
Shika	Nigeria	II	White Fulani	Milk	C/F	1959/72	1336	411	3				25
Birnin Kudu	Nigeria	II	White Fulani	Milk	C/F	1965 v	129	388	7				23
Kabomo	Nigeria	II	White Fulani	Beef	C/E	1965 v	101	436	12				23
Vom	Nigeria	IV a	White Fulani	Milk	D/F	1946/56	347	367					9
			White Fulani	Milk	D/F	1968/69	25	362					2
Mbarara	Uganda	IV b	Ankole	Milk	D/F	1956/61	128	342	4				16
			Small E.A.Zebu	Milk	D/F		86	347					
Entebbe	Uganda	IV b	Nganda	Milk	D/F	1947/56		420	9				11
Serere	Uganda	IV b	Small E.A.Zebu	Milk, beef	A or B/G	1943/51		382	7	-0.01 ±0.30	F sign. diff. of G and G*		18, 19
					A or B/F	1947/56		373	5				
					A or B/G*	until 1963		387	7				
APRU network	Botswana	III a	Africander	Beef	A/E	1970/75	1875	606x				All breeds	1
			Tswana	Beef			426	535x					
			Tuli	Beef			527	475x					
Naivasha	Kenya	III b	Boran	Beef	B or C/E	1969/74		591x					13

v : exact period not known, estimations

x : calculated from calving percentage

* : calves being suckled throughout day, cows milked morning only

Table 57. Milk production.

Station	Country	Climatic zone	Breed	Invest. purpose	Feeding/ management system	Period of data collection	Milking system	Lactation yield n	Lactation yield x̄	Lactation yield s.e.	Lactation length n	Lactation length x̄	Lactation length s.e.	Daily lactation yield	Fat %	Calculated annual milk yield	Signif. environ. effects	Signif. breed effects	h^2	Ref.
Niono	Mali	I	Maure Peul M x P	Beef, milk, draught	D	1968/73	Suckled + milked out	186 154 78	1,206 1,118 1,197	30						1,003 888 1,003	Year, month		r lact.yield =0.54 r ann. yield =0.34	
			Maure Peul M x P	Beef, milk, draught	D	1966/73	Milked out only	225 216 85	586 522 583	22	225 216 85	249 258 255	6	2.3 2.0 2.2	4.7	471 413 486	year, month, part.no.	P < M and MxP in daily and ann. yield	r lact.length=0.31 r lact.yield =0.55 r ann. yield =0.48 r daily yield=0.51	
Toukounous	Niger	I a	Azaouak	Milk	Prob. BorC	1966/67	Milked out milk recorded daily	90	1,043		90	325		3.2	5.1	712x				8
Shika	Nigeria	II	White Fulani	Milk	C	1970/71	Milked out	71	763		71	196		3.9		678x				17
			White Fulani	Milk	C		Prob. milked	28	1,019		28	259		3.9						7
			White Fulani	Milk	C	1952/57	Milked out by machine	34	1,301	68	34	291	7	4.5		1,125x				
			Sokoto Gudali	Milk	C	1952/57		13	1,312	126	13	279	17	4.7						12
Vom	Nigeria	IV a	White Fulani	Milk	D	1960/69 v	Milked out recorded daily	389	835	17	374	246								9
Mbarara	Uganda	IV B	Ankole	Milk	D	1956/61	Milked out only lact. over 100 days	153	835	31	153	229		3.6		891x		Lact. yield, daily yield		16
			Small E.A.Zebu	Milk	D			112	613	26	112	230		2.7		645x				
Entebbe	Uganda	IV b	Nganda	Milk	D	1947/58	Milked out only lact. over 100 days		1,032	43		267	5	3.9		897			1st lact.length 0.11± 0.26 1st lact. yield 0.20± 0.31	11
Serere	Uganda	IV b	Small E.A.Zebu	Milk, beef	Prob. A	1943/51	Suckled plus milked out cows milkled 2 x a day		529	16		221	4	2.4		505				
						1947/52	Milked out 2 x a day	1,319	786	19	1,319	229	4	3.4		769	Lact. length, yield			18
						Until 1963	Suckling + milked in the morning		533	11		232	4	2.3		503				

v : exact period not known, estimations.

x : calculated from calving interval figures not belonging to the same cow numbers.

Table 58. Pre-weaning weights.

Station	Country	Climatic zone	Breed	Invest. purpose	Feeding managem. system	Period of data collection	Birth weight No	Birth weight $\bar{x}$	Birth weight s.e.	3 month weight No	3 month weight $\bar{x}$	3 month weight s.e.	6 month weight No	6 month weight $\bar{x}$	6 month weight s.e.	Daily gain g	h^2	Signif. envir. effects	Signif. breed effects	Ref.
Niono	Mali	I	Maure	Beef,			231	21		231	54		231	82		339	B = .31	Year, sex,	3m x 6m	
			Peul	milk,	G/D	1968/74	89	20	0.31	89	49	0.95	89	76	1.44	311	3 m = .14	month,	Peul/others	
			M x P	draught			94	20		94	51		94	78		322	6 m = .32	parturition,		
																		feed system		
Dahra-Djoloff	Senegal	I a	Gobra	Beef	E/C	1965/70	460	24w		440	60w	1.5	362	92w	9.9	372				4
			Gobra	Beef	E/D	1968/71	41	22w	0.30	42	64w	6.8	43	122w	2.4	546		Feed system		
Toukounous	Niger	I a	Azaouak	Milk	E/B or C	1959/64	962	20			68			98		426				3
Ghazala	Sudan	I a	Western	Beef	E/A	1959/60	133	23w					133	97wy		404				15
Gawazat			Baggara	Beef	E/A	1962/64	80	21w	0.46				80	76wy	1.28x	302				16
Bulassa	Nigeria	I b	Sokoto Gudali	Milk	F/C	1968/70 v	90	22	0.27	70	62z	1.72	65	96z	2.72	406	B = 0.72 3 m = 0.04 6 m = 0.0			24
Dogondaji	Nigeria	I b	Sokoto Gudali	Beef	E/C	1968/70 v	171	22	0.27	94	76	2.0	57	113	2.67	497	B = 0.60			24
Bornu	Nigeria	I b	Wadara	Beef	E/prob. B	1965/70 v	263	23	0.23	48	80	2.3	65	113	2.72	492	3 m = 2.68 6 m = 0.92			22
Dalori	Nigeria	I b	Wadara	Milk	F/prob. B or C	1965/70 v	359	24	0.18	185	61	0.9	198	79	1.45	301				22
Shika	Nigeria	II	White Fulani	Milk	F/C	1959/70	775	23	0.09	610	62	0.6	625	101	0.7	426				25
				Beef	E/B	1973/74	37	24w					37	129wy		580				7
Birnin Kudu	Nigeria	II	White Fulani	Milk	F/C	1965 v	118	22	0.4	77	64.5	1.5	77	130	2.8	590	B = 0.4			23
Kabomo	Nigeria	II	White Fulani	Beef	E/C	1965 v	84	23	0.5	70	81	1.4	44	130	3.5	585				23
APRU network	Botswana	III a	Africander	Beef	E/A		1469	30					1360	150y		667				
			Tswana	Beef	E/A	1970/75	975	31					943	156y		699				1
			Tuli	Beef	E/A		438	29					431	153y		686				
Naivasha	Kenya	III b	Boran	Beef	E/prob. B or C	1971/72	44	28w		44	93w		44	146w		645				13

v : exact period not known, estimations

w : calculated from separate male and female weights

x : calculated on the basis of individual weights

y : calculated from 7 months weaning weights

z : females only

Table 59. Post-weaning weights.

Station	Country	Climatic zone	Breed	Invest. purpose	Feeding managem. system	Period of data collection	12 month weight			18 month weight			24 month weight			30 month weight			Signif. env. effects	Signif. breed effects	Ref.
							No	x	s.e.	No	x	s.e.	No	x	s.e.	No	x	s.e.			
Niono	Mali	I	Maure Peul M x P	Beef, milk, draught	D	1968/72	98 28 46	122 118 125	3.45	98 28 46	175 164 178	3.79	98 28 46	221 206 217	3.91	98 28 46	264 247 262	4.61	Year, month, sex		
Dahra-Djoloff	Senegal	I a	Gobra Gobra	Beef Beef	C D	1965/70 1968/71	419 42	136w 228w	2.0x 5.3x	310 42	185w 339w	2.9x 7.0x	296 42	238w 422w	2.9x 9.0x	160	288w	4.7x	Feed system		4
Toukounous	Niger	I a	Azaouak	Milk	B or C	1959/64		126			168			188			248				3
Ghazala Gawazat	Sudan	I a	Western Baggara	Beef	A	1962/64	80	135wy	4.3												15
Bulassa	Nigeria	I b	Sokoto Gudali	Milk	B	1968/70 v	55	126z	3.5	46	165z	4.4	43	208z	5.1	34	245z	5.8			24
Dogondaji	Nigeria	I b	Sokoto Gudali	Beef	B	1968/70 v	57	113	2.7	49	199	5.2	5	240	4.3	7	300	10.1			24
Bornu	Nigeria	I b	Wadara	Beef	B	1965/70 v	113	145	2.7	111	189	3.2	1.8	201	3.0	103	257	4.7			22
Dalori	Nigeria	I b	Wadara	Milk	B	1965/70 v	180	111	2.2	148	135	2.5	131	160	3.7	113	178	3.6			22
Shika	Nigeria	II	White Fulani	Milk	B	1959/70	522	150	1.1	392	188	0.9	345	226	1.5	313	266	2.2			25
Pirnin Kudu	Nigeria	II	White Fulani	Milk	D to 12 m C after	1965 v	69	180	3.2	62	236	4.1	42	277	5.3	30	299				23
Kabomo	Nigeria	II	White Fulani	Beef	D to 12 m C after	1965 v	22	209	6.2	9	255	8.0	8	333	8.1						23
Mbarara	Uganda	IV b	Ankole	Milk	B	1955/63	190	137w	3.6				175	196	3.8						20
APRU network	Botswana	III a	Africander Tswana Tuli	Beef Beef Beef	A A A	1970/75				985 690 309	271 284 283									Tswana, Tuli, Africander	1
Naivasha	Kenya	III b	Boran	Beef	B or C	1969/72	78	211w		62	265w		49	299w		35	350				13

v : exact period not known, estimations

w : calculated from separate male and female data

x : calculated from standard deviation

y : calculated from 14 months weight

z : females only

Table 60. Cow body weights.

Station	Country	Climatic zone	Breed	Feeding management system	Number	Weight (kg)	Ref.
Niono	Mali	I	Maure	D	122	322	
			Peul	D	56	302	
			M x P	D	64	326	
Dahra-Djoloff	Senegal	I a	Gobra	D	63	380	10
				Selected herd			
				B or C	71	350	10
				Unselected			
Toukounous	Niger	I a	Azaouak	A or B		325	3
Ghazala Gawazat	Sudan	I a	Western Baggara	A		272-340	14
Naivasha	Kenya	III b	Boran	B or C	139	372	13

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