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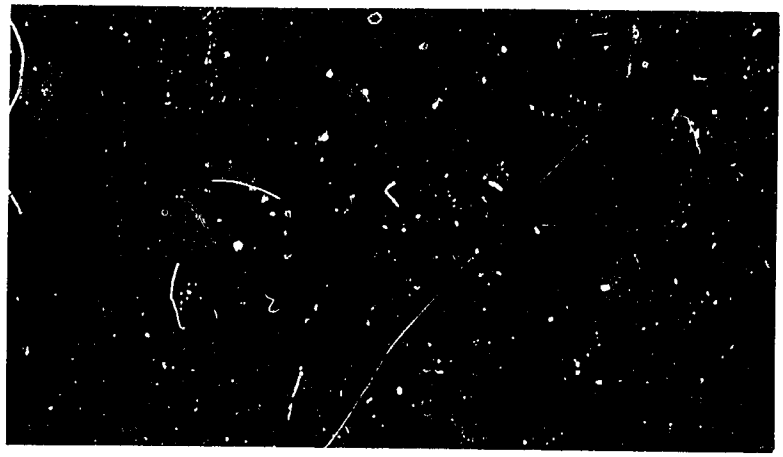

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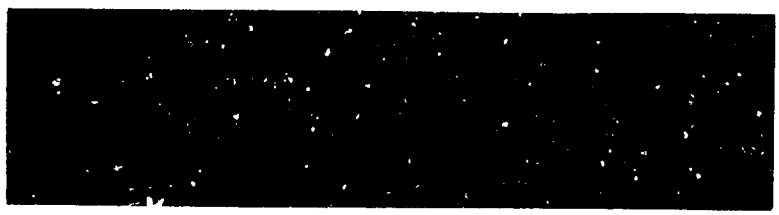

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SYSTEMS APPROACH TO GOBRA ZEBU PRODUCTION IN DAHRA, SENEGAL

by

KODJO PIERRE ABASSA

JUNE, 1984

INSTITUT SEGALAIS DE RECHERCHES AGRICOLES
AFRICAN AMERICAN INSTITUTE
AND
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OF THE UNIVERSITY OF FLORIDA
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1984

FOREWARD

Dr. Kodjo Pierre Abassa's doctorial dissertation has been duplicated and distributed by the Animal Science Department, Center for Tropical Agriculture, Institute of Food and Agricultural Sciences, University of Florida with contract funds from the Office of Agriculture, Bureau for Science and Technology, Agency for International Development, Washington, D.C.

Investigations reported in this dissertation were conducted with data from the Government of Senegal, Livestock Research Station located at Dahra-Djoloff, Senegal. The data used were that collected between the years 1968 and 1980.

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Dr. Abassa plans to return as faculty member to the Ecole Inter-Etats des Sciences et Medecine Veterinaires de Dakar, Senegal.

To my parents

Raphael Y. Abassa

Celine S. Nekou

my brothers

Celestin and Prosper Abassa

and my sisters

Vicentia and Regine Abassa

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Abstract of Dissertation to the Graduate School
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SYSTEMS APPROACH TO GOBRA ZEBU PRODUCTION
IN DAHRA, SENEGAL

By

KODJO PIERRE ABASSA

April, 1984

Chairman: Joseph H. Conrad
Major Department: Animal Science

Forage, production and reproduction data collected on purebred Gobra Zebu at Dahra Livestock Research Center were used (1) to study the growth patterns of Gobra Zebu under the conditions at the Dahra Livestock Research Center, (2) to evaluate the effects of some environmental and genetic factors affecting growth parameters required to simulate Gobra Zebu production system, (3) to validate the Texas A & M Beef Cattle Production Model and (4) to measure the effects of management alternatives on production efficiency of Gobra Zebu production system. Year and month of birth affected all the parameters studied. Age of dam was a significant source of variation influencing birth weight of female and all calves, weaning weight, yearling weight and long yearling weight of all calves. Calves born in dry years and in dry seasons were

heavier at weaning and 18 months of age and lighter at 12 months of age than those born in wet seasons and years.

Sire affected birth weight of all calves ($P<.05$) and female calves ($P<.05$), weaning weight of female and all calves ($P<.001$), weaning weight of male calves ($P<.05$), yearling weight ($P<.05$), long yearling weight ($P<.001$) and maturing rate ($P<.10$). Heritability estimates from paternal half-sib correlations for birth weight, weaning weight, yearling weight and long yearling weight were .20 ± .14, .46 ± .19, .41 ± 1.8 and .23 ± .15, respectively for female calves, .14 ± .09, .34 ± .13, .33 ± .13 and .15 ± .09, respectively, for all calves. Genetic and phenotypic correlations between body weights were all positive. Low to negative genetic and phenotypic correlations between relative growth rate (maturing rate) and body weights were obtained.

A simulation study of management alternatives likely to improve cow-calf production showed that the most promising alternative combinations which lead to the highest efficiency of nutrient utilization and cow productivity were those including feeding supplement, breeding replacement heifers from September through November, and weaning calves at constant age of 7 months.

INTRODUCTION

The Sylvopastoral Zone of Senegal or Ferlo

The Ferlo (Fig. 1) is a large plain of sahelian zone of Senegal. It is located at 15° west longitude and between 13° and 15° north latitude and covers an area of 40,000 km^2.

The climate is soudan-sahelian type in the north, sahelian-soudan type in the south. The temperature is generally high with an extreme value of 40°C from February through July. The humidity is low. The average annual rainfall and number of rainy days increase from the north to the south with 37 days and 536 mm in Matam, 67 days and 942 mm in Tabakounda (Doutre et al., 1975).

The region is characterized by the absence of rivers, which increases its aryness. Years ago, there were only fossil valleys in the Ferlo. Numerous swamps occurred along these valleys during the rainy season giving rise to dense vegetation growth with a life expectancy of no longer than four months.

Other vegetation is made up of a savanna with sparse trees including mesophytes such as Schoenefeldia gracilis, Eragrostis tremula, Onidium elgans, Aristida mutabilis, Crottalaria perotteti, Zornia glochidiata, some perennial grasses namely, Andropogon gayanus, Aristida longiflora and

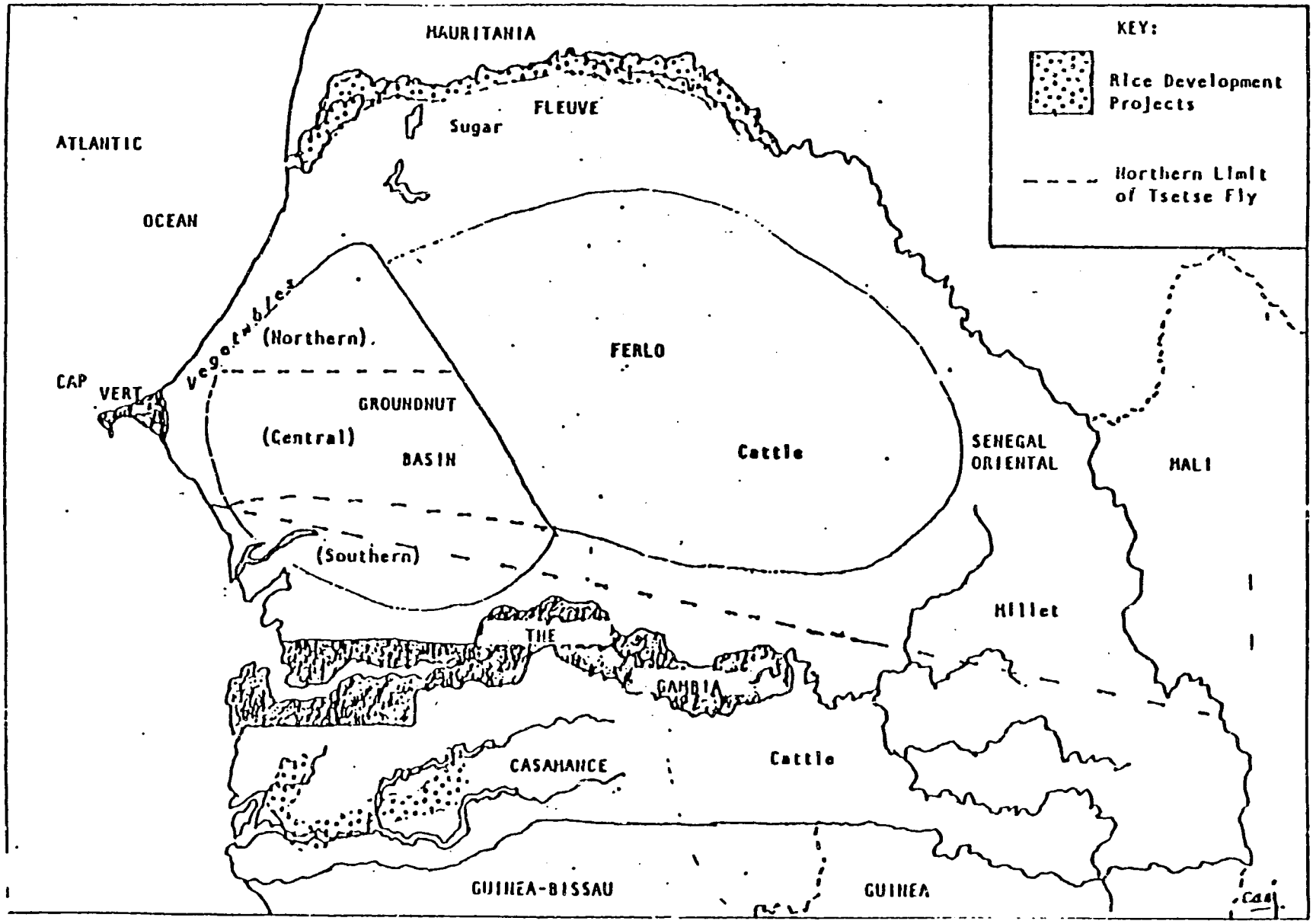

Figure 1. Senegal: agricultural production zones

browse such as Acacia seyal, Balanites aegyptiaca, Guiera senegalensis, Combretum glutinosum and Sclerocarya birrea.

The Fulani represent the dominant ethnic group of the region. They manage the majority of the livestock. In the past, the Fulani could only occupy the Sylvopastoral zone for a short period of the year. They were forced to move their herds to the south or to the Senegalese River Basin, in search of water and pasture as the swamp areas dried. The natural conditions such as water scarcity, therefore, dictated the economic activity of the region and oriented this activity towards extensive livestock production systems. Oftentimes, the herds suffered enzootic diseases such as rinderpest, pleuropneumonia and anthrax which limited their size over the years. Extensive burning was another factor constraining livestock expansion during the dry seasons. The Fulani survived these destructive environmental factors using their expertise (medicinal plants, traditional prophylactic techniques) to cure and prevent, to a certain degree, the diseases while relying on their animals for prestige, meat and milk.

Today, conditions in the sylvopastoral zone have improved somewhat and so has the life-style of the Fulani and the structure of the livestock production systems. Vaccinations of the herds against infectious diseases started after the first world war. The drilling of wells began in the 1940's. Many wells are currently found in the sylvopastoral zone making it possible for the herds to remain there throughout

the year. Villages have emerged around the wells and nomadism has been reduced from hundreds to only dozens of kilometers.

Two distinct livestock production systems are now recognized in the region. One system is the pastoral or semipastoral system where animals are either owned by sedentary farmers and non-farm households and entrusted to herders for various forms of payment or are owned by the Fulani themselves. Migratory movements of livestock characterize this system and vary with seasonal constraints (rainfalls and pasture) and availability of wells. The herds rely solely on pasture for their nutritional needs. There is no mineral or protein supplementation. The other system is the freehold farming system with fenced ranching and available water all year round; animals also rely primarily on pasture which may be supplemented with minerals and protein.

The Ferlo has two-thirds of the cattle, sheep and goats raised in Senegal. Because this area is a major livestock producing region and for other reasons mentioned earlier, the governmental Livestock Research Center of Dahra has been developed in the region to implement research and extension programs designed to improve livestock and related production system.

Problem Statement

The basic prerequisite for successful beef cattle production is a good understanding of the interactive effects of genetic, environmental and managerial components on the system of interest. The continuous failure of many research

projects designed to improve livestock production in developing countries is primarily due to the inexplicable undermining of the complex nature of animal husbandry. Researchers have spent much time and money to improve separately the constraining environment, the poorly productive genotypes and the traditional managerial practices. The results to date are a slow response to inputs, a well known low production efficiency and thus a continuous increase in meat deficit which in turn strains the all time poor trade balance. This is true of Senegal which, despite its great potential for livestock production, continues to suffer a chronic meat shortage. Mongodin and Tacher (1979) acknowledged that Senegal not only has exceptional feedstuffs available for the development of animal productions, but also is equipped with the best livestock research facilities that can be found in any West-African or Maghrebian country. Senegal also implements more domestic and external funded projects than any of its neighboring countries and yet imports cattle, sheep and goats from Mali and Mauritania.

The total meat produced in 1980 was 38,000 metric tons (USAID, 1983) while the human population was 5,661,000 (World Bank, 1983). Based on these figures, the annual per capita domestic meat consumption was 6.713 kg. This was less than 60 percent of the minimum 13 kg recommended by F.A.O. Senegal, therefore, would need 35,593 metric tons of imported meat, nearly 94 percent of the domestic production, to meet its requirements.

A research methodology which considers the system of production as a whole, studies simultaneously the integrated effects of the three groups of components (genetics, environment, management) and predicts the consequences of changing variables or applying different practices under the same production constraints will provide producers with a better guide in the decision-making process for an efficient and profitable livestock operation. This decision process may involve

- which genotypes to use and
- which managerial practices to choose when facing an environment which is to be improved.

Systems analysis provides means for such study and prediction.

Objectives

The general objective of this study was to estimate and predict the production performances of Gobra Zebu through the use of a combination of process oriented research techniques and systems analysis. The specific objectives were, under the conditions of the Livestock Research Center of Dahra (Senegal),

1. to study the growth of Gobra Zebu,
2. to estimate the environmental and genetic parameters required to simulate the Gobra Zebu production system,
3. to validate the simulation results obtained from the Texas A & M cattle production systems model against the production data obtained from Dahra and

4. to evaluate the effects of various management alternatives on the production efficiency of the Gobra Zebu production system.

REVIEW OF LITERATURE

Systems and Systems Approach to Livestock Production

A system may be defined as a set of objects together with relationships between themselves and between their attributes (Hall and Fagen, 1956) or a set of physical objects connected through interrelationships which exist within given boundaries (Cartwright, 1979). Systems, therefore, have physical or conceptual boundaries and as such can be classified as open or closed. An open system is the one that interacts with the environment (i.e., a set of elements or objects extraneous to the system). In a close system, objects do not interact with objects extraneous to the system.

A systems approach to a problem is one which defines the problem in relation to some system; it differs from the commodity or process oriented approach which is concerned with understanding some process and not with how such understanding might be used to influence the system of which the process is a part (ILCA, 1978). Cartwright (1979) defines the systems approach to (or systems analysis of) beef cattle production as a technique of examining complex production systems over time where all major inputs and outputs are accounted for by the use of mathematical models that describe

sets of dynamic, interacting processes which are considered to include all the important effects influencing the outcome. Technically, systems analysis involves model building and analysis of system behavior. A model is a set of equations describing real situations (e.g., animal functions and responses) while simulation refers to operating the model so that it approximates as closely as possible the performances under the prevailing real conditions. Since a model is an abstraction of reality, it is inherently subject to errors which are to be minimized. Modeling, however, provides the researcher with many advantages which are as follows:

1. modeling requires a good understanding of the system of interest,
2. models guard against internal inconsistencies,
3. models illuminate unwarranted assumptions, irrelevant variables and relationships,
4. models are amenable to computerized analysis and
5. models provide a logical organization and/or systematic way to examine a complex problem.

Because beef production is a complex enterprise involving numerous components most of which are interrelated, a multi-disciplinary effort (i.e., a system oriented work) both within the field of animal science and between animal science and other disciplines rather than a component or commodity research is needed to understand the input-output relationships and the interactive effects of the variable components

on the final outcome. This need has long been recognized by animal scientists, but isolated process oriented research which generates inefficient recommendations persist because they are convenient (Joandet and Cartwright, 1975) and also because of the idea that if the parts were looked after well, the whole would somehow take care of itself (Cartwright, 1979). In retrospect, one can only be content that progress has been made since the description of system principles (Forrester, 1968) nearly two decades after the development of the system theory (Bertalanffy, 1951). Many beef cattle production models of varying degrees of usefulness have been developed and used particularly in the tropics and subtropics: Beef (Walker et al., 1977a; 1977b; 1977c; Loewer et al., 1981), Argentine (Fujita, 1974), BAE (Reeves et al., 1974), Clarence (Trebeck, 1971), Brazil-Emprapa (Monteiro et al., 1980), Grafton (Beck et al., 1982), Hatsim (Juri et al., 1979), Kenya (Simpson et al., 1977), Texas (Sanders and Cartwright, 1979a; 1979b).

The Texas A & M Beef Cattle Production Model (TAMU Model)

The general objective of the model is to provide a framework for solutions to the following types of problems: given a feed resource, how can it best be used by a herd of cattle and what type of cattle can best utilize the feed resource (Sanders, 1977). Rather than assuming some level of animal performance and calculating the feed required to meet the assumed performance as it is traditionally done in

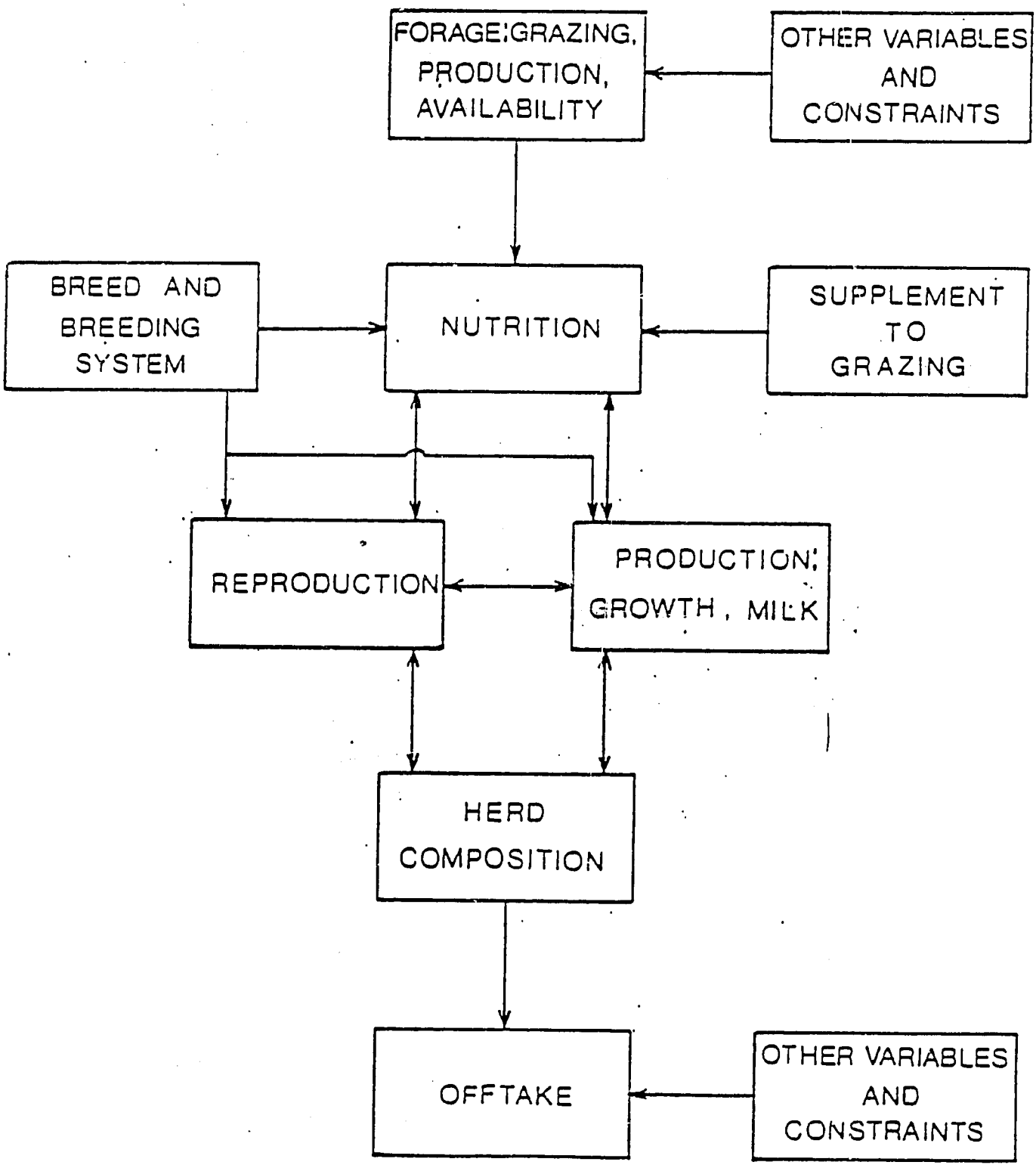

Figure 2. Components of the beef cattle production systems model (Smith, 1979)

animal science, quality and quantity of feed consumed along with genetic potential for mature size and milk production are used to simulate growth rate, milk production, fertility and death rates. The major components of the model are shown in figure 2.

The major assumption underlying the model development is that three characteristics account for a large proportion of source of variability in performance or productivity among cattle on a life-cycle basis. These characteristics are

1. mature size,
2. milk production and
3. maturing rate.

Both current and previous nutrition of animals are accounted for by specifying both the animal's present weight (W) and its structural size (WM). The latter (i.e., WM) is the weight of an animal in good condition with 3 percent and 25 percent fat at birth and maturity, respectively. Genetic potential for mature weight (WMA) and rate of increase in WM are specified by the growth curve for structural size (Fig. 3). The weight (W) can deviate from its WM depending on the nutritional status of the animal. A low plane of nutrition causes W to be below WM and a very good plane of nutrition forces it above its WM. Present nutrition is a function of animal's nutritional requirements which are determined by age, sex, size, condition and pregnancy or lactational status, and the quality and amount of feed available. Previous nutrition is reflected in the deviation of W from WM, whereas present

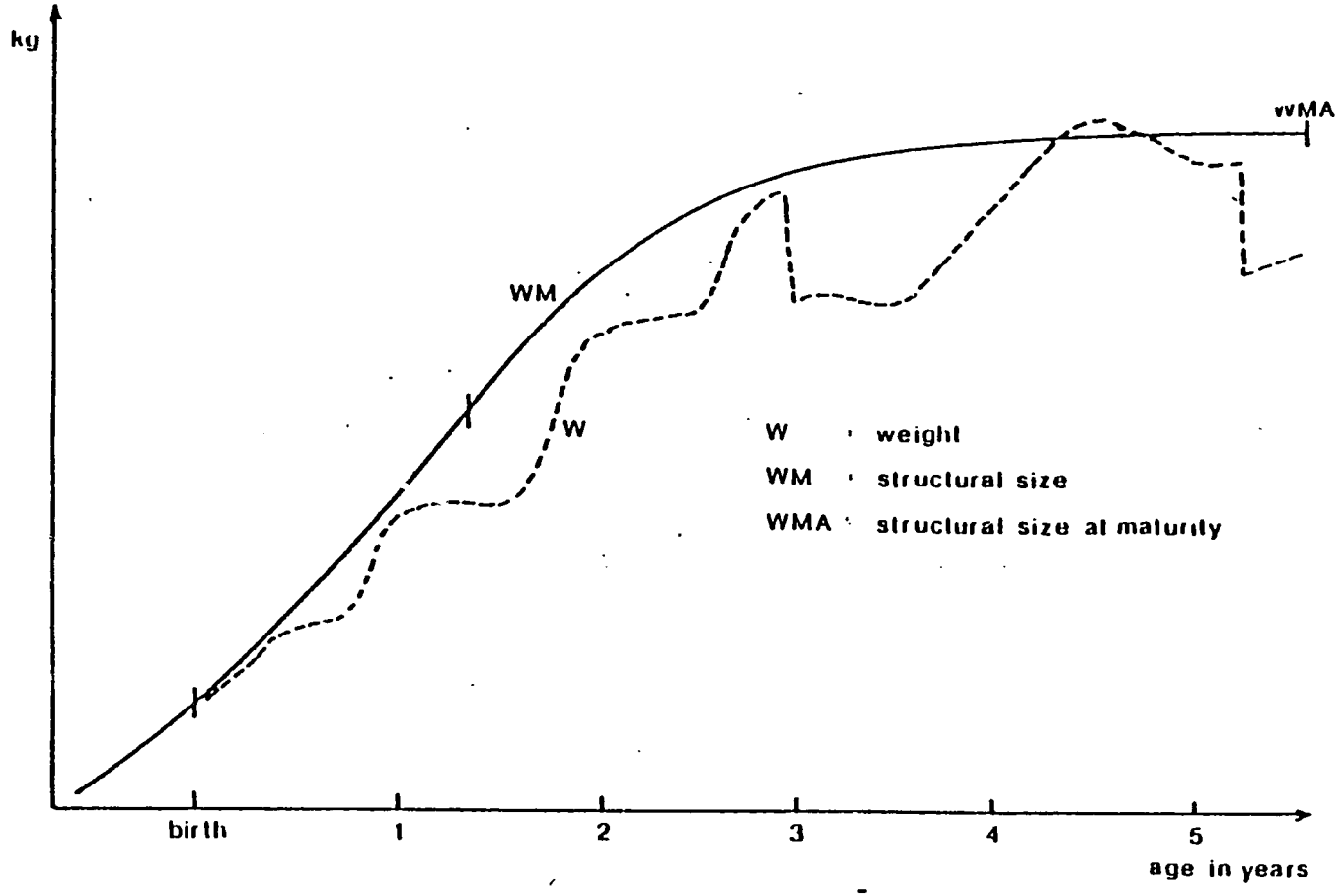

Figure 3. A typical growth curve for structural size (Smith, 1979)

nutrition in growth of WM and change in W. Actual animal performance accounts for the effects of cow age, stage of lactation, cow condition and nutrition. This performance is calculated monthly and aggregated for animals of the same age, sex, size and physiological status.

The TAMU model is written in the FORTRAN language and is made up of a main program and various linked subroutines. The main program is primarily an accounting routine that keeps inventories of the number and status of the animals in various age groups or classes. It also reads the input data and controls the output. The herd size and various management options are specified in this routine. Animal performance is simulated using GRO, FERT and DIE subroutines. Three minor subroutines (WEAN, SP and HRP) are used

1. to return to the main program the fraction of cows in the class whose calves are weaned at the end of the current month (WEAN subroutine),
2. to return to the main program the fraction of animals in the class to be sold at the end of the current month of simulation and the price per kilogram of these animals (SP subroutine) and
3. to calculate the fraction of heifers kept as replacements (HRP subroutine).

The GRO Subroutine

The GRO simulates animal growth. Feed resources are read by month into this subroutine. These are DIG (percent total digestible nutrients), AVC (available dry matter in

kilogram per mature cow per day) and CP (percent crude protein content). During each month of simulation, growth rates of W and WM and, if appropriate, the milk production for each class are calculated as functions of genotype, animal size, level of maturity, condition, physiological status and intake. Daily intake requirements for maintenance, lactation, pregnancy, growth and condition are calculated as a function of genotype, size, condition, age, sex and physiological status of the animal. The equations used to calculate the daily total requirements and other key parameters are as follows:

<u>Maintenance</u>. $M = .0306\ W^{.75} \left(\frac{WM}{W}\right)^{.5} \left(\frac{WMA}{WM}\right)^{.15}$

where $\left(\frac{WM}{W}\right)^{.5}$ and $\left(\frac{WMA}{WM}\right)^{.15}$

are correction factors for condition and degree of maturity, respectively.

<u>Pregnancy requirement</u>. $RP = .0000275WMAe^{.522(k-1)}$

where K = month of gestation.

<u>Requirement for growth in WM</u>.

$$RG = .8GWM + \frac{(.22GWM)(2WM + GWM - BW)}{WMA - BW}$$

where GWM = genetic potential for gain (kg/day) in WM and BW = birth weight.

Requirement for gain in condition. $Q = .0556\ (WM - W)$
The requirement for gain in condition is computed only if actual weight (W) is less than structural weight (WM). It is assumed that this gain is entirely composed of fat.

Intake limits. Physiological limit = $R1 = .0225 \frac{WM}{DIG}$

$$\text{Physical limit} = R2 = \frac{.0107\ WM}{1 - DIG} \text{ for } CP \geq .06$$

$$= R3 = \frac{.0107\ WM}{1 - DIG} \left(\frac{CP}{.06}\right)^{.06} \quad \text{for } CP < .06$$

$$\text{Availability limit} = R3 = AVC(T) \left(\frac{WM}{WMA}\right)^{.15}$$

where DIG, CP, AVC and T are percent digestibility, percent crude protein, available dry matter in kg per mature cow per day and current month, respectively.

Lactation requirement. $RL = .03\ PM$
where PM is the lactation potential of a cow at any given time obtained by adjusting the genetic potential for lactation (or maximum lactation potential), age (CFA), condition (CFX), month of lactation (J) and cow age in years (I) and expressed as

$$PM = CFA \cdot CFX \cdot PMA \cdot e^{-.08J} \quad \text{with}$$

$$CFA = 1.0 + .01(I - 7) - .01(I-7)^2 \quad \text{and}$$

$$CFX = 1 - \left(\frac{WM - W}{.33\ WM}\right)^{3.32}.$$

The potential level of animal performance is achieved and the

surplus of nutrients is deposited as fat if the sum of nutrient requirements calculated above is less than nutrient intake calculated by intake limit equations. Downward adjustments are made in growth, lactation and condition but not in maintenance and pregnancy in cases where the calculated requirements are above the intake limits. Body fat is mobilized to meet nutrient requirements in extreme cases.

The FERT Subroutine

The FERT simulates cow fertility. In this subroutine, occurrence of oestrus and conception rates are simulated for all classes of open breeding females at least fifteen months old. The PEST (fraction of females that begin cycling during the current month and that were not cycling previously) is computed as follows:

$$PEST = .085\ CFW \cdot CFDW \cdot CFM \cdot CFT$$

where CFW = correction factor for weight,

$$= .001 \text{ if } W < .75\ WM,$$

$$= 1.0 \text{ if } W \leq WM,$$

$$= 4\ \left(\frac{W}{WM} - .75\right) \text{ if } .75 \leq W \leq WM,$$

CFDW = correction factor for weight gain,

$$= 1 - \frac{100\ (DWM - DW)}{WM} \text{ with } DW = \text{daily weight gain}$$

and

CFM = correction factor for degree of maturity

$$= 3\ \left(\frac{WM}{.6WMA} - .67\right) \text{ if } .4\ WMA < WM < .6\ WMA$$

$$= 1 \text{ if } WM \geq .6\ WMA.$$

The fraction of cows cycling in the previous month which cycle again during the current month is computed as

$$CCYC = CFW^{.1} \cdot CFDW^{.1}$$

The conception of cycling females during the breeding season is computed as

$$PCON = .75\ CFT^{.5} \cdot CFW^{.2} \cdot CFDW^{.2}$$

where CFT = correction factor for postpartum interval,

CFW = correction factor for condition and

CFDW = correction factor for change in weight.

The conception of cycling females out of the breeding season is expressed as PCON = 0.

The DIE Subroutine

The DIE simulates animals mortality. This subroutine is used to calculate death rate for each class of animals during the current month. The death rate of the cows is a function of month of year, condition, current age, and age of calving. The death rate of newborn calves is determined by the birth month and age of dam and that of older calves by month, condition and rate of gain. A value of .001 is the assumed basic constant used to compute death rate and is corrected for condition of an animal as

$$FD = .001\ CT(T)e^{A1(1-\frac{W}{WM})^{A2}}$$

where FD = fraction of a class of animals that die during the current month,

CT(T) = month of year effect on deaths,

A1 = 140 through 200 and

A2 = 3.3.

Growth

> The process of growth is a wonderful and remarkable one even in the meanest and humblest of living creatures. No matter how small we are or how poorly our features are collected on our countenances, we should never regret that we have not attained the stature of Hercules or the features and form of Venus. We should feel astonished and thankful that we ever grew at all and that our features are recognizable as those of human race. (Robbins, 1928, p. 26)

The growth process is experimentally known (Brody, 1945; Spencer and Coulombe, 1965; Laird et al., 1965; Parks, 1970). Growth is one of the most important selection criterion for the improvement of meat animals especially beef cattle. It can be defined as increase in size or increase in differentiation or both (Brody, 1945). Increase in size usually involves increase in weight and height and can be measured in standard units, whereas, differentiation is difficult to express in units. As a result, the measurements of growth are usually concerned with one phase of growth, namely, that which involves increase in size or something related to it. These measurements commonly account for weight gain per day or growth rate, degree of maturity, maturing rate and total weight at a given age (birth weight, weaning weight, short yearling weight, long yearling weight and mature weight). There is little available literature on the growth of Zebu cattle in the western region of Africa. The following is a general review of growth in animals along

with relevant research on Bos indicus cattle in tropical and subtropical regions.

Growth Models

The growth (i.e., weight-age curve) varies from breed to breed (Brown et al., 1972) but the overall shape is sigmoidal and related to maturing patterns. Many functions have been suggested to represent growth but only a few are commonly used. These are

$Y_t = A(1 - Be^{-kt})^3$: (Bertalanffy, 1960),

$Y_t = Y_o e^{A(1 - e - kt)/k}$: Compertz (Winsor, 1932),

$Y_t = (1 + e^{-kt})^{-M}$: Logistic (Nelder, 1961),

$Y_t = A(1 - Be^{-kt})M$: (Richards, 1959),

$Y_t = Be^{-kt}$: self accelerating growth (Brody, 1945) and

$Y_t = A - Be^{-kt}$: self inhibiting growth (Brody, 1945)

where Y_t = weight at time t,

Y_o = initial weight,

A = asymptotic weight,

B = integration constant

k = rate of maturity,

M = inflection point and

e = base of natural logarithm.

Bertalanffy and Compertz's expressions overestimate weight at an early age and the logistic function underestimates mature weight (Brown et al., 1976). Richards' equation

(1959) fits data accurately but his four parameters have little biological meaning (Brown et al., 1976; Aguilar et al., 1983). Though Brody's allometric equations fit only parts of the growth curve, they remain the easiest expressions to compute and to interpret biologically.

Brody's growth curve. Growth in weight is usually represented in one or all of the three following ways:

a) absolute gain in the given magnitude per unit time,

b) relative rate (or percentage rate when multiplied by 100) gain per unit time and

c) cumutative growth or the weight at a given time.

The average absolute growth rate (AAGR) in an observed weight difference, $W_2 - W_1$, for the corresponding time difference, $t_2 - t_1$, may be represented by the equation

$$AAGR = \frac{W_2 - W_1}{t_2 - t_1}.$$

The AAGR is different from the true growth rate which is applicable only to extremely short intervals of time.

Ex: If a Gobra cow weighs 360 kg at age of 2160 days from conception, she has gained an average of 120 g a day; but there was no day when she gained exactly 120 g.

The concept of average growth rate is an abstraction and gives no idea of the actual rate at any age when the average extends over a considerable period of time (Brody, 1945).

The shorter the interval of time for which the average is computed, the more nearly does it approach the true value.

When the interval $t_2 - t_1$ is small enough to be reduced to dt (i.e., so short that there is no time for velocity of growth to change) then the true growth rate $\frac{dw}{dt}$ which is also called instantaneous growth rate can be obtained. The expression $\frac{1}{A}\frac{dw}{dt}$ (A is mature size) is the maturing rate or growth rate to mature size. The difference between slow and fast growing animals is not the same as the difference between slow and fast maturing animals.

The relative growth rate (R) is conventionally represented by the weight gain during a given time interval divided by the weight of the animal, W_1, at the beginning of the time interval:

$$R = \frac{W_2 - W_1}{W_1}$$ = average relative growth rate also called Minot's equation

The conventional (R) and the true percentage growth are nearly identical when weight $W_2 - W_1$ is very small in comparison to the weight of the animal. However, when the weight gain is relatively large compared to the body weight, R may be misleading because the weight at the beginning of time interval W_1 existed in the past not at the time of observation. The relative growth rate of an animal at a given age must be properly related to the body size at that given age, not the body size W_1 at some earlier age, t_1. Furthermore, Minot's equation fails to recognize that the

physiological meaning of a physical unit of time, such as a day, changes rapidly with age. For this reason, the growth rates computed by the equation

$$R = \frac{W_2 - W_1}{W_1}$$

(i.e., average relative growth rate) are not continuously decreasing physiological time intervals.

The use of instantaneous rates eliminates the discrepancy between physiological and physical time. The instantaneous relative growth rate (IRGR) is estimated using the weight (W) at the instant the rate dW/dt is measured, not the weight at some earlier age. The IRGR is identical to relative maturing rate $\frac{1}{u}\frac{du}{dt}$ (Fitzhugh and Taylor, 1971)

$$\text{IRGR} = \frac{dW/dt}{W} = \frac{du/dt}{u}$$

where u is the degree of maturity.

It is impossible to measure the instantaneous rate of growth in the laboratory, because of the finite time interval required for making a measurement; but even if it were possible, the experimental errors of measurements would be greater than the instantaneous gains. Instead, the infinite number of infinitesimal instantaneous rates are added up or integrated. If k = IRGR then $K = \frac{dW/dt}{W}$ and

$$\frac{dW}{dt} = kW,$$

$$dW/W = k\ dt,$$

$$\int_A^W \frac{dW}{W} = k\int_o^t dt,$$

$$\ln W = \ln A + kt \quad \text{and}$$

$$W = Ae^{kt}.$$

The equation $W = Ae^{kt}$ is used to represent the self accelerating phase of Brody's growth curve.

The instantaneous growth velocity, dW/dt, in a given time is proportional to (A - W) and is expressed as

$$dW/dt = - k(A - W)$$

where A may be the reflection of the concentration of the growth limiting factor when growth is completely inhibited and is used to represent the mature weight of the animal under a given set of conditions, (A-W) represents the amount of growth yet to be made to reach the mature weight and k or $(\frac{dW/dt}{W})$ is the relative growth rate with respect to the growth already made. The value -k or $(\frac{dW/dt}{A - W})$ is the relative growth rate with respect to the growth yet to be made and 100*k is the percentage growth rate with respect to growth already made. The equation of self-inhibiting phase of growth is derived as follows:

$$dW/dt = -k\ (A - W),$$

$$\frac{dW}{A - W} = -kdt,$$

$$\ln(A - W) = -kt + \ln B,$$

$$A - W = Be^{-kt} \text{ and}$$

$$W = A - Be^{-kt}$$

where A and k are as previously defined and B is the constant of integration.

Ex: if the growth rate of an animal fetus from 14 days to birth, k is .53 then the instantaneous percentage rate of growth is about 53 percent per day or 53 x 30 = 1590 percent per month or 53 x 7 = 371 percent per week (Brody, 1945).

The unit of time is 14 days through birth. The A value in (Ae^{kt}) has no practical significance because the data used are not from 0 to birth but from 14 days through birth.

The constant B is an age-parameter employed to correct for the fact that while age is counted from birth, the equation $W = A - Be^{-kt}$ fits the data only during the phase of growth following the infection point. When W = 0, A - W = A. By beginning to count age from a reference time, t*, the equation $W = A - Be^{-kt}$ becomes

$$W = A - Ae^{-k(t - t^*)}$$

because for t = t*, W = 0 and A = B.

More elegantly the equation becomes

$$\frac{W}{A} = 1 - e^{-k(t - t^*)}$$

which indicates that the fraction of the mature weight, W/A, is a function of the product of the velocity constant k, and the age as counted from t*. When B is known, t* may be computed as follows:

$$0 = A - Be^{-kt^*} \text{ for } t^* = t,$$

$$A = Be^{-kt^*},$$

$$\ln A = \ln B - kt^* \text{ and}$$

$$t^* = \frac{\ln B - \ln A}{k} .$$

It is often desirable to know the ages when given weights or given fractions of the mature weight are reached. These may be determined as follows:

$$A - W = Be^{-kt},$$

$$\ln(A - W) = \ln B - kt,$$

$$kt = -\ln(A - W) + \ln B \text{ and}$$

$$t = \frac{\ln B - \ln(A - W)}{k} .$$

Ex: The age of an animal when 90 percent (a fraction) of the mature weight is reached is calculated as follows:

by replacing W by .9A the equation becomes

$$t = \frac{\ln B - \ln(A - .9A)}{k} = \frac{\ln B - \ln A}{k} .$$

In general

$$t = \frac{\ln B - \ln(1 - \frac{W}{A})}{k} .$$

In the example above, the fraction $\frac{W}{A} = .90$.

Using $\frac{W}{A} = 1 - e^{-k(t-t^*)}$, we have

$$1 - \frac{W}{A} = e^{-k(t - t^*)} ,$$

$$\ln(1 - \frac{W}{A}) = -k\ (t - t^*) \text{ and}$$

$$t = t^* - \frac{1}{k} \ln(1 - \frac{W}{A}) .$$

The function $W = A - Be^{-kt}$ can be used to represent growth in weight in cattle only following the age of about five months after birth. This age corresponds approximately to the inflection point which is biologically meaningless (Laird et al., 1965).

Effect of Environmental Factors on Growth

Maturing Rate and Mature Size

Mature size of a cow is the weight over many years after positive growth of skeletal and muscular tissue has become insignificant (Brinks et al., 1962; Fitzhugh et al., 1967; Fitzhugh and Taylor, 1971). Because body weight is highly

influenced by the environment, the simple definition of mature weight as the final size that is reached may be inadequate. Maturing rate is the growth rate relative to mature size.

Very few authors have reported on the environmental factors influencing the variation in performance of the traits. Hafez (1963) reported that birth weight, dam's milking ability, maternal ability, dam age, weaning age, sex, weaning weight, nutrition, adaptability and year of birth are factors affecting maturing rate and mature size. Brown et al. (1970) found a significant effect of sex on maturing rate and mature size in cattle. Brown et al. (1974) observed that the environmental factors have "little" effect on maturing rate and an important effect on mature size. Brown et al. (1972) working in Arkansas and Wong (1974) in Florida reported effects of year of birth ($P < .001$) on both rate of maturing and mature size of beef female. Mbah (1975) observed effects of year of birth on maturing rate ($P < .01$), and mature weight ($P < .05$).

Birth Weight (BW)

Birth weight is one of the production traits most often discussed in the literature because it is related to other measures of growth. Petty and Cartwright (1966) stated that ranking individuals for birth weight provides an indication of their growth potential. There can be a positive association between low birth weight of the calf and its low vitality (Beltran et al., 1971) on one hand, between calving

difficulties and stillbirths (Laster et al., 1973a) on the other hand. Plasse (1978) and Nodot (1980) reported birth weight values of 23.6 kg for Gir and 32.43 kg for Indubrazil cattle, respectively.

Environmental factors affecting BW have been demonstrated and reported many times. Male calves are heavier than females at birth (Botkin and Watley, 1953; Koch and Clark, 1955; Cartwright et al., 1964; Plasse and Koger, 1967; Munos and Martin, 1969; Beltran, 1976; Mariante, 1978). Koch and Clark (1955) reported that the largest differences in birth weight occurred between beef calves born to 3 to 4 years old dams and those born to 10 years old cows. However, Cartwright et al. (1964) indicated that the BW increases with the age of dam up to about 6 to 7 years and declines thereafter as the age of dam increases. Significant effects of year of calving (Swiger, 1961; Cartwright et al., 1964; Plasse and Koger, 1967; Gregory et al., 1978; Nelson and Kress, 1979; Elliot, 1979) and season of calving (Beltran, 1976; Mariante, 1978) have also been reported. Beltran (1976) found that Brahman calves born during the dry season were lighter than those born in rainy season. Mariante (1978) using data from Nellore cattle in Brazil reported similar results. In contrast, Nodot (1980) observed no effect of season of birth on BW of Indubrazil calves in Mexico.

Weaning Weight (WW)

Heavy weaning weight is probably the most common selection criterion used in the beef industry. This is valuable because weaning weight is a composite measurement reflecting the maternal ability of the dam and the genetic growth potential of the calf. Average weaning weights reported for some Bos indicus cattle in the tropics or subtropics were 209, 215, 191, 95 kgs, respectively, for Indubrazil in Mexico (Nodot, 1980), Brahman in Guatemala (Plasse, 1978), Nellore in Brazil (Mariante, 1978) and Gobra Zebu in Senegal (Denis, 1971).

Variations in weaning weight are often caused by the same nongenetic factors affecting birth weight. Because year of birth is associated with variations in annual rainfall, nutrient availability and changes in management from year to year, it almost always affects WW (Clum et al., 1956; Reynolds et al., 1958; Cartwright and Kruse, 1965; Shelby et al., 1960; Sacker et al., 1971; Cruz, 1972; Bando, 1974; Beltran, 1976; Crockett et al., 1978; Bauer et al., 1978; Pereira, 1978; Nodot, 1980; Pacho, 1981). Plasse and Koger (1967), Bauer et al. (1978) and Verde and Plasse (1976) reported that calves born during the dry season were heavier at weaning than those born in rainy season. Koger (1958), Peacock et al. (1966) and Nodot (1980) found that calves born in winter were significantly heavier than fall or spring born ones.

Male calves are in general heavier at weaning than females (Cruz, 1972; Beltran, 1976; Mariante, 1978; Plasse, 1978; Nodot, 1980; Pacho, 1981); younger and older cows wean lighter calves than do intermediate age females (Cartwright et al., 1964; Plasse and Koger, 1967). Berruecos and Robinson (1968) and Nodot (1980), however, found no effect of age of dam on WW of the calves.

Yearling and Long Yearling Weight (YW & LYW)

The genetic growth potential of the individual animal in a given environment is greatly influenced by the conditions of the environment. Because this potential is more strongly reflected after weaning, evaluation of postweaning growth in beef calves is important for evaluating overall beef production efficiency. The main environmental sources of variation in postweaning growth reported in the literature are year, month of birth and sex (Munos and Martin, 1969; Pereira, 1978; Mariante, 1978; Ordonez-Vela, 1978). Pacho (1981) found "no clear trend of year effect" on 12-month and 18-month weights of Brahman heifers. Baker et al. (1974) reported that the age of dam effects on postweaning traits decline with the age of the calf. Pacho (1981) stated that the heaviest Brahman heifers at 12 and 18 months were born from 5 to 8 years old cows and the lightest ones from 4 years old dams.

Genetic Factors Affecting Growth

Sire effects, genetic and phenotypic correlations, heritabilities and repeatabilities are genetic factors commonly discussed in the literature.

Birth Weight

The sire and dam each contribute one half of the genotype of the calf but the maternal environment provided by the dam from conception through weaning accounts for a substantial part of the total environment of the calf. Cartwright et al. (1964) stated that the genotype of the sire had less influence on birth weight than that of the dam due to the influence of the maternal environment. Nevertheless, significant effects of sire on birth weight of Zebu calves have been reported by many authors (Pahnish et al., 1961; Beltran, 1976; Pereira, 1978; Mariante, 1978; Nodot, 1980).

Average heritability estimates for birth weight vary from .17 to .89 (Petty and Cartwright, 1966). Variable heritability estimates on birth weight of Bos indicus cattle are found in the literature. Some of these estimates are .27 for Brahman (Beltran, 1976), 0.13 for Santa Gertrudis (Plasse et al., 1968a), 0.62 for Nellore cattle (Mariante, 1978) and 0.24 for Inbubrazil cattle (Nodot, 1980).

Petty and Cartwright (1966) reported average genetic and phenotypic correlations of 0.58 and 0.35, respectively, between birth weight and weaning weight of beef cattle. Mariante (1978) and Nodot (1980) reported phenotypic values of 0.37 and 0.16, respectively, between birth weight and weaning weight. Correlations between weights taken at closer ages are usually higher than those between more distant ages. Cartwright and Fitzhugh (1972), summarizing studies on Brahman cattle, observed that the genetic correlations

between weights taken at different ages varied from 0.50 to higher than 0.60. Koger et al. (1957), Beltran (1976) and Mariante (1978) reported genetic correlation values of 0.47, 0.37, 0.99, respectively, between birth weight and weaning weight.

Weaning Weight

Significant effects of sire on weaning weight of Bos indicus have been reported by Martojo (1972), Mariante (1978), Plasse (1978) and Pacho (1981). Nonsignificant differences among sire groups also have been observed (Beltran, 1976; Nodot, 1980; Gregory et al., 1950). Peacock et al. (1966) stated that a limited number of bulls used in the experiment could result in nonsignificant effects of sire on weaning weight.

Average heritability estimates for weaning weight were 0.07 in Zebu breeds (Torres, 1959), 0.23 in Brahman (Cruz, 1972), 0.07 in Brahman (Beltran, 1976), 0.12 in Nellore (Mariante, 1978), 0.60 in Gir (Plasse, 1978), 0.07 in Indu-brazil (Nodot, 1980) and 0.12 in Brahman (Pacho, 1981).

The genetic and phenotypic correlations between weaning weight and weight at 12 months for Nellore cattle in Brazil were .86 and .83, respectively (Mariante, 1978) whereas the phenotypic correlation between the two traits for Brahman cattle in Florida was .50 (Pacho, 1981).

Yearling and Long Yearling Weight

Significant differences among sire groups for long yearling weights in Zebu cattle have been reported by Beltran

(1976), Hernandez (1977) and Mariante (1978). Similar effects were obtained by the last author using 12-month weights. However, Pacho (1981) found that sire had effects on 12 and 18 months weights in Angus but not in Brahman. The author stated that the lack of sire effects could be due to a lack of genetic diversity among the Brahman sires used at the station.

Average heritability estimates for 12 and 18-month weights were 0.15 and 0.23, respectively, in Brahman (Pacho, 1981), 0.14 and 0.13 in Nellore (Mariante, 1978) and 0.50 and 0.60 in Brahman cattle (Cartwright and Fitzhugh, 1972). Beltran (1976) observed a heritability estimate of 0.19 for 18-month weight.

The genetic and phenotypic correlations between 12 and 18-month weights have been estimated at .80 in Nellore cattle by Mariante (1978). Pacho (1981) obtained an average estimate of .81 for the phenotypic correlation between the two traits in Brahman cattle.

Maturing Rate, Mature Size and Degree of Maturity

Wong (1974) observed sire effects on the growth parameters. Brody (1945), Taylor (1965), Joandet (1967), Taylor and Fitzhugh (1971), Brown et al. (1972) and Wong (1974) have all observed negative genetic and phenotypic correlations between mature size and rate of maturi . This implies that individual animals that were rapidly maturing did so to a lower mature weight while slow maturing animals reach maturity at heavier weights. Therefore, later maturing calves were

probably heavier at birth than earlier maturing ones (Brown et al., 1972). Such a relation between maturing rate and mature size has important implications in beef cattle performance. Smaller cows tend to wean lighter calves and have lower salvage values, but they also have lower maintenance requirements than larger females (Morris and Wilton, 1976). Earlier maturing cows tend to produce more calves and have shorter calving intervals than do the later maturing ones (Carpenter et al., 1971).

Variable heritability (h^2) estimates for growth parameters in beef cattle are available in the literature. For mature size, h^2 estimates were .34 and .20 in Hereford and the Angus, respectively (Brown and Brown, 1972), .57 in Hereford (Fitzhugh and Taylor, 1971), .51 as pooled estimate across Angus, Brahman, Hereford and Santa Gertrudis breeds (Wong, 1974).

MATERIAL AND METHODS

The data used in this study were obtained from a government owned livestock research station located at Dahra-Djoloff, Senegal. The station was established in 1950 in the sylvopastoral region or Ferlo. Its physical environment (Tables 1 and 2) is fully described in a forthcoming study (Abassa, 1984). The vegetation is primarily composed of shrubs, annual grasses and legumes and is markedly influenced by the amount and distribution of rainfall.

Forage System

The forage system found in Dahra is natural grassland predominantly composed of Tephrosia spp., Phyllantus pendadrus, Aristida stipoides, Andropogon amplectens, Eragrostis tremula and Zornia glochidiata. These plants grow rapidly during three months (mid-July through mid-October), mature rapidly, dry out and decrease in quality as the nine month dry season proceeds. In May and June (i.e., end of dry season), both quantity and quality of forage is severely curtailed. Legumes disappear long before June either by selective overgrazing, by being carried away by the winds or destroyed by insects. Animals undergo substantial weight losses during this period. Rainfall begins by mid-July and promotes rapid pasture growth but also causes the residual mature grass to become wet, fermented and infected by fungi.

TABLE 1: CHARACTERISTICS OF THE PHYSICAL ENVIRONMENT AT THE DAHRA LIVESTOCK RESEARCH CENTER

Area	Land Formations	Soil Type	Type of Climate	Expected Mean Precipitation	Expected Mean Temperature	Expected Mean Humidity
6800 km^2	Sandy ridges	Brown-red subarid	Sahel-Senegalese	500 mm	28°C	49%
	Old sand hills	Ferruginous tropical				
		Soil drainage: average to poor				

TABLE 2: ACTUAL CLIMATOLOGICAL DATA FOR DAHRA LIVESTOCK RESEARCH CENTER

Year	Temperature Minimum (°C)	Temperature Maximum (°C)	Humidity (%)	Rainfall (mm)
1971	18.6	36.6	22.8	276.0
1972	19.0	36.7	24.4	273.3
1973	-	-	-	258.9
1974	19.1	36.7	25.2	326.8
1975	19.5	36.2	25.7	483.0
1976	19.6	35.6	22.7	369.7
1977	20.6	37.1	21.6	279.3
1978	20.2	36.6	19.0	296.4
1979	20.0	36.2	24.6	356.9
1980	18.1	36.4	23.6	378.7

These conditions are thought to depress appetite and to further decrease the already low nutrient intake. About 31 to 63 percent of the total weight losses recorded during seven months of dry season (i.e., from January through July) occur in July. This phenomenon is called "The July Crisis" (Denis et al., 1979).

The contribution of the browse as supplements to the poor mature grass straw during the critical stage of the dry season is substantial. As discussed elsewhere (Abassa, 1984), the browse usually represents the primary feed source for the animals during this period.

Research Activities at Livestock Research Center of Dahra

A major activity at the center is the improvement of the local beef cattle breed of the region, the Gobra Zebu. The center also breeds horses, sheep and goats. Selection for growth and meat production of Gobra Zebu started in 1955. Subsequently, the center has pursued the goal of selecting and breeding improved bulls which are released to and used by traditional herders or cattlemen of the region. The total environment of the station is maintained as close as possible to that of the traditional cattle production system in the Ferlo. Animals are on range throughout the year and there is little or no supplemental feeding. However, some improved management practices which never exist in traditional system are used. These are

- mineral supplementation all year round,

- water supply ad libitum,
- regularly scheduled vaccinations,
- controlled breeding season,
- partitioning of the herd in categories of animals,
- rational use of the available pasture (existence of large paddocks' and
- weaning and culling policies.

This system is called an improved extensive cattle production system and is an improved form of freehold farming system.

The breeding season for the Gobra Zebu was set at 4 months beginning August 15th through December 15th in 1969 (Denis and Thiongane, 1975), but has been modified to fit the environmental changes of rainfall and pasture availability. In 1976 and 1977, it was from September through January. The new schedule since 1978 is from October through December.

Calves are weaned at a constant age of six months at Dahra Livestock Research Center. All weaned calves are grouped on the same pasture(s) from 6 to 12 months of age. From 12 months of age, they are raised separately as steers and heifers.

Seventy percent of males are culled at weaning while the remaining 30 percent is included in a collective six months testing program and selected for growth and conformation. Ten percent of the yearlings are then selected to be tested individually for growth, feed consumption, sex drive, fertility and progeny performance. Each individual test lasts twelve months after which the final selection is made for the bulls to be mated to an elite cow herd. The remaining 20

percent of the yearlings are distributed to the herders or producers in traditional systems.

Eighty percent of females are maintained as replacement heifers after weaning. They are bred at 23 to 24 months of age by the young bulls in the individual testing program. After three calves, they are culled, sent to traditional herders or selected as elite cows based on their performance records.

Growth and Reproduction Data

Records collected from 1968 to 1980 at Dahra research station included body weights of Gobra Zebu from birth to maturity, reproductive data including age at first calving, conception and calving rates, weaning rate, cow and calf survival rates. In the analyses, age of dam was considered as discrete variable. Nine age classes or groups of cows are defined (Table 3). The data involves 607 purebred Gobra Zebu females sired by 39 purebred Gobra Zebu bulls. Body weight measurements are made on 1589 animals. A large proportion of these records was deleted due to misrecording, mispunching, too many missing values, unknown age of dam and birth data. Table 4 shows the number of records initially available, the number of records eliminated and the final number of records used for analyses.

Growth performances were characterized through the analyses of birth weight (BW), weaning weight (WW), yearling weight (YW: 12-month weight), long yearling weight (LWY:

TABLE 3: COW AGE GROUPS BY CLASS

Class	Age (years)
1	2
2	3
3	4
4	5
5	6
6	7
7	8-10
8	11-12
9	12

TABLE 4: INITIAL NUMBER OF OBSERVATIONS, NUMBER OF RECORDS DELETED AND FINAL NUMBER OF OBSERVATIONS AVAILABLE FOR ANALYSIS

Character	Sex	Number of Observations		
		Initial	Deleted	Final
Birth weight	Male	613	419	194
	Female	788	429	359
Weaning weight	Male	583	389	194
	Female	686	327	359
Yearling weight	Male	492	298	194
	Female	670	311	359
Long yearling	Male	361	167	194
	Female	596	237	359
Growth rate	Female	359	115	244
Mature size	Female	359	115	244

18-month weight), relative growth rate (K), mature size (A) and degree of maturity (u) of the calves.

Analyses of the Data

Preliminary management of the data were performed using the Statistical Analysis System (SAS) version 79.6 (Barr et al., 1979). Analyses of variance of the growth data were by the method of Mixed Model Least Squares and Maximum Likelihood (Harvey, 1977). An IBM 3033 computer under MVS and TCP operation systems at University of Florida in Gainesville was used to perform the overall statistical analyses and a Prime Computer to simulate beef cattle production. Least-squares analysis of variance (Harvey, 1960) was used for efficient analyses of unbalanced data available for this study.

Models

Growth Models

Brody's growth function (Brody, 1945) was used in this study to describe growth in each female. Although this model does not express in a single equation calf growth, it is the simplest and the easiest to interpret biologically. The function is expressed as

$$Y_{it} = A_i - B_i e^{-k_i t} + E_{it}$$

where Y_{it} = weight at age t of the ith Gobra Zebu female with t = 6, 9, 12 --- 72 months,

A_i = an estimate of mature weight for ith female,

B_i = an estimate of the constant of integration specific to ith female,

k_i = an estimate of the rate of maturity peculiar to ith female and

E_{it} = error associated with the duration of predicted weight at age t.

The growth parameters were estimated through the use of Gauss-Newton nonlinear iteration methods (Barr et al., 1976).

Statistical Model

$$Y_{ijk} = u + a_i + F_k + R_{ijk}$$

where Y_{ijk} = observed value of any growth character in kth animal, and jth fixed effects,

u = fixed effect common to all observations,

a_i = random effect due to ith sire (this effect is omitted when appropriate),

F_k = fixed effects due to sex, year of birth, month of birth, age of dam and

R_{ijk} = random error N $(0, \sigma^2)$.

The expectations for mean of squares may be summarized as shown in table 5.

Simulation Model

The Texas A & M Cattle Production Systems Model was used to simulate herd production in order to examine and compare outcomes from the genotype, environment and various managerial practices under consideration. Animal genotype, feed and management inputs used for the original run along with

TABLE 5: SOURCES OF VARIATION AND THEIR EXPECTED MEANS OF SQUARES

Source	E(MS)
A (random)	$\sigma_R^2 + K_1{}^*\sigma_A^2$
Fixed	$\sigma_R^2 + K\sigma_F^2$
Remainder	σ_R^2

* k_1 = average number of progeny per sire

For m = number of categories (i.e., sires) and n_i = the number of observations per category, K_1 is expressed as

$$K_1 = \frac{1}{m-1}\left(\Sigma n_i - \frac{\Sigma n_i^2}{\Sigma n_i}\right).$$

management alternatives to be tested after completion of model validation were specified.

Animal genotype inputs. The genetic potential for Gobra mature cow size (WMA) was set at 425 kg and the daily genetic potential for milk production at 6.7 mg.

Forage inputs. Feed resources are specified on a monthly basis in terms of crude protein content (CP), dry matter digestibility (DIG), and daily per animal availability of dry matter (AVC). The parameters, CP and DIG, refer to what is actually consumed by animals and not to what is available for consumption. The parameter, AVC, is expressed as an upper limit of daily forage dry matter intake per mature animal. This limit reflects the phenomenon that what is available to consume may be less than what an animal would consume if a greater amount of feed of the same quality were available.

Forage characteristics set for each month after an extensive review of data from the Dahra Livestock Research Center and the sylvopastoral zone (Raynal, 1964; Valenza and Fayolle, 1965; Denis and Valenza, 1975; Bille, 1971; 1977a; 1977b; Denis and Thiongane, 1972; Boudet, 1975; Cornet and Poupon, 1978; Cornet, 1981; Friot et al., 1980) are shown in table 6 and figure 4.

Management inputs. Cows are maintained in the herd to a maximum age of 12 years. Forty replacement heifers enter the cow herd every year and are bred at 24 months of age. The breeding season is from October through January. The production

TABLE 6: CHARACTERISTICS OF CONSUMED FORAGE IN AVERAGE DRY YEARS AT DAHRA LIVESTOCK RESEARCH CENTER

Month	Daily Available Dry Matter Per Mature Animal (kg)	Crude Protein (%)	Forage Digestibility (%)
Jan	6.0	6.1	52.0
Feb	6.0	5.0	51.0
Mar	5.5	4.5	50.0
Apr	5.3	4.3	47.0
May	5.2	4.3	45.0
Jun	5.0	4.0	42.0
Jul	9.0	7.0	53.0
Aug	12.0	11.0	60.0
Sep	12.0	11.0	60.0
Oct	10.0	8.0	53.0
Nov	7.5	8.0	52.5
Dec	7.0	7.2	52.0

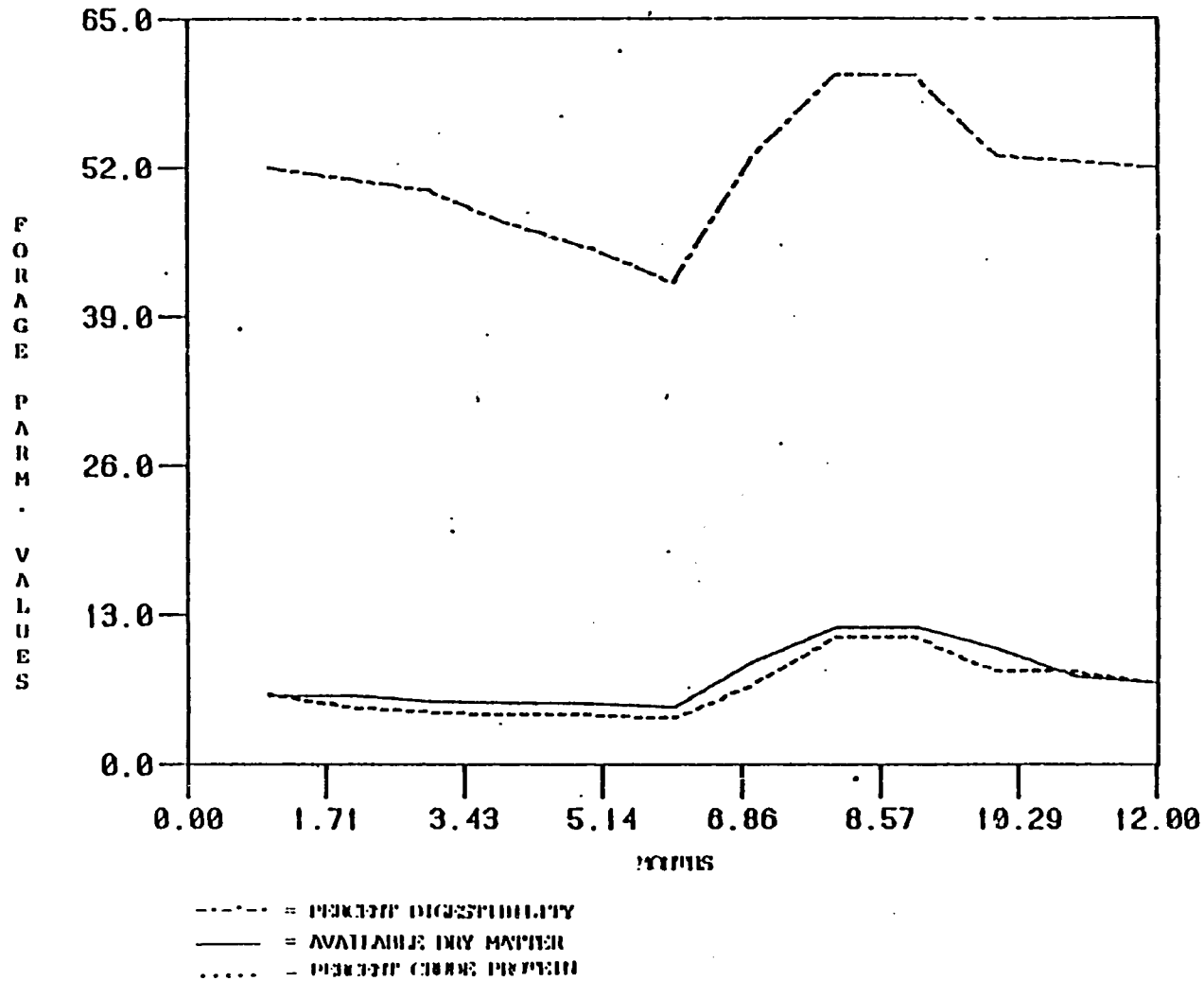

Figure 4. Characteristics of consumed forage in average dry years at Dahra Livestock Research Center

year starts at the first of July and the fiscal year starts at the first of January. Calves are weaned at constant age of 6 months and the male and extra heifers are sold after weaning which begins in January. Cows are culled and sold at the time their calves are weaned. There is no creep feeding.

RESULTS AND DISCUSSION FROM DATA ANALYSIS

Tables 7 and 8 show the unadjusted average value of growth traits of interest along with annual rainfall (RF). The unadjusted mean values are more useful for comparing actual and simulated results than least squares means. The latter are adjusted for unequal numbers of observations per subcell and are more appropriate for comparisons of mean differences. Since one of the major objectives of this dissertation is the comparison of simulated and actual results, unadjusted rather than adjusted means were used.

Growth

Analyses of variances were performed for weights at birth, six months or weaning, 12 months and 18 months. Maturing rate and mature size were also included.

Birth Weight (BW)

Least squares analysis of variance and least squares means for birth weight in all calves, female and male calves, are shown in tables 9, 10 and 11.

Effects of environmental factors

Month of birth, year of birth, dam age and sex were the sources of variation tested. Month of birth reflects, in part, the within year variation of the quality and quantity of forage resources available. It affected BW in male ($P<.01$),

TABLE 7: AVERAGE RAINFALL AND UNADJUSTED PRODUCTION DATA

Years	RF (mm)	BW (kg)	WW (kg)	YW (kg)	LYE (kg)
1968	349.0	25.2	108.7	-	-
1969	776.6	24.7	92.1	132.8	265.7
1970	209.5	27.0	91.7	132.2	103.0
1971	276.0	25.0	117.2	135.2	218.0
1972	273.3	27.6	112.8	160.5	235.4
1973	258.9	25.9	116.3	162.7	234.7
1974	326.8	25.3	107.3	149.6	211.4
1975	483.0	26.3	82.9	135.1	181.1
1976	369.7	24.0	86.4	124.4	171.7
1977	279.3	23.9	122.0	128.8	156.8
1978	296.4	26.5	106.3	160.5	210.0
1979	356.9	23.5	113.8	145.7	210.1
1980	378.7	24.5	127.9	128.7	206.3

TABLE 8: UNADJUSTED AVERAGE WEIGHTS (KG) AT BIRTH AND WEANING

Dry Years			Wet Years		
Years	BW	WW	Years	BW	WW
1971	25.0	117.2	1968	25.2	108.7
1972	27.6	112.8	1969	24.7	92.1
1973	25.9	116.3	1974	25.3	107.3
1977	23.9	122.1	1975	26.3	82.9
1978	26.5	106.3	1976	24.0	86.4
			1979	23.6	113.84
			1980	24.5	127.9
Average	25.8	114.9	Average	24.8	102.7

TABLE 9: LEAST SQUARES ANALYSIS OF VARIANCE FOR BIRTH WEIGHT AND WEANING WEIGHT IN ALL CALVES

Source	D.F.	Mean Squares	
		Birth Weight	Weaning Weight
Sire	27	30.00*	1164.89***
Month of birth	11	71.73***	2691.22***
Dam age	8	32.60*	1493.98***
Year of birth	12	64.96***	3327.35***
Sex	1	293.89***	3759.23**
Remainder	567	17.74	421.08

*P <.05 or P <.10

**P <.01

***P <.001

TABLE 10: LEAST SQUARES ANALYSIS OF VARIANCE FOR BIRTH WEIGHT AND WEANING WEIGHT IN FEMALE GOBRA ZEBU

Source	D.F.	Mean Squares	
		Birth Weight	Weaning Weight
Sire	27	25.686*	924.314***
Month of birth	11	34.640*	1537.545***
Year of birth	11	43.364***	578.440***
Dam age	7	38.242*	1481.557
Remainder	304	16.325	360.868

*P< .05

**P< .01

***P< .001

TABLE 11: LEAST SQUARES ANALYSIS OF VARIANCE FOR BIRTH WEIGHT AND WEANING WEIGHT IN MALE GOBRA ZEBU

Source	D.F.	Mean Squares	
		Birth Weight	Weaning Weight
Sire	19	22.166	839.691*
Month of birth	10	54.745**	1566.007**
Year of birth	11	66.806***	1762.480***
Remainder	153	17.985	501.093

*P<.05

**P<.01

***P<.001

all calves (P<.001) and female calves (P<.05). The LS mean birth weight for all calves (Table A1) varied from 23.56 ± .74 kg for calves born in June to 27.37 ± .76 kg for calves born in September. Lighter weights were recorded during the dry season and the heavier ones during the wet season. This is in agreement with the observations of Beltran (1976) and Mariante (1978) on Bos indicus cattle in tropical environments. Data also showed a BW of 28.11 ± 1.49 kg for February which indicated that calving in that month may be a management alternative to consider.

Year of birth had effects (P<.001) on birth weight of female, male and all calves. The LS means for all calves (Table A1) varied from 20.75 ± 1.45 for 1977 to 29.87 ± 1.12 kg for 1972. Figure 5 shows the variation in BW of female calves across years. Since birth weight is generally positively correlated with mature size (Cartwright and Fitzhugh, 1972; Mbah, 1975) and selection for growth based on BW was practiced at Dahra during the period covered by this study, similar variation in genetic potential for mature weight in female Gobra would be expected. No clear phenotypic trend with regard to change of the trait over years could be detected in males and all calves but a wide variation was found (Table 12 and Fig. 6).

Age of dam had effects on BW of all calves (P<.10) and female calves (P<.05), but had no effect on BW of male calves. These effects were expected to be expressed primarily through prenatal maternal environment. The least

TABLE 12: PHENOTYPIC TRENDS ANALYSES FOR BIRTH WEIGHT

All Calves			Male Calves			Female Calves		
Source	D.F.	MS	Source	D.F.	MS	Source	D.F.	MS
Month of birth	11	83.61	Month of birth	10	59.87***	Month of birth	11	44.33**
Dam age	8	30.81*				Dam age	7	37.[illegible]
Sex	1	295.94***						
Year of birth	12	85.60***	Year of birth	11	95.48***	Year of birth	11	33.41*
Linear	1	121.32*	Linear	1	65.97*	Linear	1	33.51
Quadratic	1	202.99***	Quadratic	1	13.57	Quadratic	1	194.41***
Cubic	1	62.98*	Cubic	1	79.47*	Cubic	1	.01
Quartic	1	4.34	Quartic	1	76.64*	Quartic	1	2.94
Quintic	1	95.78*	Quintic	1	90.62	Quintic	1	18.16
Residual	7	77.12***	Residual	6	120.66**	Residual	6	19.74
Remainder	594	10871.18	Remainder	172	18.44	Remainder	329	17.03

*P <.05

**P <.01

***P <.001

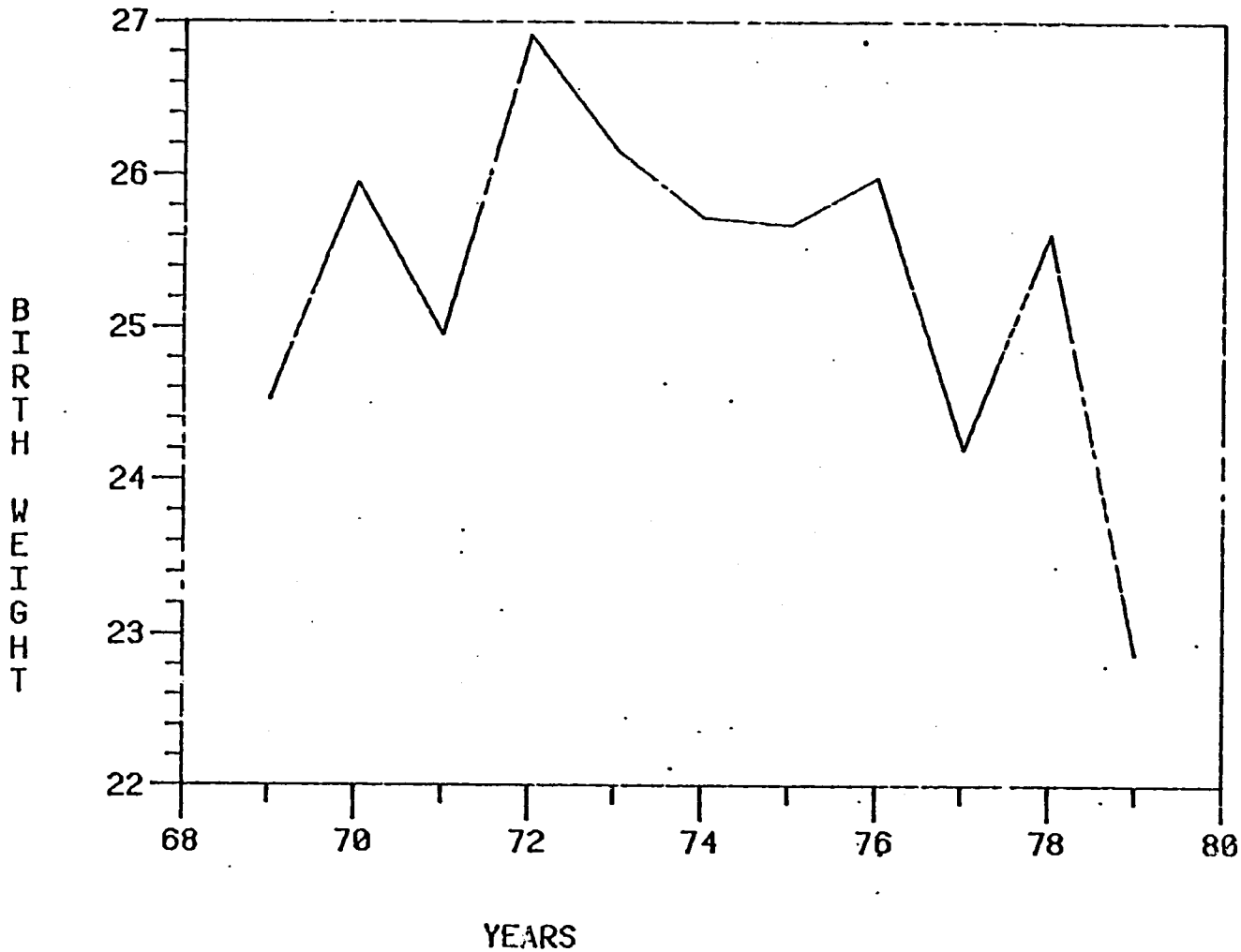

Figure 5. Birth weight by year of birth in female calves

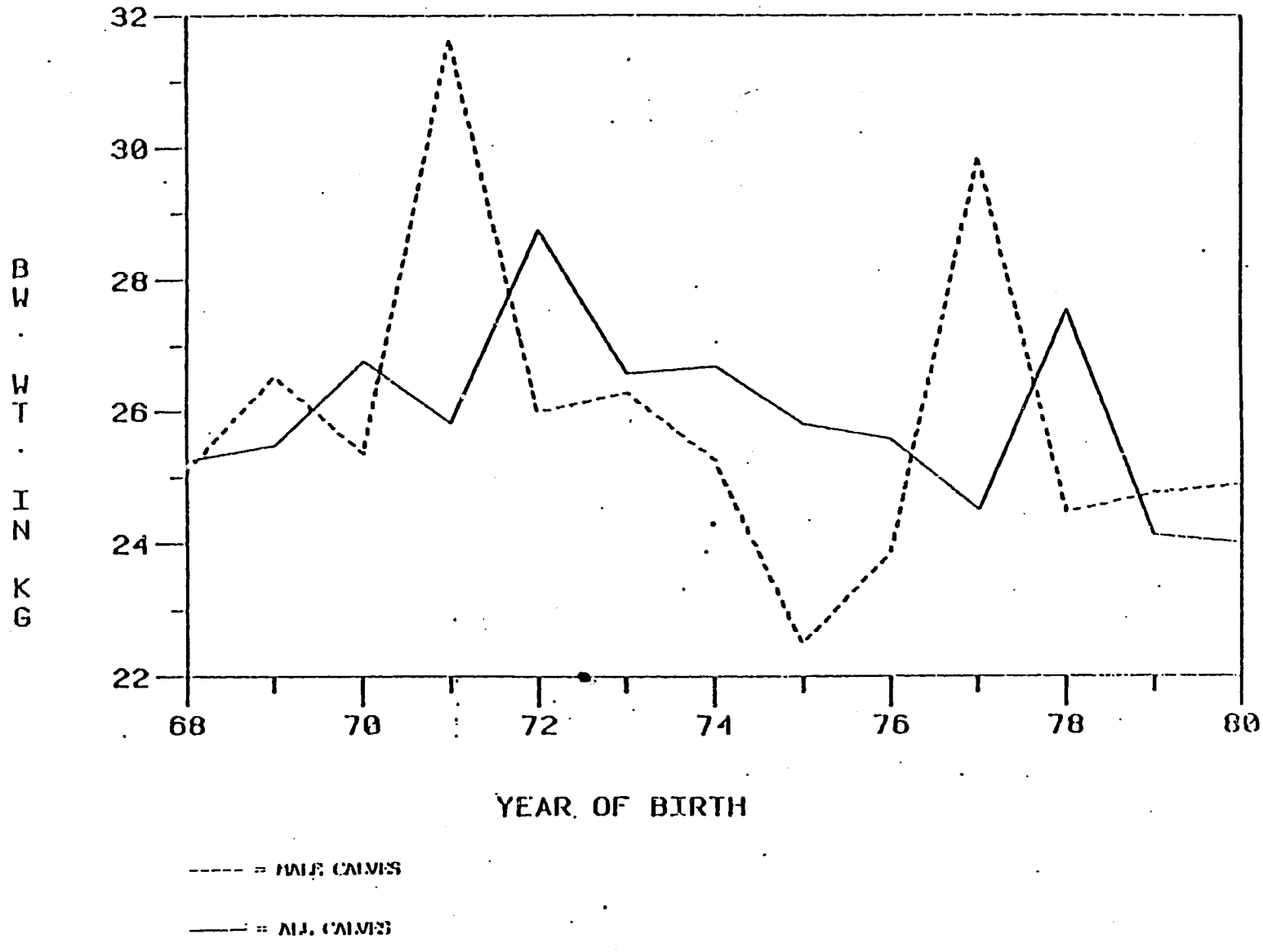

Figure 6. Birth weight by year of birth in male and all calves

square mean weights (Table A2) varied from 24.17 ± .79 kg for 4 year old cows to 26.43 ± 75 kg for 8-10 year old cows.

Sex of the calf affected ($P<.001$) birth weight. Most of the currently available literature reports lighter birth weights for female than male calves. In this study (Table 13), males (26.44 kg) were 1.61 heavier than female calves (24.76 kg).

Effects on genetic factors

Sire had effects on weight at birth of female calves ($P<.05$) and all calves ($P<.05$), but no effect on birth weight of male calves (Tables 10, 11 and 12).

Heritability estimates obtained from paternal half-sib correlations, genetic and phenotypic correlations, are shown in tables 14 through 17. The h^2 estimates (Table 20) were .14 ± .09 for all calves and .20 ± .14 for female calves. Similar results were reported for Bos indicus cattle by Plasse et al. (1968a), Beltran (1976) and Nodot (1980). Genetic and phenotypic correlations of birth weight with weaning, yearling and long yearling weight were all positive. In female calves, genetic correlations between birth weight and each of weaning, yearling and long yearling weights were .45, .23 and .37, respectively. In all calves, they were .49, .31 and .14. These values are lower than those reported by Cartwright and Fitzhugh (1972) in Brahman cattle but are in close agreement with the observations of Koger et al. (1957) and Beltran (1976).

TABLE 13. LEAST SQUARES MEANS AND STANDARD ERRORS IN KG FOR BIRTH WEIGHT, WEANING WEIGHT, 12-MONTH WEIGHT AND 18-MONTH WEIGHT IN GOBRA ZEBU

Category	Birth Weight	Weaning Weight	Yearling Weigth	Long Yearling Weight
Female	24.94 ± 4.33	104.37 ± 23.79	141.35 ± 32.99	198.50 ± 41.01
Male	26.44 ± 5.05	114.03 ± 30.34	152.65 ± 34.99	226.78 ± 52.86
Overall	25.52 ± 4.60	107.79 ± 26.52	145.04 ± 34.34	207.62 ± 46.64

TABLE 14: GENETIC CORRELATIONS BETWEEN GROWTH TRAITS IN FEMALE GOBRA ZEBU

Growth Traits	Birth Weight	Weaning Weight	Yearling Weight	Long Yearling Weight
Maturing rate	.45 ± .51	-.21 ± .52	.01 ± .57	-.76 ± .51
Birth weight		.45 ± .36	.23 ± .42	.37 ± .47
Weaning weight			.67 ± .18	.52 ± .28
Yearling weight				.92 ± .10

TABLE 15: PHENOTYPIC CORRELATIONS BETWEEN GROWTH TRAITS IN FEMALE GOBRA ZEBU

Growth Traits	Weaning Weight	Yearling Weight	Long Yearling Weight	Mature Size	Maturing Rate
Birth weight	.29	.22	.23	.16	.07
Weaning weight		.71	.59	.16	.06
Yearling weight			.79	.13	.09
Long yearling weight				.24	.05
Mature size					-.06

TABLE 16: GENETIC CORRELATIONS BETWEEN GROWTH TRAITS IN ALL CALVES

Growth Traits	Weaning Weight	Yearling Weight	Long Yearling Weight
Birth weight	.49 ± .31	.31 ± .34	.14 ± .45
Weaning weight		.73 ± .14	.75 ± .18
Yearling weight			.94 ± .09

TABLE 17: PHENOTYPIC CORRELATIONS BETWEEN GROWTH TRAITS IN ALL CALVES

Growth Traits	Weaning Weight	Yearling Weight	Long Yearling Weight
Birth weight	.30	.26	.22
Weaning weight		.73	.64
Yearling weight			.76

TABLE 18: PHENOTYPIC CORRELATIONS BETWEEN GROWTH TRAITS IN MALE CALVES

Growth Traits	Weaning Weight	Yearling Weight	Long Yearling Weight
Birth weight	.16	.34	.21
Weaning weight		.59	.67
Yearling weight			.65

Phenotypic correlations between birth weight and each of weaning, yearling and long yearling weights were estimated at .30, .26, and .22, respectively, in all calves and .29, .22 and .23 in female calves.

Weaning Weight (WW)

Least squares analysis of variance, least squares means for WW of all calves, females and males are shown in tables 9, 10, 11, and 13.

Effect of environmental factors

The same effects included for birth weight were considered. Month of birth had an effect (P<.01) or (P<.001) on WW in all three analyses. The LS means WW for all calves, female and male calves were 107.79 ± 24.12, 104.37 ± 21.57 and 114.03 ± 27.68 kg, respectively. In females (Table A3), the lighter weights were recorded for calves born in December and in February (78.40 and 85.47 kg) while the heavier calves were those dropped in April and May (119.12 and 115.94 kg). Calves born in June-July also showed positive but far smaller constant estimates for WW than those born in April and May. Except for September, calves born from August through February consistently showed negative constant estimates for WW. A very close trend was found for WW in male calves (Table A4). The heavier calves at weaning were born in May, the lighter ones in January-February and the constant estimates for the trait were negative through November through April. These observations have an important implication for the management decision making process although the LS means used above

reflect an average year rather than a specific year. Breeding cows to calve from April through July may well be a good alternative to test and compare with the current practice which allows calves to be born beginning in July. Creep feeding may be needed since April-July is the last half of the dry season.

Year of birth was a significant source of variation ($P<.001$) in WW in all analyses. The heaviest females at weaning (Table A3) were born in 1977 (121.02 ± 9.54 kg) and the lightest ones in 1970 (86.23 ± 6.77 kg). For the males (Table A4), those born in 1975 and 1976 were the lightest calves and those born in 1971 and 1972 were the heaviest ones (59.83 ± 12.67 and 56.05 ± 19.37 vs 132.83 ± 13.58 and 124.35 ± 14.03). The environmental data collected at Dahra revealed that 1970 was the most severe dry year (209.5 mm of annual rainfall) of the period covered by this study. The same data also showed 1971, 1972 and 1977 were among the five dry years covered by this study. There is, therefore, evidence that unless the year was extremely dry, the heaviest weights recorded at weaning were for calves born during dry years. Similar results were reported by Plasse and Koger (1967), Bauer et al. (1978) and Verde and Plasse (1976). This suggests that even though forage may be abundant in wet years animals may be more susceptible to parasite infestations and mineral deficiencies such as phosphorus if cow-calf operations are not properly managed. There was no clear phenotypic

trend of year effect on WW although there were wide variations across years (Table 19 and Fig. 7).

The dam age affected ($P<.001$) WW in all calves analyses (Table 9). The heavier calves at weaning were born from 4 to 10 year old cows and the lighter from cows of 11 to 12 years of age or older (Table A6). The differences in weaning weights were small among calves born from 3 to 10 year old cows. These results agree with those reported for Bos indicus cattle by Koger et al. (1962), Meade et al. (1961), Cruz (1972) and Mariante (1978). A policy of culling cows older than 10 years should be considered as potentially good alternatives designed to improve cow-calf productivity.

The literature reveals a generally significant effect of sex on weaning weight of the calves. As expected, in this study, sex was a source of variation ($P<.001$) in weights of calves at weaning. Male calves (114.03 kg) were 9.66 kg heavier at weaning than females (104.37 kg). Santiago (1972) found a difference of 8.00 kg in favor of Nellore male calves but most reports on Bos indicus cattle showed differences higher than 10 kg (Beltran, 1976; Cruz, 1972; Koger and Knox, 1945; Botkin and Whatley, 1953; Koch and Clark, 1955; Brinks et al., 1961; Meade et al., 1963; Peacock et al., 1969).

Effect on genetic factors

Sire had effects on weaning weight of female and all calves ($P<.001$) and male calves ($P<.05$). The least squares

TABLE 19: PHENOTYPIC TRENDS ANALYSES FOR WEANING WEIGHT

All Calves			Male Calves			Female Calves		
Source	D.F.	MS	Source	D.F.	MS	Source	D.F.	MS
Month of birth	11	3200.25***	Month of birth	10	1425.56**	Month of birth	11	1940.41***
Dam age	8	2045.37***				Dam age	7	682.34
Sex	1	4481.62**						
Year of birth	12	5557.84***	Year of birth	11	2443.87***	Year of birth	11	2415.24***
Linear	1	3545.34**	Linear	1	4187.73**	Linear	1	1016.16
Quadratic	1	2.38	Quadratic	1	15.82	Quadratic	1	482.19
Cubic	1	1619.17*	Cubic	1	4271.76**	Cubic	1	175.17
Quartic	1	2036.34*	Quartic	1	2324.91*	Quartic	1	2942.51**
Quintic	1	14412.72***	Quintic	1	296.33	Quintic	1	11958.55***
Residual	7	6439.74***	Residual	6	2631.01***	Residual	6	1665.52***
Remainder	594	454.89	Remainder	172	538.49	Remainder	329	403.68

*P<.05

**P<.01

***P<.001

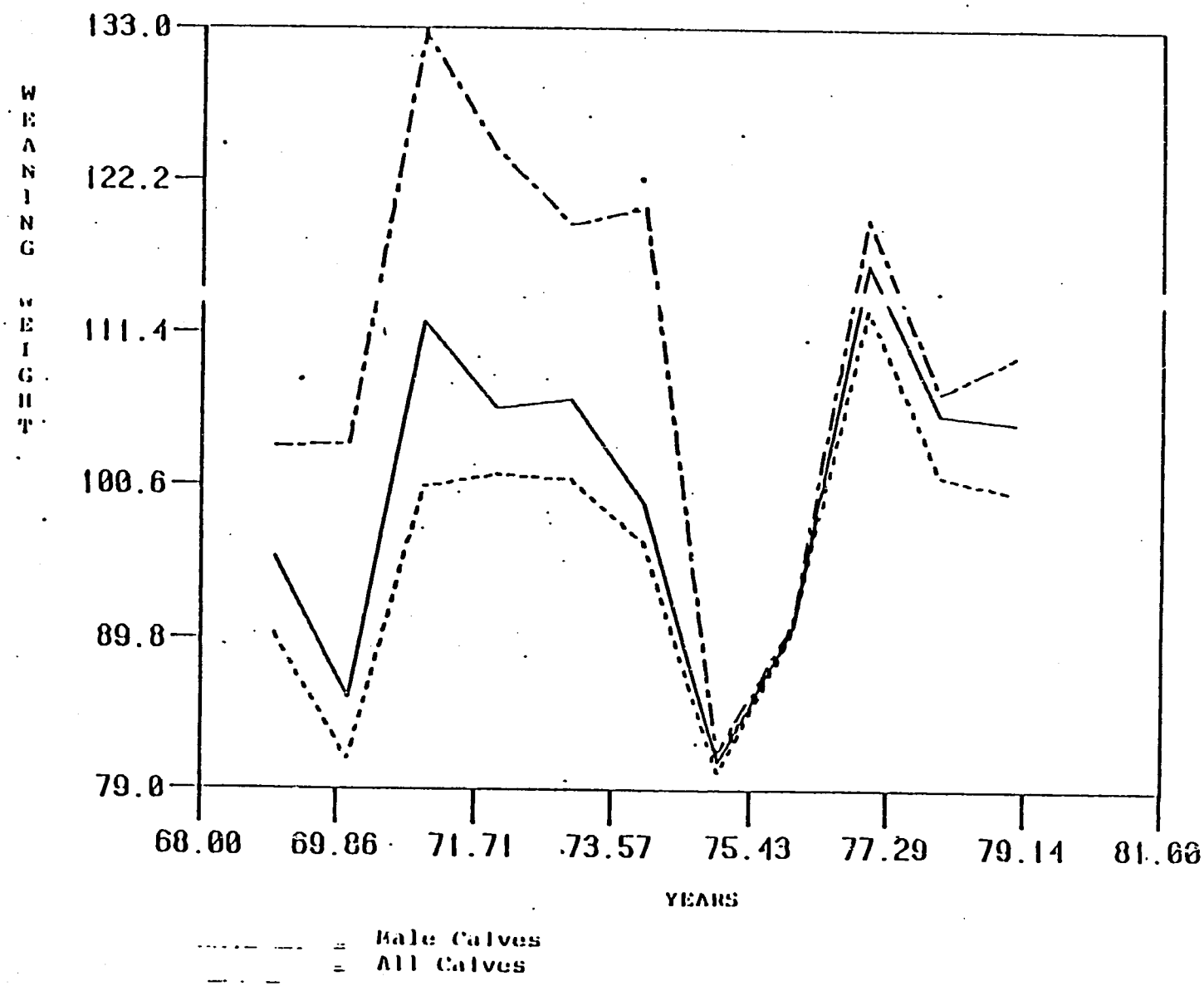

Figure 7. Weaning weight by year of birth

constants and means for sire could not be obtained because sire was absorbed in Harvey's LSMLMM procedure.

The heritability estimates from paternal half-sib correlations, genetic and phenotypic correlations between weaning weight and weights at various ages are shown in tables 14 through 20. The h^2 estimates were .31 ± .24 for male calves, .46 ± .19 for female calves and .34 ± .13 for all calves. Higher heritabilities for weaning weight in female calves when compared to that of male calves were also reported in literature (Pahnish et al., 1961; Francoise et al., 1973). In general, heritability estimates found in this study are similar to the values of .30, .33, .30, .36, .43, .48 and .30 reported by Rollins and Wagnon (1956), Minyard and Dinkel (1960), Knapp and Nordskog (1946), Dinkel and Musson (1956), Shelby et al. (1957), Swiger et al. (1962) and Gottlieb et al. (1962), respectively.

Genetic and phenotypic correlations between growth traits are presented in tables 14 through 18. In female calves, genetic correlations between weaning weight and each of yearling weight and long yearling weight were .67 and .52, respectively, whereas phenotypic correlations were found to be .71 and .59. In all calves, genetic correlations were .73 and .75 and phenotypic correlations were .73 and .64, respectively, between weaning weight and each of the two postweaning traits. These genetic correlations fell in the range of .50 to greater than .60 reported by Cartwright and Fitzhugh (1972) for the weights taken at different ages on Brahman

TABLE 20: HERITABILITY ESTIMATES FROM PATERNAL HALF-SIB CORRELATIONS FOR GROWTH RATES

Category	Growth[a] Rate	Birth[b] Weight	Weaning Weight	Yearling[c] Weight	Long Yearling[d] Weight
Female	.22 ± .18	.20 ± .14	.46 ± .19	.41 ± .18	.23 ± .15
Male			.31 ± .24		
All calves		.14 ± .09	.34 ± .13	.33 ± .13	.15 ± .09

[a] The analysis of growth rate was performed for females only

[b,c,d] Sire had no effects on weights at birth, 12 months and 18 months of males. Therefore, h^2 for these growth traits were not estimated.

cattle. Mariante (1978) working with Nellore cattle in Brazil, however, found higher values than those found in this study. He reported .86 and .62 for genetic correlations, .83 and .70 for phenotypic correlations between weaning weight and each of yearling weight and long yearling weight, respectively.

Yearling Weight and Long Yearling Weight

Least squares analysis of variance and least squares means for yearling and long yearling weights are shown in tables 21 through 23 and in table 13.

Effect of environmental factors

Factors affecting preweaning and weaning traits were also, with few exceptions, significant sources of variation in postweaning weights.

Month of birth affected ($P<.01$ or $P<.001$) both 12-month and 18-month weights in all analyses. Heavier bulls at 12 months were born from September through February (except November) and lighter ones from April through August (Table A7). The heaviest bulls were born in December and the lightest ones in June and August. A consistently opposite trend was found for bulls at 18 months: lighter bulls (Table A8) were those born from November through February and heavier ones from April through October. In heifers, least squares constant estimates (Table A9) showed very similar trends: heavier yearling weights were obtained for females born from November through May and heavier long yearling weights from March through September (Table A10).

TABLE 21: LEAST SQUARES ANALYSIS OF VARIANCE FOR YEARLING AND LONG YEARLING WEIGHT IN ALL CALVES

Source	D.F.	Mean Squares	
		Yearling Weight	Long Yearling Weight
Sire	27	1955.38***	1984.94*
Month of birth	11	4947.22***	9404.01***
Dam age	8	1792.23*	2333.47*
Year of birth	12	8763.71***	13730.31***
Sex	1	9063.45***	80216.31***
Remainder	567	726.62	1161.89

*P<.02 or P<.05

**P<.01

***P<.001

TABLE 22: LEAST SQUARES ANALYSIS OF VARIANCE FOR YEARLING AND LONG YEARLING WEIGHT IN MALE GOBRA ZEBU

Source	D.F.	Mean Squares	
		Yearling Weight	Long Yearling Weight
Sire	19	1246.58	1910.46
Month of birth	10	2929.28***	3536.54**
Year of birth	11	3737.81***	10240.01***
Remainder	153	848.24	1415.45

**$P < .01$

***$P < .001$

TABLE 23: LEAST SQUARES ANALYSIS OF VARIANCE FOR YEARLING AND LONG YEARLING WEIGHT IN FEMALE GOBRA ZEBU

Source	D.F.	Mean Squares	
		Yearling Weight	Long Yearling Weight
Sire	25	1436.71***	1530.47*
Month of birth	11	2936.87***	6774.63***
Dam age	7	1602.93*	1640.23*
Year of birth	11	5334.27***	8350.78***
Remainder	304	618.88	908.94

*P <.05

**P <.01

***P <.001

In other words, animals born from mid-wet through mid-dry season were heavier at 12 months and lighter at 18 months and vice versa. This cyclically seasonal behavior may well suggest when to sell bulls and extra heifers kept on natural pastures in a stocker operation. In fact, unless economic studies show otherwise, it seems unrealistic to prefer a management alternative which leads to light calves at weaning to the one which does not. However, in choosing among alternatives as to how long to maintain young animals on pasture, one should keep in mind that there may be a high risk associated with calving from mid-dry season to mid-wet season because the severe shortage of forage resources may make this period very detrimental to the herd.

Year of birth affected ($P<.001$) yearling and long yearling weight of male, female and all calves (Tables 21, 22 and 23). The heavier females at 12 and 18 months were born in 1968, 1971, 1972, 1977 and 1978 all of which were dry years except 1968 (Tables A9 and A10). The lighter ones were born in 1970 (severe dry year), 1969, 1974, 1975 and 1979 (all wet years). These results, together with those on weaning weights indicate that calves born during wet periods suffered a decreased growth rate during the subsequent dry period and showed no tendency to improve prior to 18 months of age. No clear phenotypic trend of year effect from polynomial regressions (Tables 24 and 25) could be detected though there were wide variations across years (Figures 8 and 9). Pacho (1981) also found no trend of year effect on 12-month and 18-month weights of Brahman heifers.

TABLE 24: PHENOTYPIC TRENDS ANALYSES FOR YEARLING WEIGHT

Females			Males		
Source	D.F.	MS	Source	D.F.	MS
Month of birth	11	3976.58***	Month of birth	10	2851.90*
Dam age	7	2035.38**	Dam age		
Year of birth	11	8764.26***	Year of birth	11	12601.18***
Linear	1	14885.45***	Linear		26786.51***
Quadratic	1	23.55	Quadratic		29956.69**
Cubic	1	4740.60**	Cubic		6071.39*
Quartic	1	6383.35**	Quartic		57601.16***
Quintic	1	55714.57***	Quintic		1623.51
Residual	1	14659.38***	Residual		2362.29***
Remainder	329	681.03	Remainder		1470.13

*P<.05

**P<.01

***P<.001

TABLE 25: PHENOTYPIC TRENDS ANALYSES FOR LONG YEARLING WEIGHT

Females			Males		
Source	D.F.	MS	Source	D.F.	MS
Month of birth	11	7625.07**	Month of birth	10	3586.13***
Dam age	7	1876.17*	Dam age		
Year of birth	11	13490.00***	Year of birth	11	5175.99***
Linear	1	2154.79***	Linear		3308.60*
Quadratic	1	4881.30*	Quadratic		.38
Cubic	1	26.79	Cubic		2040.32
Quartic	1	15562.51***	Quartic		6642.31**
Quintic	1	1653.54***	Quintic		856.63
Residual	1	956.17***	Residual		7347.94***
Remainder			Remainder		892.24

*P<.05

**P<.01

***P<.001

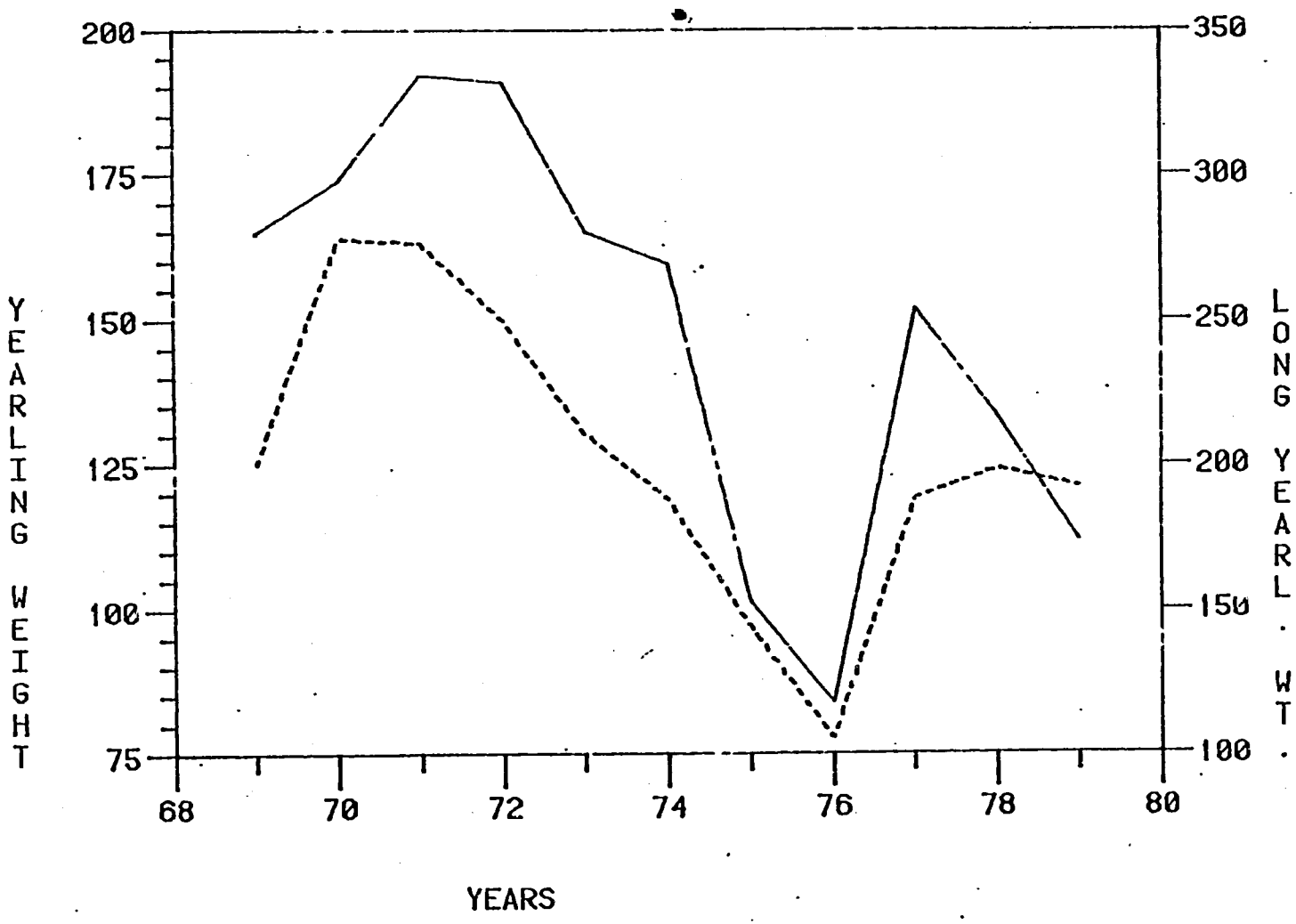

Figure 8. Post-weaning weight by year of birth in male Gobra

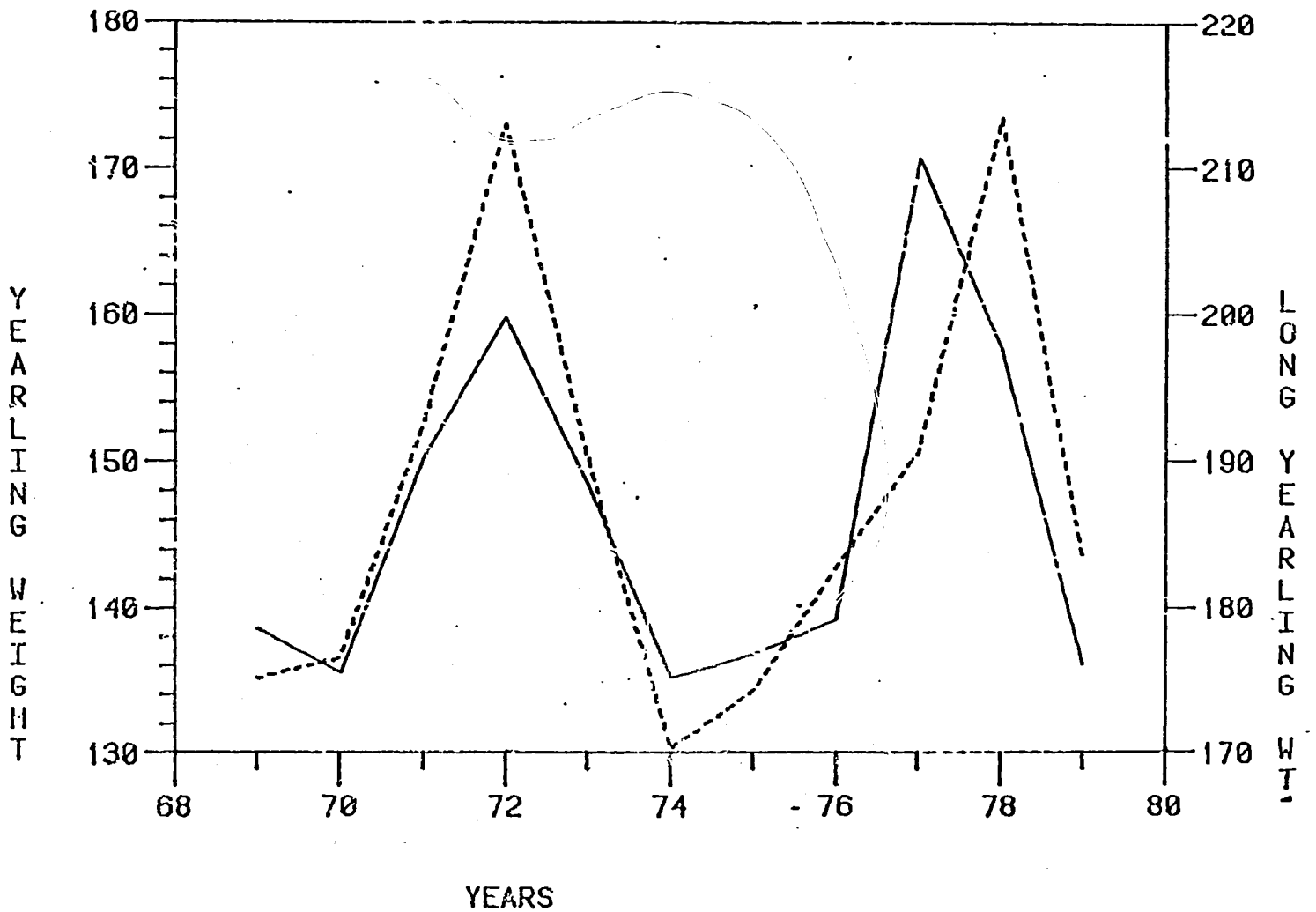

Figure 9. Post-weaning weight by year of birth in female Gobra

Dam age was a significant source of variation on yearling (P<.02) and long yearling (P<.05) weights for all calf data analyzed. At 12 and 18 months, the heaviest average weights were recorded for animals from 3 years old cows and the lightest from cows older than 12 years (Table A11).

Sex affected yearling and long yearling weights (P<.001). As found in the literature (Mariante, 1978; Beltran, 1976; Corlis and Rudder, 1975), the weight differences between males and females increases with the age of calves. In this study, males were 11.3 kg (152.65 vs 141.35) and 28.28 kg (226.78 vs 198.50) heavier than females at 12 and 18 months, respectively (Table 13).

Effect of genetic factors

There were sire effects on long yearling weight (P .05) and yearling weight (P<.001) in both female and all calves. Heritability estimates from paternal half-sib correlations for yearling and long yearling weights were .41 ± .18 and .23 ± .15 in female calves and .33 ± .13 and .15 ± .09 in all calves, respectively. Pacho (1981) found heritability estimates of .13 ± .10 and .22 ± .18 for weights at 12 and 18 months, respectively, in Brahman heifers. Similar low values were reported for Brahman and Nellore calves by Beltran (1976) and Mariante (1978). Pacho (1981) stated that the low estimates were due to the environmental stress resulting in increased environmental variance. Woldehawarita et al.

(1979), however, reported a heritability estimate of .44 for pasture yearling weight in beef cattle.

Estimates of genetic and phenotypic correlations between yearly and long yearling weights in heifers were .92 ± .10 and .79 (Tables 14 and 15), respectively. In all calves, these estimates were .94 ± .09 and .76, respectively (Tables 16 and 17). These estimates were the highest that were obtained between any two growth traits in this study. This is in accord with the fact that body weights taken at closer ages are more correlated than those taken at more distant ages. There is also evidence that correlations between two body weights taken under maternal environment tended to be lower than those obtained between postweaning body weights (e.g., in heifers, correlations were .45 and .49 between birth weight and weaning weight, .67 and .71 between weaning weight and yearling weight).

Growth Curve Parameters

The least squares analysis for growth curve parameters (asymptotic weight, A, and rate of maturity, K) are presented in table 26.

Effect of environmental factors

Month of birth affected ($P < .10$) the asymptotic weight (mature weight) but had no effect on maturing rate. Heavier mature sizes were recorded for females born from April through May and lighter ones from February through March (Table A12). All positive constant estimates tended to concentrate in the interval April-September (i.e., from mid-dry season to mid-wet season). This confirms the

TABLE 26: LEAST SQUARES ANALYSIS OF VARIANCE FOR ASYMPTOTIC WEIGHT (MATURE SIZE) AND MATURING RATE IN FEMALE GOBRA ZEBU

Source	D.F.	Mean Squares	
		Mature Size	Maturing Rate
Sire	20	1983.43	.014*
Month of birth	11	3174.61*	.008
Year of birth	11	6149.55**	.032***
Remainder	201	1820.52	.009

*P <.10

**P <.01

***P <.001

TABLE 27: LEAST SQUARES MEANS AND STANDARD ERRORS FOR GROWTH EQUATION PARAMETERS IN FEMALE GOBRA ZEBU

Parameters	L.S. Means (kg)	S.E. (kg)
Mature size (A)	398.83	45.85
Maturing rate (K)	.169	.112
Integration constant (B)	402.73	73.71

preceding observations that calves dropped in wet seasons, under the prevailing conditions, would reach a poor mature weight as a result of a consistently decreased growth before and after weaning.

Year of birth affected both the mature size ($P<.01$) and maturing rate ($P<.001$). This is in agreement with the available literature (Hafez, 1963; Brown et al., 1972; Wong, 1974; Mbah, 1975). The variation in mature size across years is shown in figure 10.

Effects of genetic factors

Sire had effects ($P<.10$) on maturing rate and no effects on the asymptotic weight. The low or nonexisting sire effects on these traits may be due to the limited number of bulls used and the small size of the sire progeny groups used to evaluate the differences among sire groups. Peacock et al. (1966) and Gregory et al. (1950) came to the same conclusion after studying sire effects on weight traits. Schaeffer and Wilton (1975) indicated a need for 100 to 150 progeny per sire to accurately evaluate the differences among sires. Kennedy and Henderson (1975) concluded that a substantial population size is needed for precise estimation of variance components.

Genetic correlations (Table 14) between maturing rate and body weights at birth, weaning, 12 and 18 months were .45 ± .51, -.21 ± .52, .01 ± .57 and -.76 ± 51, respectively. The phenotypic correlation between mature weight and rate of maturity (Table 15) was negative (-.06). This series of low to negative correlations is in agreement with the finding of

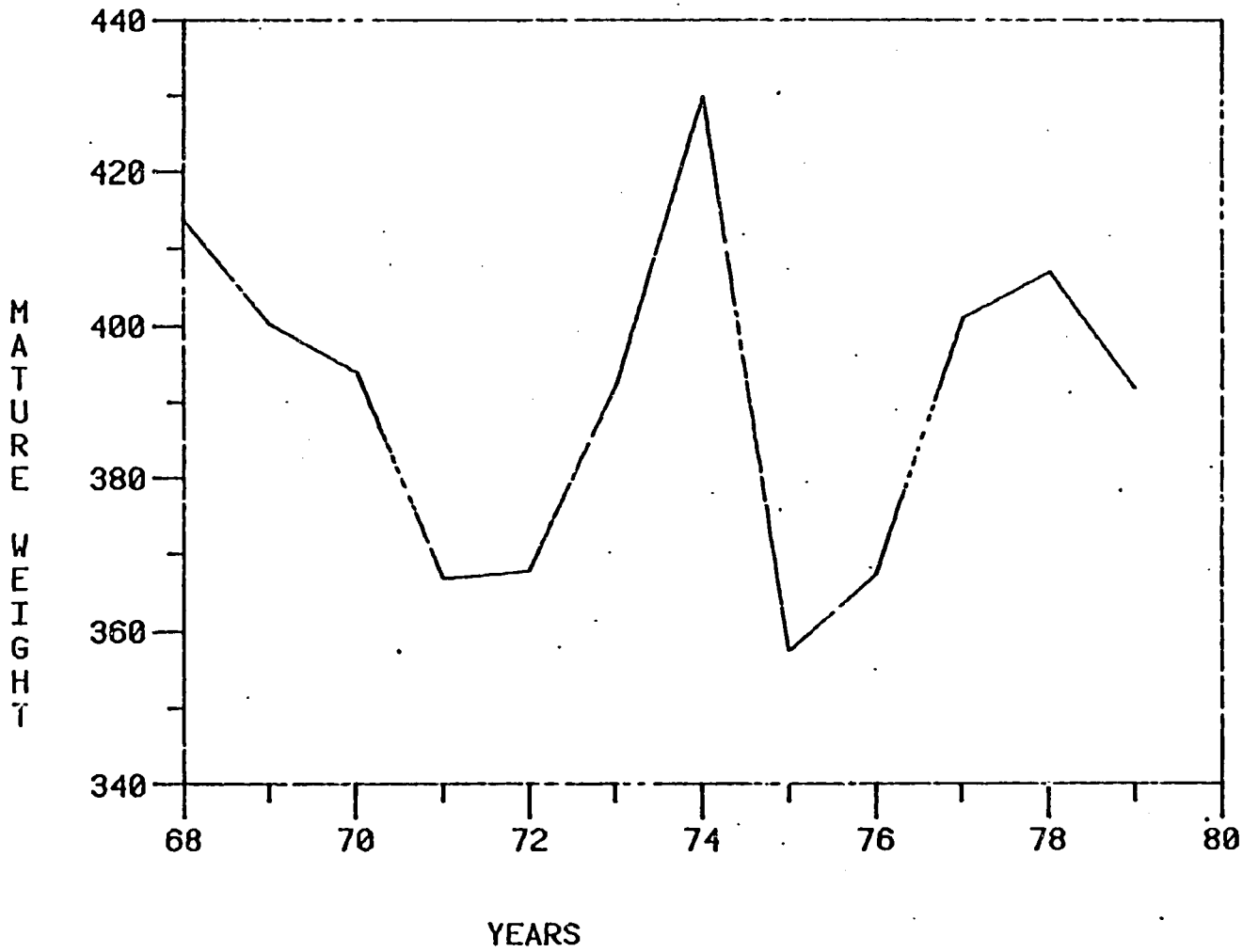

Figure 10. Mature weight by year of birth in female Gobra

earlier authors (Joandet, 1967; Brown et al., 1972). Their direction and magnitude confirm the observation of Joandet (1967), Fitzhugh et al. (1971) and Wong (1974) that rapidly maturing beef females did so to a lighter mature weight and vice versa. However, early maturing females may not be lighter at birth than later maturing ones as has been suggested by Brown et al. (1972).

The least squares means of the growth parameters in table 27 describe the growth pattern of Gobra Zebu females under the conditions of Dahra Livestock Research Center. Average mature size, rate of maturity and constant of integration were estimated at 398.83 ± 45.81 kg, 16.9 percent for 90 days (or .187 percent per day) and 402.73, respectively. These parameter values were used to generate the growth curve shown in figure 11 and ages required for various degrees of maturity presented in table 28. Female Gobra were about 50 percent mature by 12 months and 99 percent mature at about 7 years and 3 months of age.

Overall, heritability estimates indicate that progress can be made through selection for growth. Selection for weaning weight in females would be expected to be about .89 and .5, as efficient in improving YW and LYW, respectively, as selection for the traits directly themselves. Genetic correlations between body weights while indicating that correlated responses in selecting for growth should be anticipated, suggest that selection for relative growth rate

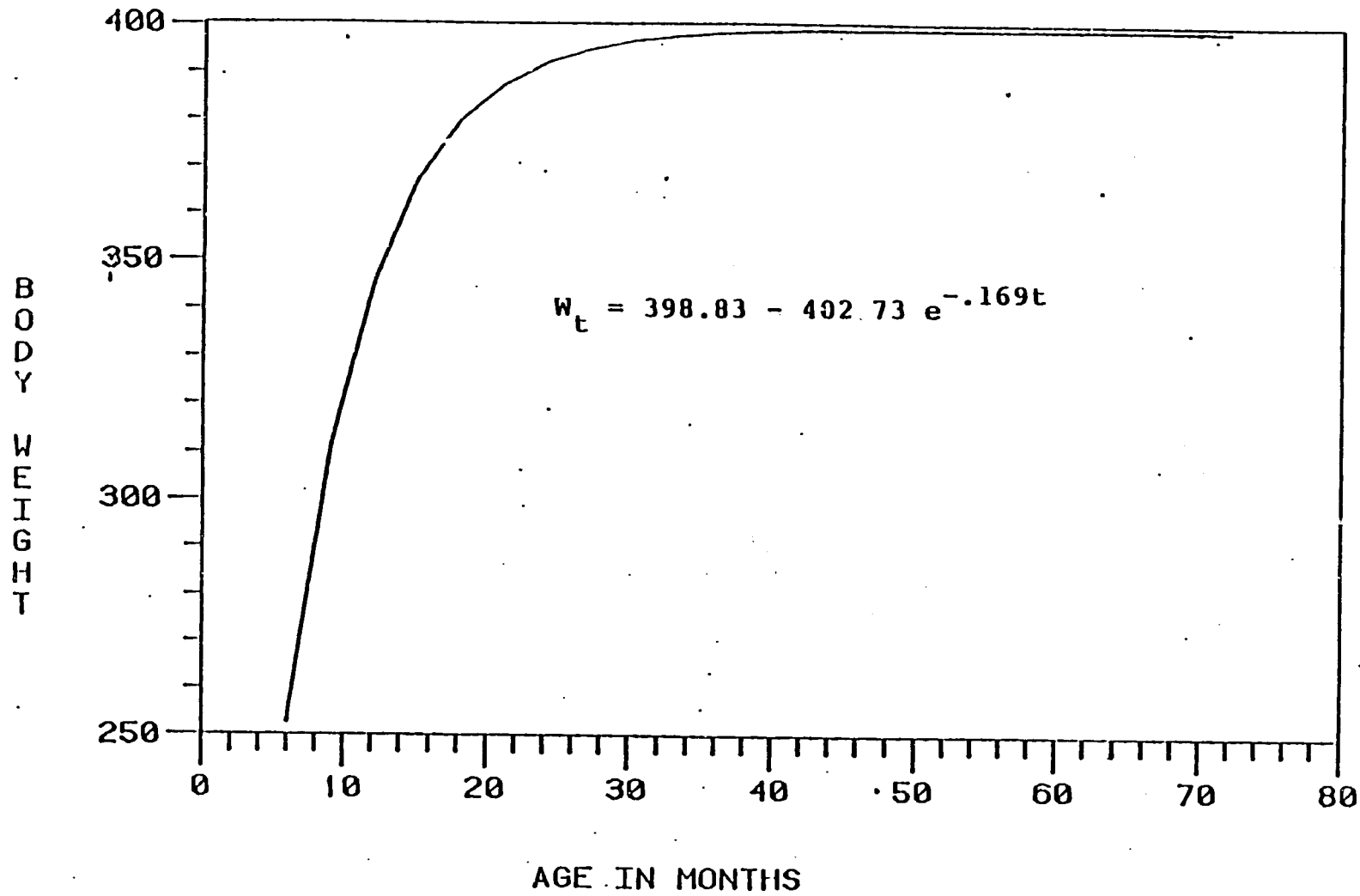

Figure 11. Growth curve of Gobra female

TABLE 28: DEGREE OF MATURITY (U) AND CORRESPONDING AGES FOR GOBRA ZEBU FEMALE

Age[a] (Months)	U	$\ln(1 - \frac{W}{A})$
5.11	.25	- .28768
6.33	.30	- .35667
7.64	.35	- .43078
9.07	.40	- .51083
10.61	.45	- .59784
12.31	.50	- .69315
14.18	.55	- .79851
16.27	.60	- .91629
18.64	.65	-1.0498
21.38	.70	-1.2040
24.62	.75	-1.3863
28.58	.80	-1.6094
33.69	.85	-1.8971
45.95	.90	-2.3026
59.16	.95	-2.9957
75.80	.98	-3.9120
87.60	.99	-4.6052

[a]Age (or t) = $t^* - \frac{1}{k}\ln(1 - \frac{W}{A})$ where

t^* = age (month) from which the self-inhibiting phase of growth was fitted.

in females could be expected to decrease both weaning and long yearling weight.

Model Based Simulation of Gobra Zebu Production System

Many management alternatives or alternative combinations cannot be screened by field research techniques because of resource limitations. Simulation can be used to integrate and extend experimental data and select the most promising combinations of practices for field testing. Based on the growth data analysis and other livestock production data collected at Dahra, the following management practices can be selected for simulation of Gobra Zebu cattle production performances.

The Baseline

Run1. Under the real conditions of Dahra Livestock Research Center, replacement heifers were bred from October through December to calve first at 3 years of age. Calves were weaned at constant age of 6 months. There was no feed supplementation. Run1 will simulate the performances of Gobra Zebu based on its genotype and potential for milk production and the actual forage resource base. This run is called the baseline.

Change in Breeding Age

Run2. Calving first at 2 years of age in the original environment.

Change in Breeding Season

Run3. Breeding from September through November in the original environment.

Run4. Breeding from August through October in the original environment.

Run5. Breeding from October through December in the original environment.

Run6. Breeding from July through September in the original environment.

Run7. Breeding from October through December; breeding to calve first at 2 years of age; weaning at 6 months.

Run8. Breeding from September through November; breeding to calve first at 2 years of age; weaning at 6 months.

Run9. Breeding from August through October; breeding to calve first at 2 years of age; weaning at 6 months.

Change in Weaning Age

Run10. Calving first at 3 years of age; breeding from October through January; weaning at 5 months.

Run11. Calving first at 3 years of age; breeding from October through January; weaning at 7 months.

Run12. Calving first at 2 years of age; breeding from October through January; weaning at 7 months.

Supplementation Alternatives

One kg of groundnut based supplemental feed characterized by 9.8 percent crude protein and 60 percent digestibility was used as daily supplement.

Run13. Supplementing all cow herd from May through July; breeding from September through November; weaning at 6 months.

Run14. Supplementing all cow herd from June through July; breeding from September through November; weaning at 6 months.

Run15. Supplementing all cow herd in July; breeding from September through November; weaning at 6 months.

Run16. Supplementing 2 year old females only; setting breeding season and weaning age as in Run15.

Run17. Supplementing yearlings only; setting breeding season and weaning age as in Run15.

Run18. Supplementing yearling and 2 year old females; setting breeding season and weaning age as in Run15.

Run19. Supplementing mature cows only; setting breeding season and weaning age as in Run15.

Run20. Supplementing all cow herd from May through July; calving first at age of 2 years; breeding from October through December; weaning at 6 months.

Run21. Supplementing all cow herd from June through July; setting calving age, breeding season and weaning age as in Run20.

Run22. Supplementing all cow herd in July; setting calving age, breeding season and weaning age as in Run20.

Run23. Supplementing 2 year old females from May through July; setting calving age, breeding season and weaning age as in Run20.

Run24. Supplementing yearling replacements only from May through July; setting calving age, breeding season and weaning age as in Run20.

Run25. Supplementing yearling replacements and 2 year old females; setting calving age, breeding season and weaning age as in Run20.

Run26. Supplementing all cow herd from May through June; calving first at 3 years of age; breeding from September through November; weaning at 7 months.

Run27. Supplementing all cow herd from June through July; setting calving age, breeding season and weaning age as in Run26.

Run28. Supplementing all cow herd in July only; setting calving age, breeding season and weaning age as in Run26.

Run29. Supplementing 2 year old replacements from May through July; setting calving age, breeding season and weaning age as in Run26.

Run30. Supplementing yearlings only from May through July; setting calving age, breeding season and weaning age as in Run26.

Run31. Supplementing yearling and 2 year old replacements; setting calving age, breeding season and weaning age as in Run26.

Run32. Supplementing mature cows only from May through June; setting calving age, breeding season and weaning age as in Run26.

Run33. Supplementing all cow herd from May through July; calving first at 2 years of age; breeding from October through December; weaning at 7 months.

Run34. Supplementing all cow herd from June through July; setting calving age, breeding season and weaning age as in Run33.

Run35. Supplementing all cow herd in July; setting calving age, breeding season and weaning age as in Run33.

Run36. Supplementing yearling replacements and 2 year old females; setting calving age, breeding season and weaning age as in Run33.

Run37. Supplementing mature cow herd only; setting calving age, breeding season and weaning age as in Run33.

VALIDATION

Gobra Zebu performance and forage data from the Dahra Livestock Research Center were used to verify that the model structure and input parameters closely simulated existing conditions at the center during the average dry year.

Model Modification

Preliminary simulations overestimated intake for immature animals although the intakes for very immature and mature animals were properly simulated. The expression of intake $(WM/WMZ)^{.15}$ of the source program was changed to $(WM/WMZ)^{.90}$ so that intake of limited available forage became

$$R_3 = AVC * (WM/WMZ)^{.90}$$

where AVC = maximum available dry matter per animal,

WM = measure of skeletal size and

WMZ = genetic potential for size in females.

The estimate of this intake was, therefore, more closely related to degree of maturity than was found in original program.

Table 29 shows the overall unadjusted means and the simulated results obtained from Run1 or baseline. Based on the analogy between the actual and simulated results, further simulations were conducted with confidence.

TABLE 29: MEAN ACTUAL AND SIMULATED VALUES

Character	Actual	Simulated
Birth weight, kg	25.78	26.25
Average, weaning weight, kg	114.93	115.60
Preweaning average daily gain, kg	.495	.496
Calving rate, %	60.83	61.07
Survival to weaning, %	87.22	87.60
Cow weight in July, kg		
1 years	136.0	134.93
2 years	181.0	181.76
3 years	306.3	255.79
4 years	319.8	290.20
5 years	317.66	316.63
6 years	350.85	337.04
7 years	328.13	356.17
8 years	338.55	369.35
9 years	366.40	379.96

RESULTS OF SIMULATIONS

Based on the results from analysis of data collected at the research station of Dahra, only a cow calf production system was considered. Average dry year forage data were used as the basis for the simulation runs. An average wet year should result in improved nutrition but performance may decrease due to diseases not accounted for by the model. A simulation of Gobra Zebu performance for wet years may be misleading because of the overestimation of the production results.

Tables 30 through 37 show production and reproduction parameters resulting from run 1 through run 37.

Baseline

Actual forage, genetic and management data outlined earlier were used in run 1, the original run, which served as baseline for subsequent comparisons. Calving rate and calf survival to weaning were 61.07 percent and 87.60 percent, respectively. Average weaning weight and weight of steers sold after weaning were 115.8 kg and 122.77 kg, respectively. Productivity indices defined in terms of efficiency of nutrient utilization (kg liveweight sold/100 kg DM consumed) and cow productivity (kg liveweight sold/cow exposed) were 3.73 and 86.59, respectively.

TABLE 30: SIMULATED EFFECT OF CHANGING BREEDING AGE ON PRODUCTION PERFORMANCE IN THE ORIGINAL ENVIRONMENT (BREEDING SEASON = OCTOBER-JANUARY: WEANING AGE 6 MONTHS)

Production Parameters Per 100 Cows Exposed Per Year	Calving First At 3 Years of Age (Baseline) (Run 1)	Calving First At 2 Years of Age (Run 2)
Total dry matter consumed (mt)	231.60	231.30
Calves born (%)	61.07	61.30
Calves weaned (%)	53.50	53.25
Survival rate to weaning (%)	87.60	86.87
Average weaning weight (kg)	115.80	116.10
Average weight of steers sold (kg)	122.77	122.49
Total livestock sold (mt)	8.66	8.74
Composition of the sales		
Males (%)	49.52	51.13
Females (%)	50.48	48.87
Production indices		
kg liveweight sold/100 kg DM consumed	3.74	3.77
kg liveweight sold/cow exposed	86.59	87.41

Effect of Changing Breeding Age on Production Performance

Very few cattle herd managers in the tropics consider breeding young Zebu females to calve first at 2 years of age because of slow growth and delayed puberty due to harsh nutritional and environmental conditions. Under the conditions of Dahra Research Center, few yearling replacement heifers were bred to calve at 2 years of age and there was a speculation that these females may perform well. Run 2 considered breeding replacement heifers to calve first at 2 years of age. Results showed that, while calving rate, percentage calves weaned, average weight of steers sold and efficiency of nutrient utilization in both the baseline and this run remained nearly the same, calf survival to weaning decreased slightly from 87.60 to 86.87 percent. Lower calf survival to weaning was expected when 2 year old cows were included in the herd since they produced less milk than 3 year old cows. Cow productivity (87.41), however, was slightly higher when heifers calved first at 2 years than when they calves at 3 years of age due to a larger proportion of marketed steers (51.13 percent) as compared to the baseline (49.52).

Effect of Changing Breeding Season on Production Performances

Breeding Heifers to Calve First at 3 Years of Age

Runs 3, 4, 5 and 6 were designed to analyze the effects of changing breeding seasons on Gobra Zebu performances when the breeding age, weaning age and forage data base remained the same as in the original run. Productivity indices were

TABLE 31: SIMULATED EFFECT OF CHANGING THE BREEDING SEASON ON PRODUCTION PERFORMANCE IN THE ORIGINAL ENVIRONMENT (AGE AT FIRST CALVING = 3 YEARS)

Production Parameters Per 100 Cows Exposed Per Year	Baseline (Run 1)	Breeding Season: September Through November (Run 3)	August Through October (Run 4)	October Through December (Run 5)	July Through September (Run 6)
Total dry matter consumed (mt)	231.6	233.5	230.2	333.1	226.8
Calves born (%)	61.07	60.52	58.20	60.40	53.89
Calves weaned (%)	53.50	52.31	49.24	52.38	45.26
Survival rate to weaning (%)	87.60	86.43	84.60	86.72	83.98
Average weaning weight (kg)	115.8	116.85	115.5	118.4	113.15
Average weight of steers sold (kg)	122.77	123.25	122.08	124.49	118.96
Total liveweight sold (mt)	8.66	9.436	8.879	9.06	7.79
Composition of the sales					
Males (%)	49.52	47.79	50.09	50.07	51.98
Females (%)	50.48	52.21	49.91	49.93	48.02
Production indices					
kg liveweight sold/100 kg DM consumed	3.739	4.040	3.85	3.88	3.43
kg liveweight sold/cow exposed	86.592	94.36	88.79	90.59	77.93

consistently higher for runs 3, 4 and 5 than for the original run. Breeding from September through November resulted in the highest efficiency (4.04) and the highest cow productivity (94.36) followed by breeding from October through December (3.88 and 90.59) and by breeding from August through October (3.85 and 88.79). The lowest percentage calving rate and calf survival rate (53.89 and 83.98, respectively) occurred when the breeding season was set from July through September. Calving rate and calf survival were slightly lower for runs 3, 4 and 5 than the baseline but they allowed increased growth which was high enough to increase efficiency and productivity per cow. The best overall alternative among these four simulations was the one which considers breeding cows from September through November to calve first at 3 years of age.

Breeding Heifers to Calve First at 2 Years of Age

Runs 7, 8 and 9 simulated the effects of breeding from October through December, September through November and August through October, respectively. Both practices of breeding from September through November and from August through October showed no improvement as indicated by efficiency and cow productivity. In run 8, low calving rate and low percentage of calves weaned combined with increased calf mortality to weaning were sufficient to offset increased productivity due to increased growth. In run 9, calves were dropped from May through August. This calving season without supplementation was expected to be highly stressful on 2 year

TABLE 32: SIMULATED EFFECT OF CHANGING BREEDING SEASON ON PRODUCTION PERFORMANCE (AGE AT FIRST CALVING = 2 YEARS)

Production Parameters Per 100 Cows Exposed Per Year	Baseline (Run 1)	Breeding Season: October Through December 6 Months (Run 7)	September Through November 6 Months (Run 8)	August Through October 6 Months (Run 9)
Total dry matter consumed (mt)	231.60	233.40	231	229.7
Calves born (%)	61.07	59.65	58.81	57.58
Calves weaned (%)	53.50	51.82	50.17	49.19
Survival rate to weaning (%)	87.60	86.87	85.32	85.42
Average weaning weight (kg)	115.8	118.30	117.15	115.1
Average weight of steers sold (kg)	122.77	124.51	123.56	121.51
Total liveweight sold (mt)	8.66	8.76	8.65	8.57
Composition of the sales				
Males (%)	49.52	50.91	50.00	48.45
Females (%)	50.48	49.09	50.00	51.55
Production indices				
kg liveweight sold/100 kg DM consumed	3.74	3.75	3.74	3.73
kg liveweight sold/cow exposed	86.59	87.64	86.52	85.76

old dams which are still growing and nursing calves. Decreased calf survival rate (85.42 percent) combined with poor growth (115.1 kg and 121.51 kg for average weaning weight and average steers weights sold after weaning, respectively) caused the cow productivity index to drop below that found in the baseline (85.76 vs 86.6). Although calving, weaning and calf survival rates had decreased and efficiency of nutrient utilizations had remained the same as compared to those in the original run, the most desirable alternative was that of run 7 which showed higher cow productivity due to higher average weaning weight (118.3 kg), average weight of steers sold after weaning (124.51 kg) and higher proportion of marketed steers (51 percent).

Effect of Changing Weaning Age on Production Performance

Simulated results on five weaning alternatives are presented in table 33. Runs 1, 10 and 11 show the herd performances when calves born to 3 year old cows were weaned at 6, 5 and 7 months of age, respectively. The highest efficiencies of nutrient utilization (3.95 and 3.92) and the highest cow productivity indices (94.89 and 90.72) were obtained when calves were weaned at 7 months. The least desirable alternative consisted of weaning calves at 5 months. In this alternative, production performances were characterized by a poor growth (103.75 kg for average weight of calves at weaning and 109.08 kg for average weight of steers sold), a high proportion of heifers sold (56 percent) and a low cow productivity index (83.93).

TABLE 33: SIMULATED EFFECT OF CHANGING WEANING AGE ON PRODUCTION PERFORMANCE

Production Parameters Per 100 Cows Exposed Per Year	Calving Age = 3 Years			Calving Age = 2 Years	
	Wean at 6 Months (Baseline)	Wean at 5 Months (Run 10)	Wean at 7 Months (Run 11)	Wean at 6 Months (Run 2)	Wean at 7 Months (Run 12)
Total dry matter consumed (mt)	231.6	234	240.1	231.3	231
Calves born (%)	61.07	65.72	61.69	61.30	59.31
Calves weaned (%)	53.50	57.82	53.77	52.25	51.86
Survival rate to weaning (%)	87.60	87.98	87.66	86.87	87.44
Average weaning weight (kg)	115.8	103.75	127.15	116.10	126.95
Average weight of steers sold (kg)	122.77	109.08	134.22	122.49	133.64
Total liveweight sold (mt)	8.66	8.39	9.48	8.74	9.07
Composition of the sales					
Males (%)	49.52	43.70	49.80	51.13	50.13
Females (%)	50.48	56.30	50.20	48.87	49.87
Production indices					
kg liveweight sold/100 kg DM consumed	3.74	3.58	3.95	3.77	3.92
kg liveweight sold/cow exposed	86.59	83.93	94.89	87.41	90.72

Effect of Supplementation on Production Performance

Various supplementation regimes were simulated as heifers were bred to calve first at 3 or 2 years of age. The best breeding season for each breeding age was used along with the same weaning ages which were set to 6 and 7 months.

Breeding to Calve First at 3 Years of Age

Runs 12 through 18, described earlier, showed that supplementing all the cow herd from May through July resulted in higher levels of production than other supplementation alternatives. Productivity index per cow and efficiency of nutrient utilization were 104.27 and 4.26, respectively. Calving rate, calf survival to weaning, average weaning weight and average steer market weight were 69.27 percent, 89.25 percent, 120.55 kg and 127.11 kg, respectively. Supplemention of 2 year old females only was the least desirable alternative as measured by cow productivity and efficiency of nutrient utilization of 88.61 and 3.80, respectively. Among selective supplementation alternatives, the highest productivity indices were obtained when only mature cows were supplemented. Each of the supplementation alternatives showed improved productivity compared to the original run.

Breeding to Calve First at 2 Years of Age

Runs 19 through 24 showed the same trends as those found for runs 12 through 18. The highest productivity indices were obtained when all the cow herd was supplemented from June through July. The least desirable alternative was still

TABLE 34: SIMULATED EFFECT OF VARYING SUPPLEMENTATION PERIOD AND FEMALE AGE GROUP ON PRODUCTION PERFORMANCE (AGE AT FIRST CALVING = 3 YEARS; BREEDING SEASON = SEPTEMBER-NOVEMBER; WEANING AGE = 6 MONTHS

Production Parameters Per 100 Cows Exposed Per Year	Supplement All Cow Herd In May-July (Run 12)	Supplement All Cow Herd In June-July (Run 13)	Supplement All Cow Herd In July (Run 14)	Supplement Two Year Old Females Only (Run 15)	Supplement Yearlings Only (Run 16)	Supplement Yearlings and Two Year Olds (Run 17)	Supplement Mature Cows Only (Run 18)
Total dry matter consumed (mt)	244.4	240.1	237.2	232.6	234.7	233.8	242.1
Calves born (%)	69.27	66.33	62.74	59.05	60.72	60.29	67.83
Calves weaned (%)	61.83	57.37	52.82	51.39	51.40	51.37	60.04
Survival rate to weaning (%)	89.25	86.40	85.79	87.02	84.64	85.29	88.52
Average weaning weight (kg)	120.55	119.7	118.9	117.4	117.0	117.6	120.5
Average weight of steers sold (kg)	127.11	126.17	125.36	123.76	123.75	123.88	126.79
Total liveweight sold (mt)	10.42	10.06	9.11	8.86	9.38	9.02	10.23
Composition of the sales							
Males (%)	50.00	49.5	48.82	50.08	48.87	50.00	50.06
Females (%)	50.00	50.5	51.18	49.92	51.13	50.00	49.94
Production indices							
kg liveweight sold/100 kg DM consumed	4.26	4.18	3.93	3.80	3.99	3.85	4.22
kg liveweight sold/cow exposed	104.27	100.62	93.35	88.61	93.03	90.15	102.34

TABLE 35: SIMULATED EFFECT OF VARYING SUPPLEMENTATION PERIOD AND FEMALE AGE GROUP ON PRODUCTION PERFORMANCE (AGE AT FIRST CALVING = 2 YEARS; BREEDING SEASON = OCTOBER-DECEMBER; WEANING AGE = 6 MONTHS)

Production Parameters Per 100 Cows Exposed Per Year	Supplement All Cow Herd In May-July (Run 19)	Supplement All Cow Herd In June-July (Run 20)	Supplement All Cow Herd In July (Run 21)	Supplement Two Year Old In May-July (Run 22)	Supplement Yearlings Only In May-July (Run 23)	Supplement Yearlings and Two Year Olds (Run 24)
Total dry matter consumed (mt)	244	240.9	236.8	233.5	235.6	236.2
Calves born (%)	68.09	66.45	62.99	60.73	67.48	62.74
Calves weaned (%)	59.54	58.36	55.25	52.60	53.24	53.84
Survival rate to weaning (%)	87.44	87.82	87.71	86.61	86.59	85.80
Average weaning weight (kg)	121.5	120.6	119.85	117.8	118.7	118.4
Average weight of steers sold (kg)	127.82	126.94	125.98	124.31	124.91	124.61
Total liveweight sold (mt)	9.46	9.85	9.28	8.99	9.11	9.16
Composition of the sales						
Males (%)	51.53	50.68	51.27	49.92	50.14	50.37
Females (%)	48.47	49.32	48.73	50.08	49.86	49.63
Production indices						
kg liveweight sold/100 kg DM consumed	3.88	4.08	3.92	3.85	3.86	3.87
kg liveweight sold/cow exposed	94.61	98.50	92.86	89.97	91.08	91.58

the one that supplemented the 2 year old cow herd only. Productivity indices were 4.08 and 98.50 for the most desirable alternative and 3.85 and 89.97 for the least desirable one.

In general, supplementation when heifers were bred to calve first at 2 years and wean calves at 6 months of age resulted in lower productivity than when heifers were bred to calve first at 3 years of age and wean calves at 6 months.

Breeding to Calve First at 3 Years and Wean at 7 Months

Runs 25 through 31 showed the same trends described above. Supplementation of all the herd resulted in higher productivity than other supplementation practices. The most efficient and productive alternative consisted of supplementing all the cow herd from May through July (Run 25) and the least efficient and productive one was to supplement the yearling replacement heifers only from May through July (Run 29). Supplemention of the mature cow herd only was the best among all the selective supplementations and was even superior to supplemention of the whole cow herd in July. In general, supplementing all the cow herd as heifers were bred to calve first at 3 years of age showed higher cow productivity indices when calves were weaned at 7 months than when they were weaned at 6 months of age. The differences between cow productivity indices for run 25 and run 12, run 26 and run 13, and run 27 and run 14 were 1.57, 3.51 and 5.18, respectively. The relative productivity increases for these three pairs of runs were 1.51, 3.37 and 5.25 percent, respectively.

TABLE 36: SIMULATED EFFECT OF VARYING SUPPLEMENTATION PERIOD AND FEMALE AGE GROUP ON PRODUCTION PERFORMANCE (AGE AT FIRST CALVING = 3 YEARS; BREEDING SEASON = SEPTEMBER-NOVEMBER; WEANING AGE = 7 MONTHS)

Production Parameters Per 100 Cows Exposed Per Year	Supplement All Cow Herd In May-June (Run 25)	Supplement All Cow Herd In June-July (Run 26)	Supplement All Cow Herd In July (Run 27)	Supplement Two Year Old Females In May-July (Run 28)	Supplement Yearlings Only In May-July (Run 29)	Supplement Yearlings and Two Year Olds (Run 30)	Supplement Mature Cows Only May-June (Run 31)
Total dry matter consumed (mt)	251.3	247	242.2	238.1	240	240.8	240.6
Calves born (%)	66.5	63.86	62.92	59.47	59.96	59.66	66.13
Calves weaned (%)	57.98	55.2	51.85	49.63	50.70	49.00	57.84
Survival rate to weaning (%)	87.18	86.42	82.41	83.45	84.55	82.15	87.45
Average weaning weight (kg)	134.55	133.5	131.05	129.9	130.35	130.5	121.25
Average weight of steers sold (kg)	142.16	141.0	138.86	137.18	137.60	137.73	127.78
Total liveweight sold (mt)	10.58	10.41	9.85	8.17	8.96	9.04	9.94
Composition of the sales							
Males (%)	49.57	50.22	48.22	48.52	50.62	50.44	49.28
Females (%)	50.43	49.78	51.78	51.48	49.38	49.56	50.72
Production indices							
kg liveweight sold/100 kg DM consumed	4.21	4.21	4.06	3.85	3.73	3.75	4.13
kg liveweight sold/cow exposed	105.84	104.13	98.51	91.70	89.64	90.39	99.44

Decreased efficiencies of -.05 and -.03 were found as management practices changed from run 12 to run 25 and from run 13 to run 26, respectively. A higher increase in productivity should be expected for July supplementation as weaning age is changed from 6 to 7 months of age.

Breeding to Calve First at 2 Years and Wean at 7 Months

Run 32 showed the highest efficiency of nutrient utilization (4.55) and cow productivity index (115.76) followed by run 36 (4.47 and 111.63). Calving rate (67.91 percent), calf survival to weaning (87.15 percent) and average weaning weight (133.6 kg) were also the highest for run 32 as compared to those in runs 33, 34, 35 and 36. The least desirable run in this series was run 35 which resulted in an efficiency of 3.93 and a cow productivity index of 95.97. The increases in cow productivity indices as management practices were changed from run 18 to 31, 19 to 32 and 20 to 33 were 18.27, 4.75 and 7.37 percent, respectively, while increases in nutrient efficiencies were 14.72, 2.15 and 4.62 percent, respectively. For management practices where heifers were bred to calve at 2 years, a high increase in productivity should be expected when supplemention is applied to the whole cow herd from May through July and weaning age is increased from 6 to 7 months.

TABLE 37: SIMULATED EFFECT OF VARYING SUPPLEMENTATION PERIOD AND FEMALE AGE GROUP ON PRODUCTION PERFORMANCE (AGE AT FIRST CALVING = 2 YEARS; BREEDING SEASON = OCTOBER-DECEMBER; WEANING AGE = 7 MONTHS)

Production Parameters Per 100 Cows Exposed Per Year	Supplement All Cow Herd In May-July (Run 32)	Supplement All Cow Herd In June-July (Run 33)	Supplement All Cow Herd In July (Run 34)	Supplement Yearlings and Two Year Olds (Run 35)	Supplement Mature Cows Only (Run 36)
Total dry matter consumed (mt)	254.1	247.8	243.7	244.1	249.5
Calves born (%)	67.91	64.09	60.77	59.68	66.01
Calves weaned (%)	59.59	55.44	52.17	51.87	57.05
Survival rate to weaning (%)	87.75	86.50	85.83	86.91	86.42
Average weaning weight (kg)	133.6	132.45	131.8	130.3	133.4
Average weight of steers sold (kg)	140.92	132.85	132.94	138.24	133.12
Total liveweight sold (mt)	11.57	10.34	10.02	9.57	1.16
Composition of the sales					
Males (%)	48.27	49.74	48.67	49.78	47.61
Females (%)	51.73	50.26	51.33	50.22	52.39
Production indices					
kg liveweight sold/100 kg DM consumed	4.55	4.17	4.11	3.93	4.47
kg liveweight sold/cow exposed	115.76	103.42	100.25	95.97	111.63

SUMMARY AND CONCLUSION

The Livestock Research Center of Dahra located in the sylvopastoral zone of Senegal was chosen for this study. Long dry season of 8 to 9 months per year and poor quality and quantity of forage resources are key factors characterizing the area. Growth and effects of environmental and genetic factors affecting growth parameters were examined in order to determine the parameters required to select management alternatives likely to improve productivity and to simulate pure-bred Gobra Zebu production system. Monthly availability and quality of forage resource base were used to describe the environments while genotype was specified by potential mature size and potential milk production. A dynamic mathematical model (Texas A & M University Cattle Production Systems Model) was used to simulate a cow-calf production system for Gobra Zebu. The model was developed to predict production of a herd of cattle based on forage or feed resources and may be used to predict management procedures and traits of cattle that would best utilize the forage resources.

There were substantial month and year differences in growth performances which confirmed the important role of the environment on Gobra Zebu production in Dahra. Calves born in dry years and part of dry seasons were heavier at weaning,

lighter at 12 months and heavier at 18 months of age than those born in wet years or wet seasons. There were no clear trends in the effects of year on most of the production traits.

The heavier calves at weaning were born from 4 to 10 year old cows and the lighter calves at weaning were born to cows older than 10 years of age.

Heritability estimates from paternal half-sibs correlations for birth weight, weaning weight, yearling weight, long yearling weight and maturing rate of female calves were .20 ± .14, .46 ± .19, .41 ± .18, .23 ± .15 and .22 ± .18, respectively. The h^2 estimates for birth weight, weaning weight, yearling weight and long yearling weight of all calves were .14 ± .019, .34 ± .13, .33 ± .13 and .15 ± .09, respectively.

Genetic and phenotypic correlations between body weights were all positive. Low to negative genetic correlations of -.21 ± .52, .01 ± .57, -.76 ± .51 were found between maturing rate and each of weaning weight, yearling weight and long yearling weight.

Results of simulation indicated that setting the breeding season from September through November and October through December for 2 year old replacement heifers and for yearling replacement heifers, respectively, were the best practices under the conditions of Dahra. Weaning at 7 months instead of 6 months of age resulted in higher efficiency of nutrient utilization and cow productivity. Results also showed higher herd productivity indices when heifers were bred to calve

first at 2 years of age than when they were bred to calve at age of 3 years if supplementation is provided to the cow herd and if the weaning age is set to 7 months. In real conditions, however, females bred to calve at 2 years of age may not rebreed during the subsequent year. The practical use of this management alternative and many others can be tested through field research. Supplementation of the mature cow herd only from May through July and of the whole cow herd from May through July or June through July were some of the best alternatives available. Finally, as weaning age was changed from 6 to 7 months, the highest percentage increase in efficiency and cow productivity were obtained when supplementation was practiced in July only with heifers that were bred to calve first at 3 years of age.

RECOMMENDATIONS

Based on the data collected at the Dahra Livestock Research Center, the following practices are recommended.

Production System

Since calves born in wet seasons were lighter at weaning, heavier at 12 months and lighter at 18 months than those born in dry seasons, only a cow-calf operation should be recommended on the limited forage resource base of Dahra.

Breeding

The data analyses show that calving from mid-dry season, particularly after February in Dahra, was more advantageous than any other time of the year. The analyses also indicated a decreased growth for calves born to cows older than 10 years of age. Therefore, a 90 day breeding season (instead of 120 days) beginning earlier than October should be established to allow calving from March through June and cows older than 10 years of age should be culled.

Selection for Growth

Higher heritability for weaning weight than for other growth traits indicate that selection for growth should focus on weaning weight. The absence of clear trends in effect of year on most production traits indicated that selection indices should be applied on within year basis and not across years.

Management Alternatives

Alternative management combinations which include feeding supplement, breeding replacement heifers from October through December or from September through November, and weaning calves at a constant age of 7 months should receive more attention. Many of these alternatives, especially those including supplementation practices, may not be cost effective although they are biologically sound. Economic analyses should be performed using the technical coefficients that have already been determined. The simulation results provide valuable guidelines for research on management practices that should be tested in the field. They are specific to Gobra Zebu raised under the specific conditions of Dahra livestock research center. For this reason, care must be exercised in trying to extrapolate these results to other areas of sylvo-pastoral zone.

APPENDIX

TABLE A1: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR BIRTH WEIGHT IN ALL CALVES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	20	-.02	25.55 ± 1.21
	Feb	11	2.53	28.11 ± 1.49
	Mar	3	.08	25.65 ± 2.62
	Apr	17	-.64	24.92 ± 1.22
	May	25	-1.26	24.30 ± 1.07
	Jun	145	-2.00	23.56 ± .74
	Jul	161	-.62	24.94 ± .72
	Aug	77	.43	26.00 ± .79
	Sep	84	1.80	27.37 ± .76
	Oct	32	-.96	24.60 ± 1.00
	Nov	27	.84	26.41 ± 1.01
	Dec	25	-.16	25.40 ± 1.14
Year of birth	68	14	1.29	26.86 ± 1.73
	69	36	1.60	27.17 ± 1.27
	70	67	2.80	28.37 ± 1.17
	71	75	1.82	27.39 ± 1.17
	72	80	4.30	29.87 ± 1.12
	73	76	2.27	27.84 ± 1.16
	74	58	1.68	27.25 ± 1.21
	75	33	-.95	24.61 ± 1.39
	76	26	-1.00	24.56 ± 1.24
	77	59	-4.82	20.75 ± 1.45
	78	44	-.68	24.89 ± 1.41
	79	55	-4.21	21.35 ± 1.40
	80	4	-4.21	21.44 ± 2.51

TABLE A2: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR DAM AGE ON BIRTH WEIGHT IN ALL CALVES

Dam Age (Years)	Number of Observations	Constant Estimate	Least Squares Means and S.E. (kg)
3	57	-.61	24.95 ± .95
4	91	-1.39	24.17 ± .79
5	87	.22	25.80 ± .78
6	88	.43	26.01 ± .79
7	61	-.69	24.87 ± .87
8-10	127	.86	26.43 ± .75
11-12	64	.66	26.23 ± .88
>12	46	-.23	25.33 ± .94

TABLE A3: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR WEANING WEIGHT IN FEMALE CALVES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	15	-3.61	97.01 ± 6.36
	Feb	7	-15.15	85.47 ± 8.71
	Mar	3	0.69	101.31 ± 12.29
	Apr	12	18.50	119.12 ± 6.79
	May	14	15.32	115.94 ± 6.39
	Jun	23	8.82	109.44 ± 4.42
	Jul	97	8.29	108.91 ± 4.17
	Aug	42	-1.27	99.35 ± 4.70
	Sep	50	5.06	105.69 ± 4.50
	Oct	18	-7.42	93.20 ± 6.13
	Nov	15	-7.02	93.60 ± 6.24
	Dec	13	-22.21	78.40 ± 7.11
Year of birth	68	14	8.09	108.91 ± 8.64
	69	32	-10.48	90.13 ± 6.78
	70	35	-19.39	86.23 ± 6.77
	71	43	-0.16	100.46 ± 6.62
	72	41	0.78	101.40 ± 6.23
	73	42	0.43	101.06 ± 6.83
	74	34	-4.15	96.46 ± 6.88
	75	18	-7.69	92.92 ± 8.65
	76	16	-4.63	95.98 ± 7.17
	77	22	20.40	121.02 ± 9.54
	78	28	11.79	112.41 ± 8.67
	79	34	5.01	105.64 ± 8.63

TABLE A4: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR WEANING WEIGHT IN MALE CALVES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	5	-23.98	74.52 ± 15.42
	Feb	3	-36.53	61.97 ± 15.03
	Apr	4	-2.46	96.04 ± 13.17
	May	10	24.14	122.65 ± 9.16
	Jun	44	9.54	108.06 ± 5.45
	Jul	56	16.45	114.96 ± 5.31
	Aug	13	13.22	111.73 ± 7.84
	Sep	27	16.28	114.79 ± 6.11
	Oct	14	8.09	106.60 ± 7.90
	Nov	9	-17.16	81.34 ± 9.34
	Dec	9	-7.60	90.90 ± 10.03
Year of birth	69	4	4.80	103.31 ± 18.68
	70	22	4.97	103.48 ± 14.03
	71	29	34.32	132.83 ± 13.58
	72	22	25.84	124.35 ± 14.03
	73	28	20.63	119.14 ± 13.52
	74	11	21.88	120.39 ± 15.46
	75	14	-38.67	59.83 ± 12.67
	76	6	-42.45	56.05 ± 19.37
	77	25	-7.51	90.99 ± 15.11
	78	13	-20.15	78.35 ± 15.25
	79	16	-7.04	91.46 ± 15.38
	80	4	3.37	101.88 ± 18.45

TABLE A5: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR WEANING WEIGHT IN ALL CALVES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	20	-9.44	96.42 ± 6.70
	Feb	11	-20.67	85.19 ± 7.92
	Mar	3	-6.34	99.53 ± 13.19
	Apr	17	13.01	112.88 ± 6.76
	May	25	19.87	125.74 ± 6.12
	Jun	145	7.80	113.67 ± 4.22
	Jul	161	9.89	115.76 ± 4.75
	Aug	77	3.37	109.24 ± 5.00
	Sep	84	8.35	114.73 ± 4.88
	Oct	32	-4.55	101.31 ± 5.82
	Nov	27	-7.45	98.41 ± 5.88
	Dec	25	-14.33	91.53 ± 6.42
Year of birth	68	14	5.49	111.36 ± 9.00
	69	36	-10.36	95.50 ± 7.06
	70	67	-20.24	85.62 ± 6.55
	71	75	6.36	112.23 ± 6.55
	72	80	0.17	106.04 ± 6.33
	73	76	0.78	106.65 ± 6.48
	74	58	-6.57	99.29 ± 6.72
	75	33	-18.09	87.78 ± 7.51
	76	26	-12.07	93.79 ± 6.71
	77	59	15.29	121.16 ± 7.78
	78	44	4.71	110.58 ± 7.60
	79	55	5.78	111.65 ± 7.55

TABLE A6: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR DAM AGE ON WEANING WEIGHT IN ALL CALVES

Dam Age (Years)	Number of Observations	Constant Estimate	Least Squares Means and S.E. (kg)
3	57	-.02	105.84 ± 5.62
4	91	1.83	107.71 ± 4.99
5	87	.91	106.78 ± 4.96
6	88	-1.13	104.73 ± 4.98
7	61	1.66	107.54 ± 5.29
8-10	127	1.74	107.62 ± 4.84
11-12	64	-7.38	98.48 ± 5.33
>12	46	-14.62	91.24 ± 5.58

TABLE A7: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR YEARLING WEIGHT IN MALES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	5	7.32	156.17 ± 19.93
	Feb	3	4.79	153.63 ± 19.43
	Apr	4	-6.18	142.64 ± 16.98
	May	10	-.90	147.93 ± 11.70
	Jun	44	-17.84	130.99 ± 6.71
	Jul	56	-11.61	137.21 ± 6.52
	Aug	13	-17.70	131.13 ± 9.94
	Sep	27	18.93	167.77 ± 7.62
	Oct	14	12.29	161.13 ± 10.02
	Nov	9	-12.72	136.11 ± 11.93
	Dec	9	23.62	172.46 ± 12.85
Year of birth	69	4	15.65	164.69 ± 24.18
	70	22	25.06	173.89 ± 18.11
	71	29	43.24	192.08 ± 17.52
	72	22	41.79	190.63 ± 18.11
	73	28	15.89	164.73 ± 17.44
	74	11	10.56	159.40 ± 19.99
	75	14	-47.60	101.23 ± 16.32
	76	6	-65.08	83.74 ± 25.10
	77	25	2.85	151.69 ± 19.52
	78	13	-15.59	133.24 ± 19.71
	79	16	-37.07	111.76 ± 19.88
	80	4	10.27	159.11 ± 23.90

TABLE A8: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR LONG YEARLING WEIGHT IN MALES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	5	-12.30	189.96 ± 25.64
	Feb	3	-28.02	174.34 ± 24.99
	Apr	4	22.70	224.97 ± 21.82
	May	5	30.66	232.94 ± 14.94
	Jun	44	11.98	214.26 ± 8.37
	Jul	56	18.77	221.05 ± 8.11
	Aug	13	4.23	206.50 ± 12.64
	Sep	27	18.29	220.56 ± 9.58
	Oct	14	6.21	208.48 ± 12.74
	Nov	9	-42.44	159.82 ± 15.24
	Dec	9	-30.08	172.18 ± 16.44
Year of birth	69	4	-2.00	200.27 ± 31.17
	70	22	75.55	277.82 ± 23.29
	71	29	73.84	276.12 ± 22.52
	72	22	47.23	249.50 ± 23.29
	73	28	8.03	210.30 ± 22.42
	74	11	-14.37	187.90 ± 25.73
	75	14	-58.45	143.82 ± 20.96
	76	6	-96.55	105.72 ± 32.35
	77	25	-13.59	188.67 ± 25.12
	78	13	-3.07	199.19 ± 25.36
	79	16	-9.75	192.51 ± 25.58
	80	4	-6.85	195.42 ± 30.79

TABLE A9: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR YEARLING WEIGHT IN FEMALES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	15	10.61	161.51 ± 8.16
	Feb	7	-5.84	145.05 ± 11.28
	Mar	3	21.79	172.69 ± 16.00
	Apr	12	17.74	168.60 ± 8.73
	May	14	6.00	157.90 ± 8.70
	Jun	73	-10.63	140.26 ± 5.50
	Jul	97	-14.86	136.63 ± 5.19
	Aug	42	-20.94	129.95 ± 5.02
	Sep	50	5.92	156.82 ± 5.65
	Oct	18	-10.47	140.42 ± 7.84
	Nov	15	2.89	153.79 ± 8.00
	Dec	13	2.79	153.70 ± 9.16
Year of birth	68	14	51.67	202.57 ± 11.17
	69	32	-12.40	138.50 ± 8.71
	70	35	-15.00	135.89 ± 8.70
	71	43	-0.56	150.22 ± 5.50
	72	41	8.87	159.75 ± 7.99
	73	42	-2.63	148.26 ± 8.17
	74	34	-15.85	135.24 ± 8.84
	75	18	-14.07	136.82 ± 11.20
	76	16	-11.71	139.19 ± 8.23
	77	22	19.84	170.74 ± 12.37
	78	28	6.71	157.61 ± 11.23
	79	34	-14.85	136.00 ± 11.17

TABLE A10: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR LONG YEARLING WEIGHT IN FEMALES

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	15	-29.64	163.52
	Feb	7	-53.55	139.62
	Mar	3	17.79	210.97
	Apr	12	31.36	224.54
	May	14	31.09	224.24
	Jun	73	17.41	210.59
	Jul	97	11.25	204.42
	Aug	42	8.97	202.15
	Sep	50	14.90	208.08
	Oct	18	-12.31	180.86
	Nov	15	-8.35	184.82
	Dec	13	-28.93	164.24
Year of birth	68	14	62.78	255.95
	69	32	-18.01	175.16
	70	35	-16.54	176.63
	71	43	-.67	192.50
	72	41	19.81	212.98
	73	42	-3.10	190.07
	74	34	-22.91	170.26
	75	18	-18.89	174.28
	76	16	-10.34	182.82
	77	22	-2.40	190.76
	78	28	20.22	213.40
	79	34	-9.91	183.25

TABLE A11: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR DAM AGE ON YEARLING AND LONG YEARLING WEIGHTS

Parameter	Dam Age (years)	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Yearling weight	3	57	11.62	171.25 ± 7.30
	4	91	-4.49	155.13 ± 6.46
	5	87	.78	160.41 ± 6.42
	6	88	-1.23	158.39 ± 6.46
	7	61	-.89	158.73 ± 6.87
	8-10	127	1.07	160.69 ± 6.26
	11-12	64	-4.89	154.73 ± 6.91
	12	46	-13.88	145.74 ± 7.24
Long yearling weight	3	57	10.87	220.93 ± 7.74
	4	91	-8.88	201.17 ± 6.44
	5	87	.91	210.97 ± 6.38
	6	88	-5.63	204.41 ± 6.43
	7	61	-1.88	208.17 ± 7.08
	8-10	127	-1.13	208.92 ± 6.12
	11-12	64	-6.76	203.29 ± 7.16
	>12	46	-12.61	197.44 ± 7.66

TABLE A12: LEAST SQUARES MEANS, STANDARD ERRORS (S.E.) AND CONSTANT ESTIMATES FOR MATURE WEIGHT IN FEMALE GOBRA

Class	Sub Class	Number of Observations	Constant Estimates	Least Squares Means and S.E. (kg)
Month of birth	Jan	12	19.1	410.50 ± 14.08
	Feb	2	-55.77	335.40 ± 31.89
	Mar	3	-50.49	340.69 ± 27.21
	Apr	11	15.13	406.32 ± 14.14
	May	11	33.07	424.25 ± 14.20
	Jun	55	20.56	411.75 ± 7.71
	Jul	61	9.67	400.85 ± 7.47
	Aug	30	18.62	409.80 ± 9.04
	Sep	33	4.97	396.16 ± 9.14
	Oct	8	-10.56	380.62 ± 17.18
	Nov	8	9.61	400.80 ± 16.07
	Dec	10	-14.15	377.03 ± 17.15
Year of birth	68	10	22.62	413.80 ± 21.45
	69	24	8.98	400.17 ± 15.67
	70	28	2.54	393.72 ± 15.31
	71	40	-24.45	366.72 ± 14.48
	72	33	-23.35	367.82 ± 14.49
	73	34	6.19	392.38 ± 16.17
	74	13	38.61	429.80 ± 17.92
	75	11	-33.71	357.46 ± 25.77
	76	13	-23.71	367.46 ± 16.44
	77	6	9.86	401.05 ± 28.17
	78	13	15.87	407.06 ± 23.75
	79	19	.53	391.71 ± 21.93

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BIOGRAPHICAL SKETCH

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Joseph H. Conrad, Chairman
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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