~~Beef~~ Cow-Calf Production Experiments on the Savannas of Eastern Colombia

Effects of Minerals, Early Weaning, Crossbreeding, Urea Feeding, and Pastures on Herd Production

Howard H. Stonaker

Ned S. Raun

Juvenal Gomez

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL

INSTITUTO COLOMBIANO AGROPECUARIO

WINROCK INTERNATIONAL

Library of Congress Cataloging in Publication Data

Stonaker, Howard H.
Beef cow-calf production experiments on the savannas of eastern Colombia.

Bibliography: p.
1. Beef cattle--Colombia--Cow-calf system. 2. Beef cattle--Llanos Orientales (Colombia and Venezuela)--Cow-calf system. 3. Beef cattle--Cow-calf system--Research--Colombia. 4. Beef cattle--Cow-calf system--Research--Llanos Orientales (Colombia and Venezuela)
I. Raun, Ned S. II. Gomez, Juvenal. III. Title.
SF196.C64S76 1984 636.2'13'09861 85-131175
ISBN 0-933595-00-X (pbk.)

Preface

Latin America's extensive grasslands offer a vast natural resource base for the production of meat, milk, and other basic human foods. Yet, despite their promise of greatly expanded agricultural production (especially of cattle), the savannas have not been fully exploited. Surprisingly little research and development have been done on these grasslands, perhaps because of their relative isolation and the infertility of the soils (primarily oxisols and ultisols).

The savannas of eastern Colombia (the Llanos Orientales), although they represent a small part of these grasslands, presented an exceptional challenge and opportunity for research and development when the Centro Internacional de Agricultura Tropical (CIAT) was founded in 1967. ICA (Instituto Colombiano Agropecuario) and CIAT administrations were strongly agreed that high priority should be given to collaborative research to develop more efficient and economical systems of cattle production in the Llanos and similar areas in Latin America that are used almost exclusively for raising cattle.

Their collaboration produced the herd systems research documented here, which confirms the low levels of livestock productivity within limited-input systems of management and clearly indicates that major increases in productivity can be obtained with available inputs and management practices.

Moreover, these results highlight needs for additional research to develop even more productive systems to meet future demands for meat, milk, and other foods. New research opportunities have continued to develop; for example, protein banks have been created, using small, intensively managed areas of legumes as reserve sources of protein and energy during times of greatest nutritional stress. Additional research potential also is found in the excellent performance of new grass species (such as *Andropogon gayanus*) that are particularly suited to Llanos conditions. These grasses are currently being used in herd systems experiments to replace the less-well-suited molasses grass discussed in this report. Such research provides the technology needed for the expanded development of the extensive acid infertile soil areas of the Latin American tropics.

Gustavo Nores
Director, Land Resources
Centro Internacional de Agricultura Tropical
Cali

Hernando Gutierrez de la Roche
Director, Ciencias Animales
Instituto Colombiano Agropecuario
Bogota

Ned S. Raun
Vice-President, Programs
Winrock International
Morrilton, Arkansas

Acknowledgments

The herd systems project owes a special acknowledgment to the research staff and other workers at Carimagua (the ICA experiment station) who lived and worked in isolation from their families. Many workers lived permanently at Carimagua because of the technical nature of the research and the necessity to understand and cope with unforeseen conditions that arose on an almost daily basis. ICA and CIAT did much to make living conditions more pleasant for these dedicated people. Communications with Carimagua were maintained via radio and/or a charter plane service between Cali, Bogota, and Carimagua, adding immeasurably to the efficiency of the operations.

Among the animal scientists and veterinarians from ICA and CIAT (including breeding, health, nutrition, and management specialists) were Horacio Ayala,[a/] Joaquin Cortes,[c/] Juvenal Gomez,[d,e/] Focion Gonzalez,[c/] Otto Mario Marin,[a/] Juan Jose Salazar,[a,c/] Jaime Villar.[b/] CIAT participants included Eduardo Aycardi,[b/] Raul Botero,[a/] D. H. Bushman,[b,c/] Ingo Kleinheisterkamp,[a,e/] Orlando Lozano,[d/] Hemerson Moncada,[d/] C. P. Moore,[a/] N. S. Raun,[a,c,e/] Hernan Rivadeneira,[b/] Jairo Salazar,[d/] S. Lebdosoekojo,[b/] H. H. Stonaker,[a,c,e/] Eric Wells,[b,c/] and Gerrit Zemmelink.[b/] Statisticians from CIAT

---

a/Coleader b/Special studies c/Planning d/Supervision at Carimagua e/Final report were Maria Cristina Amezquita[b,e] and David Franklin.[c] Jim Bemis,[e] Venetta Vaughn,[e] and Esther Raun[e] helped with the editing and word processing at Winrock International. Also, we are indebted to the reviewers for their painstaking screening of the manuscript for errors and for validity of the interpretations.

This publication was made possible by the combined support and collaboration of CIAT, ICA, and Winrock International.

H. H. Stonaker
N. S. Raun
Juvenal Gomez
March 1984
Winrock International
Morrilton, Arkansas

Table of Contents

List of Tables

List of Figures

List of Appendix Tables

Summary

STUDY HIGHLIGHTS

Beef cow-calf performance in the tropical savannas (Llanos Orientales) of eastern Colombia was examined in an extensive 5-year experiment (1972-1977) at the ICA experiment station, Carimagua, to determine the effects of practices such as mineral and urea supplementation, molasses grass pasture, early weaning, and crossbreeding. These improved systems of herd management were evaluated in 9 herds at the 22,000-ha Carimagua ranch located south of Orocue on the Meta River (latitude 4° 37' N, longitude 70° 36' W, elevation 200 m) (figure 1). The soil, rainfall, and temperature at Carimagua are considered typical of a vast area of tropical savannas (FAO, 1966).

Discussion of the research is organized relative to two experiments known as the mineral experiment and the pastures experiment.

Mineral supplementation effects with 9-month weaning included:

- increased calving rate from 43% to 61% (table 8)
- increased calf crop, from 31% to 61% (table 8)
- lowered death losses in cows, from 17% to 2% (table 10)

- lowered calf mortality at 18 months, from 27% to 12% (table 12)
- increased cow weights (9%), from 304 kg to 331 kg (table 4)
- increased calf weights (29%), from 131 kg to 169 kg at 9 months (table 11)
- increased annual beef production per animal unit from 51 kg to 84 kg (table 28)
- increased annual beef production per cow from 68 kg to 130 kg (table 28)
- elimination of bone fractures

Early weaning effects included:

- increased calving rate from 52% to 81% and calf crop from 43% to 64% in the mineral experiment (tables 5 and 7). Effects were greater in the nonmineral-fed herds than in mineral-fed herds
- increased calving rate from 60% to 84% and calf crop from 55% to 74% in the pasture experiment (tables 18 and 19)
- lowered cow mortality to zero as compared to 12% to 16% in cows with 9-month-weaned calves (table 27)

The combination of mineral supplementation and 3-month weaning on native grass pastures resulted in calving rates exceeding 80% and calf crops above 70% (table 27).

Molasses grass pasture produced 3.29 times more beef per ha than did native savanna (table 14). Molasses grass in the rainy season (rotated with savanna in the dry season) produced 2.48 times more beef per ha than did savanna alone. However, molasses grass without urea supplementation was completely unsatisfactory in the dry season, resulting in an 18% death loss in cows.

Molasses grass with urea supplementation in the dry season produced approximately the same amount of beef per herd as did native pasture or native pasture with molasses grass. In contrast, urea supplementation in the dry season had little effect on cattle grazing lowland native (bajo) pasture. Although urea was essential in year-round use of molasses grass, its use was associated with urea toxicity problems and increased abortions.

Crossbreeding Zebu cows with Criollo bulls produced a 5% to 10% increase in weight at 18 months in first-cross calves (tables 11 and 22).

The most beef produced annually per animal unit (95-96 kg, table 28) was obtained from a system in which either 9- or 3-month-weaned calves were fed minerals while on native or native/molasses grass pasture and sold at 9 months of age. About 92 kg of beef were produced per animal unit by selling 3-month-weaned calves at 3 months of age.

For a system based on native pastures, it was estimated that the greatest amount of beef production per cow would be obtained in a system using mineral supplementation, weaning at 3 months, and selling 18-month-old steers. Such a system would produce over twice as much (212%) beef per cow as that obtained from a system without minerals and using 9-month weaning; on a per animal unit basis, the production would be 167%.

Some improved cattle management systems were demonstrated as feasible and capable of nearly doubling production above that obtained from unimproved systems.

Chapter I

Introduction

PURPOSE AND OBJECTIVES

This collaborative report of the Instituto Colombiano Agropecuario (ICA) and Centro Internacional de Agricultura Tropical (CIAT) documents extensive experiments dealing with beef cow-calf production under various systems of herd management in the Llanos Orientales, the savannas of eastern Colombia.

The basic objective of the experiments was to develop more efficient and economical cattle production systems through study of the effects of mineral and urea supplementation, molasses grass pastures, early weaning, and crossbreeding (either as single variables or in combinations).

The rationale for the experiments--and for the establishment of the station, Carimagua, in the Llanos of Colombia--stemmed from several conditions relative to basic resources in Colombia and other countries in Latin America:

1. The primary product of the land in many of these countries is cattle, and beef is a basic food in the diet of the people. Approximately two-thirds of the beef in Latin America is produced in tropical regions (which contain 71% of the cattle population), and beef is an important commodity for export and foreign exchange in several of these countries (Raun, 1976).

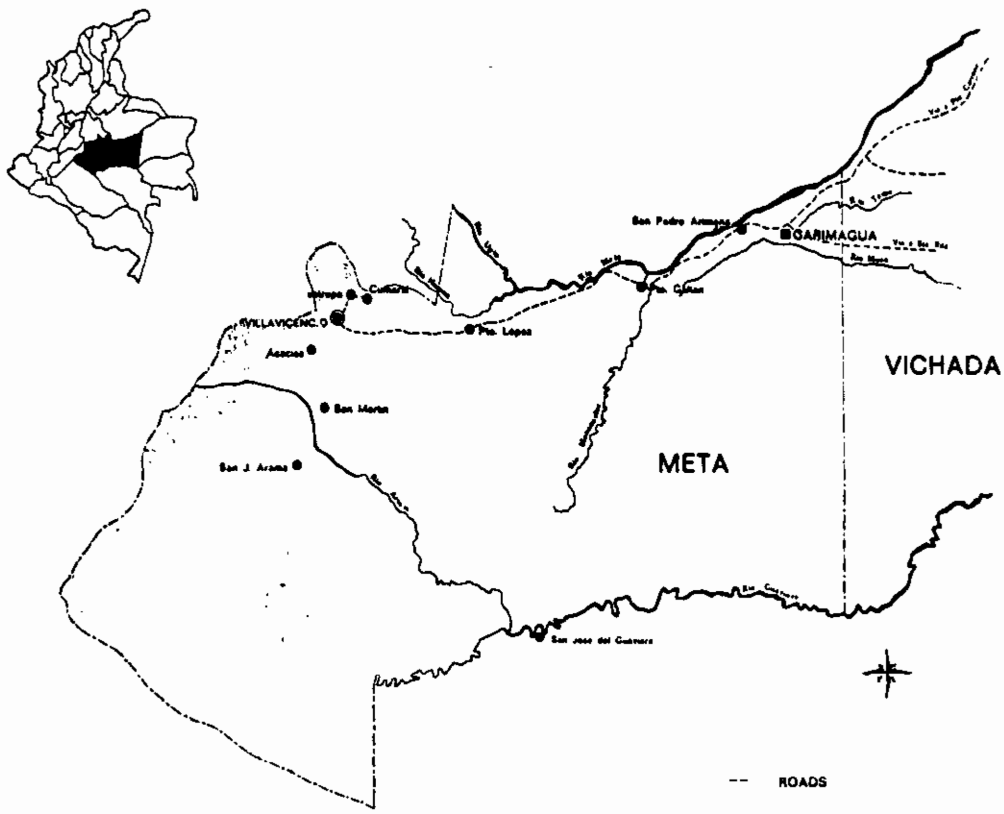


Figure 1. Carimagua, the experimental ranch, is located in the Llanos Orientales of Colombia.

2. The national resource of land and cattle was reported to be grossly under-utilized relative to potential. Raun (1976) documented the low animal productivity in the region (calving rates of 40% to 50%; animals slaughtered at 3 to 5 years of age at weights of 350 to 450 kg; and an extraction rate of 13%). The annual production of carcass beef from the total beef herd in the area averaged 25 kg per head, as compared to 36 kg in Argentina and 49 kg in Australia, where only pasture-based production systems are used. (By comparison, the production of carcass beef is 80 kg per animal in the United States, where forages provide about 73% of the total feed units and grains provide 23%.)
3. Of the 150 million cattle in the lowland tropics, about one-half are on savannas that are characterized by acid, infertile soils. These savannas comprise approximately 300 million hectares (Raun, 1976). Other factors contributing to the great agricultural potential of the lowland tropics include high levels of solar energy (1.6 to 1.9 times greater than that of the humid temperate areas), uniformly high temperatures, ample rainfall in most areas, and a uniform photoperiod (CIAT, 1968).
4. This savanna area of Colombia had no research facilities dedicated to improving production within such an ecosystem. Although a number of experiment stations are found in the richer agricultural regions of Colombia and Venezuela, only Calabozo in Venezuela and La Libertad near Villavicencio, Colombia, are located in these acid, infertile soil areas. They are, however, on the edge of the savannas, where soils and

other production conditions of these stations are more favorable to cultivation than are those of much of the poorer savannas. No sizable research facility was centrally located in the savannas.

5. Discoveries that had met with great success in Australia and Africa were largely unproved in South America. Paladines (1975) reviewed the work relative to the tropical savannas of America and found that most of the work was descriptive or ecological in nature. As a result of the lack of production information, it was necessary to carefully evaluate the usefulness of information from Australia and Africa.
6. An improved cattle industry could be the basis for expanding the agricultural frontier in tropical America. Colombia, as well as an intercontinental scientific community, could make use of the results. As an internationally funded organization, CIAT had an especial interest in this objective.

CARIMAGUA STATION: BACKGROUND

For several years prior to the ICA purchase of Carimagua and establishment of the ICA-CIAT Herd Systems I Project, the ICA and CIAT organizations had discussed the advantages of an experiment combining various ingredients of good cattle production into herd management systems. Shorter-term experiments could not adequately evaluate the treatment effects on cow longevity, morbidity, mortality, or lifetime production. Thus, there was a critical need to study the total life cycle of cow production and herd systems under the conditions of the tropical savannas. The consensus was that the treatments, within economic limits, should consist of optimum combinations of inputs vs those thought to be representative of unimproved systems commonly in use.

It was hoped that a sufficiently large ranch could be found so that herd performance differences could be measured statistically. Herds of about 30 to 35 cows would be required in each pasture group so that herd differences of 5% to 10% could be detected with statistical reliability. Differences of this magnitude were considered essential for meaningful economic decisions.

Although this publication deals specifically with the variables noted previously, extensive related studies were conducted on cattle health, economics, and nutrition. Additional information also was obtained on several crops of the savanna region and on related human resources and attitudes. It seems unlikely that the large number and variety of investigations would have taken place without the purchase of Carimagua by ICA.

Carimagua Ranch

Carimagua, an Indian word meaning water of the gods, is the name of a 22,000-ha ranch that is south of Orocue and bordered by the Muco River on the south. The Meta River, to the north, is the largest of several rivers draining the Llanos Orientales and during the rainy season is navigable by barges from Puerto Lopez, near the foothills of the Andes, to Puerto Carreno on the Orinoco River.

During the political violence of the 1940s, a reign of terror in the Llanos forced a great exodus of people from the region, including the owners of the ranch at the time. These owners were known as progressive ranchers and had made many improvements on the ranch, such as building barges to ship cattle and produce and planting new orchards and improved grasses (*Hyparrhenia rufa*, "puntero"). From the late 1940s until the ICA purchase of the ranch in October 1969, the ranch had been understocked and underdeveloped, which is not an unusual history for ranches in the region.

Brunnschweiler (1972) implied that the region was more heavily populated in Spanish colonial times. The capital, Pore, in the Casanare region north of the Meta River, is now a small town of 1,000, but was once a city of 20,000 and the seat of government for approximately 130 villages. The missions established by the Jesuits had many cattle--said to be of the San Martinero breed, probably a cross between Andalusian "Retinto" and the Asturian "Valle" (Brunnschweiler, 1972).

Physiography, Soils, and Climate

Carimagua is located at lat. 4° 37' N, long. 70° 36' W, with an elevation of 200 meters. Sanchez and Isbell (1978) defined the soils as oxisols with an oxic horizon of low-activity clays (16 meq/100 g clay), consisting of mixtures of kaolinite, iron oxides and quartz, and low in weatherable minerals. These are usually deep, well-drained, red or yellow, acid soils, with excellent granular structure, very low fertility, and uniform properties with depth. These oxisols, plus the ultisols (which have less desirable physical properties than oxisols and are acid and low in fertility) make up 57% of Colombia and 59% of tropical South America. Sanchez and Isbell (1978) reported a description by Spain (1975) of topsoil chemical properties of Carimagua:

pH	Org. C %	Clay %	Exch.cations(meq/100g) Al	Ca	Mg	K	ECEC	Al sat. %
4.5	3.2	35	3.5	0.5	0.3	0.08	4.5	78

Figure 2 shows rainfall and temperature patterns: most of the 2,000 mm rainfall occurs from May through October;

the mean annual temperature is 27° C. Major plant species at Carimagua were identified by Blydenstein (1972) and are listed in appendix A. The primary upland grass is Trachypogon, whereas sedges predominate in the flooded areas. The soil, plant, and animal characteristics of this section of the Llanos of Colombia have been described in detail by the FAO (1966).

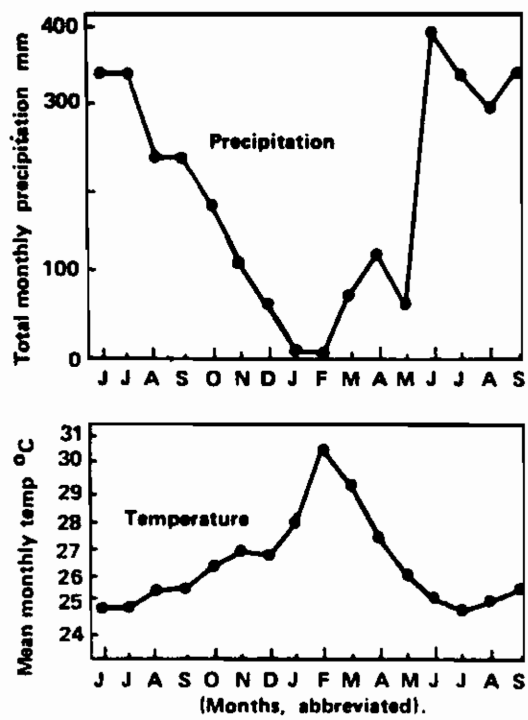


Figure 2. Precipitation and temperature in Carimagua from June 1972 to September 1973.

Chapter II

Herd-Systems Experimental Design Variables and Procedure

Practical knowledge of cattle production in the Llanos was available through the experiences of local ranchers and professionals, many of whom were well-acquainted with the Llanos Orientales. Their observations served as a basis for selecting the relatively few important production factors that could be managed in an experimental design that would allow extensive study of cattle under a variety of experimental treatments. Further guidance in developing the final experimental design was provided by professional statisticians.

The more important possibilities for increasing production were finally narrowed to (1) mineral supplementation, (2) molasses grass pastures, (3) urea supplementation in the dry season, (4) early weaning, and (5) crossbreeding. Initially, seasonal breeding was included as a treatment but was later replaced by urea supplementation in the dry season.

Additional observations were made by scientists with interests in breeding, economics, health, management, nutrition, and pastures. Most observations and biological samples were taken in the herds at 56-day intervals (except for calving data). Special nutritional and health studies also were conducted.

Discussion of the treatments in the following sections is organized around two experiments: (1) the mineral experiment and (2) the pasture experiment.

TREATMENTS

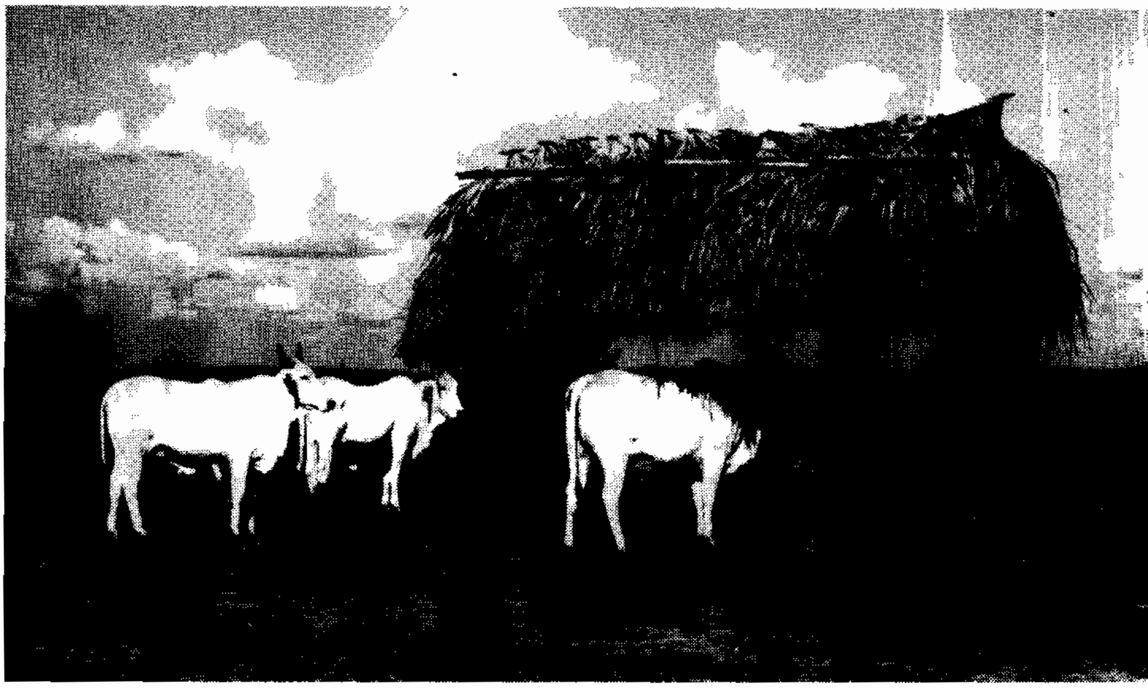
Mineral Supplementation

Although a relatively simple practice, mineral supplementation was not widespread in the Llanos in the 1970s--despite the fact that Theiler et al., 1928, had published their phosphorus supplementation results almost 50 years previously.

Summarizing the work of a number of researchers, Lebdosoekojo et al. (1980) reported that most beef cattle production in savanna areas relied on native pasture that is considered to be low yielding and of poor nutritive value. The acid soils in these areas promoted mineral deficiencies. Phosphorus supplementation reduced body weight loss in the dry season. Mineral supplementation increased live weight gains. Greater improvement of reproductive performance was found when phosphorus and protein were supplemented together.

Scientists, extensionists, and lending agencies in Colombia agreed that mineral supplementation was an essential aspect of good cattle production, and it was widely advocated.

Thus, limited use of this simple practice represents another case of the inability to predict adoption--always a difficult task in transfer of technology. This nonadoption applies to Llanos ranchers as well as to sophisticated Australian producers. Frank (1976) has noted that adoption of innovations usually follows a logical sequential order. Examples of improved practices developed by Australian researchers--but not adopted by graziers--include pasture development, calf weaning based on age and seasonal conditions, controlled mating, selection on performance records, the segregation of heifers, and vibrio vaccination.



Pregnant heifers at the beginning of the experiment. These were on molasses grass pasture. The log trough and shelter were for ad lib mineral feeding.

Crossbred San Martinero x Zebu calf with grade Zebu dam in Herd 9. Molasses grass, urea supplement, mineral supplement, 9-month weaning.

In contrast, practices that have been readily adopted include nitrogen supplements, botulism vaccine, and *Bos indicus* infusion in the dry tropics of Australia.

It seems almost certain that Llanos ranchers knew about mineral supplements but remained unconvinced of the economics of supplementation, had little confidence in the quality of minerals available, or had insufficient funds to purchase them. The research team felt that incorporation of a mineral treatment into the experiment would provide a better understanding of the biological and economic implications of mineral supplementation in the Llanos.

Pastures

Paladines (1975) found that among the differences between American and African savannas were the generally higher acceptance of the African grasses by cattle and the longer and more severe droughts in African savannas.

Knowledge related to pastures and forages in Latin America is now immeasurably greater than in 1972, particularly knowledge of better or improved species of legumes and grasses (CIAT, 1980). Thus, the molasses grass chosen as an improved pasture for the herd systems study in 1972 would surely be replaced with more productive alternatives if such an experiment were to be begun today.

The application of greater technology and other improvements was pointed out by Grigg (1970). He reported that the annual cattle extraction rate in Tanzania is only 7% for native pastoralists, as compared with 18% to 20% for European-owned ranches. More sobering were his observations that the British and French had launched a number of development schemes in the African savannas in the 1940s and 1950s. Many were failures and few have been commercially successful, thus the optimism of that period is now much qualified.

The pasture research in Australia, as indicated previously, has strongly supported research opportunities for improving production per hectare and per animal.

Unimproved production conditions in the Colombian savannas had generally resulted in low productivity of pastures and cattle. For example, a field survey (Stonaker et al., 1976) of 40 Llanos beef herds leased by farmers through a cooperative indicated that these herds had mean annual calving rates of 52% to 55%. Only 9% to 13% of the nursing cows were pregnant. Conception was seasonal, occurring mostly in the dry season and the early rainy seasons.

The inconsistencies between unimproved practices and what seemed to be adaptable improvements from other regions led to the development of these experiments.

Early Weaning

Dr. James Wiltbank, reproductive physiologist, encouraged the research team to incorporate early weaning as a technique for increasing calving rate. Koger et al. (1962) had found that, on native range in Florida, the stress of lactation apparently resulted in a large number of cows failing to reach estrus during the breeding season. Reproductive performance of females of different breed groups differed markedly. For example, Brahman cows had a weaning percentage of about 18% less than that of F_1 Brahman-Shorthorn cows.

On cleared jungle land in the Amazon region of Peru, 2,876 exposures of Zebu cows to bulls resulted in a 59% calving rate (Vaccaro et al., 1977). At the second exposure, the rate was 49%. The interval from first to second calving was 614 days. Calving rates were estimated to be too low to economically justify land clearance for pasture development. To cover these costs, a calving rate of 70% would be required. A new system of cow management was proposed to include breeding twice yearly, weaning at 6 months,

Early-weaned calves when about 6-months to 8-months old. Of the mothers, 96% were pregnant in contrast to only 21% of their nursing herd mates. These calves received .68 kg of concentrate and gained .46 kg per day. The average age at weaning was only 80 days.

Low-lying lands (bajos) provide grazing in the dry season.

developing legume pastures, and crossbreeding to European breeds.

Bellows et al. (1974) observed that the postpartum intervals to first estrus were shortened by early weaning. Cows with calves weaned at 3 days to 10 days were in estrus an average of 20 days after calving, whereas cows with calves weaned at 90 days were in estrus within 43 days. Weight gains of early-weaned calves were normal and digestive problems were minimal. Laster et al. (1973) investigated the effect on postpartum reproduction of weaning 1 week before the beginning of the breeding period. They found that weaning increased overall conception in the 42-day breeding period by 25.9% in 2-year-old cows, 15.6% in 3-year-olds, and 7.9% in cows 4 years or older. There were 13.8% more 2-year-old cows and 15.6% more mature cows pregnant at the end of the first 21 days of breeding in the weaned than in the nonweaned groups, but these differences were not statistically significant.

Morley et al. (1976) observed that the fertility of groups of lactating Angus was highly correlated with average live weight and change in live weight at breeding. These relationships did not hold for nonlactating cows. Prediction equations indicated a range of values of probability of pregnancy from .07 (for cows weighing 290 kg that lost 40 kg during breeding season) to .93 (for cows weighing 530 kg that gained 20 kg during the breeding season). Similar relationships were shown for heifers in another study in which age as well as weight at breeding were used for predicting probability of pregnancy.

Lamond (1969) studied 15,000 cows (Shorthorn, Hereford, Brahman, Devon-Shorthorn, Hereford-Shorthorn, and various Brahman grades) of different ages, in 13 herds of from 247 to 2,595 animals. Variation in pregnancy rate in June and September 1964 between herds was 44% to 77%. Lactating heifers had lower pregnancy rates than did lactating cows--

which, in turn, had lower rates than did nonlactating animals. Within classes, cows in poor body condition had lower fertility than did those in good or fat condition. According to Harwin et al. (1967), the calving rates for Afrikanders were: nonlactating cows (84%), lactating cows (61%), 3-year-old cows (51%), heifers (87%), and 64% for all cows. Corresponding rates for the Sussex were: 79%, 78%, 78%, 92%, and 78%. The effect of lactation on the calving rate was significant for Afrikander, but not for Sussex cows. Donaldson et al. (1967) found that mean pregnancy rate for lactating cows was 46%; for nonlactating cows, 77.5%.

Early weaning posed a substantial problem in raising the weaned calves under Llanos conditions. Information about the effects of early weaning on reproductive rates was required before effective experiments could be designed to study methods of raising early-weaned calves.

Protein Supplementation

Researchers at Carimagua were aware of the prevailing low protein content of upland Llanos Orientales grasses during the long dry season of December through April.

Substantial improvements in cattle production had been obtained on African veldt pastures when protein supplemented. Van Niekirk (1975) reviewed the extensive results of many workers in southern Africa concerning the crucial role of protein as the major limiting nutrient in winter grassveldt. These results indicated that--because winter grasses are fibrous and low in digestibility--energy feeds could not be recommended until protein deficiencies were corrected. Weight loss was minimized under these conditions by the use of fish meal or molasses and urea supplements. Animals supplemented in this way greatly increased intake of pasture and consumed even the most unpalatable grasses.

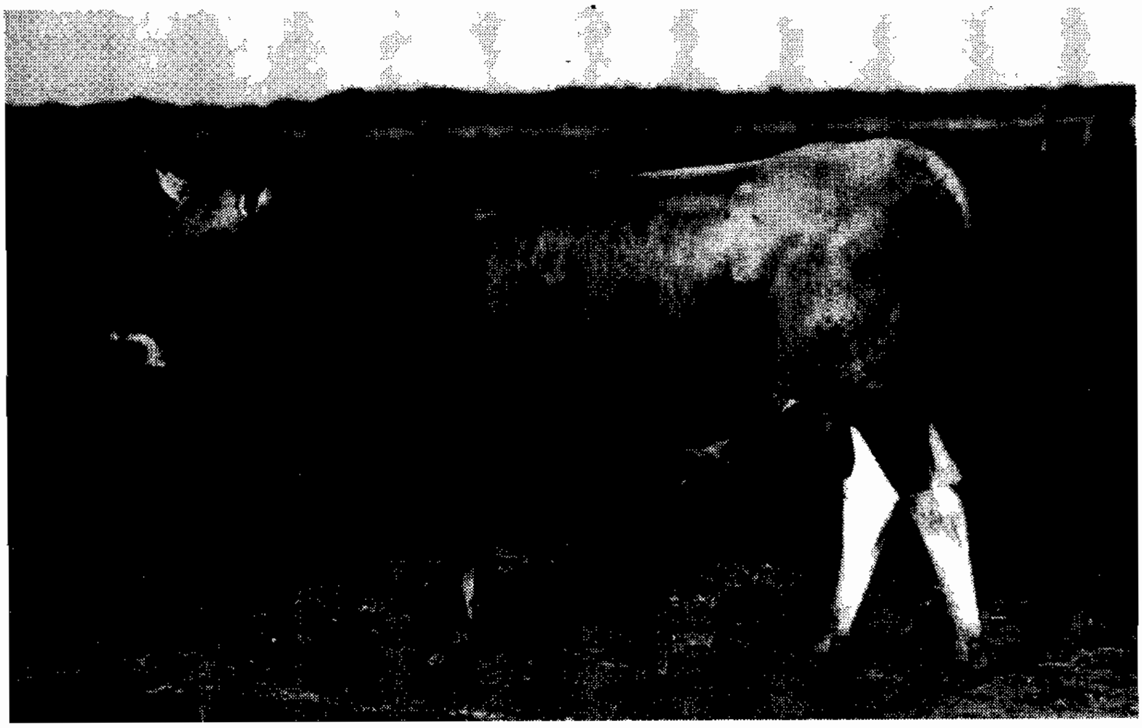
Cattle that are unsupplemented in the dry season in the sour grassveldt may lose weight for 6 to 8 months of the year, which can amount to 25% to 30% of maximum summer weight. Mortality is high and heifers do not calve until they are 3.5 to 4 years old. The average calving percentage in much of Africa is less than 50%. The end result is an extremely poor rate of meat production with low herd-extraction rates (for example, 5% to 26% in the various countries in southern Africa).

Thus there seemed to be ample reason for including urea as a protein supplement treatment during the dry season at Carimagua.

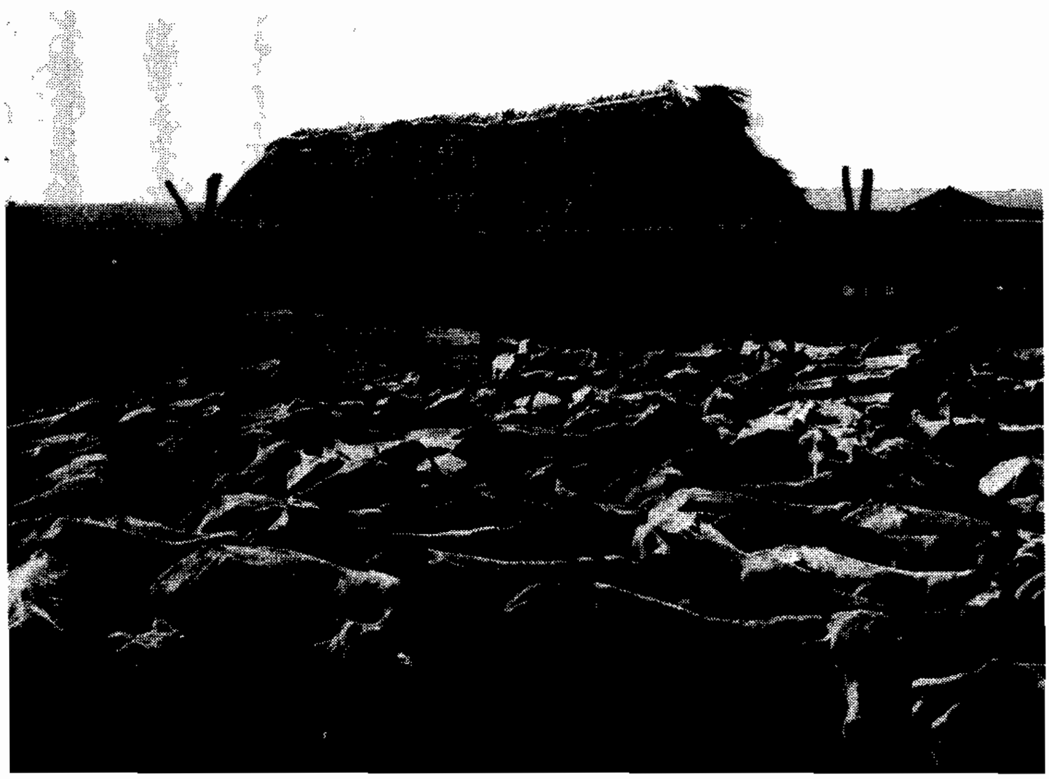
Cattle Breeding

In isolated parts of Colombia and Venezuela, primitive conditions of cattle raising remained much like those existing at the time of Spanish colonization. The Zebu bull had been practically the only improved input within the last century.

In recent years, substantial studies have been made of the heterosis in crosses between Criollo breeds and Brahman or other Indian breeds. At the Venezuelan Llanos station, Plasse (1976) reported 10% heterosis in weaning weight and 14% greater 18-month weight for F_1 progeny of Criollo and Brahman. In Colombia, reviews by Salazar (1973) and Stonaker (1971) indicated similar results. Despite this, there has been only limited interest among cattlemen in crossing the Brahman or Zebu females to Criollo bulls. However, the reciprocal cross was highly popular when there were large numbers of Criollo cows available. Generally speaking, heterosis in body weight for calves and yearlings appears to be higher for Zebu-Criollo crosses in the tropics than that reported in crosses of British or European breeds in temperate climates.



A San Martinero bull representative of those used in the experiment.



Heifers at the Carimagua corrals. These heifers were purchased from neighboring ranches in 1972 for the Herd Systems Experiment.

Previous to the Carimagua experiment, crossbred Criollo x Zebu calves had not been compared with grade Zebu (Brahman) calves under the difficult conditions of the Llanos. However, their growth rates to weaning had been shown to exceed those of straight Zebu and Criollo breeds by 10% to 15% at the ICA stations (Stonaker, 1971). Thus it seemed desirable to incorporate crossbred calves into the study using San Martinero bulls as the Criollo breed for crossing. San Martinero bulls, as well as Brahman, were readily available from the ICA station, La Libertad, near Villavicencio.

Sufficient cows of known pedigree were not available in the Llanos to incorporate crossbred Criollo x Zebu cows into the project, although considerable data had been accumulated to indicate the higher reproductive rates of these crossbred cows relative to the Zebu cows (Hernandez, 1976). Therefore, grade Zebu heifers were purchased as the foundation of the cow herd.

PROCEDURES

Experimental Design

The two experiments and corresponding treatments were arranged factorially as follows:

	Mineral Experiment	
	M_1	M_2
U_1	Herd 3	Herd 5
U_2	Herd 2	Herd 4

	Pasture Experiment		
	P_1	P_2	P_3
U_1	Herd 5	Herd 8	Herd 6
U_2	Herd 4	Herd 9	Herd 7

The treatments were (figure 3):

M_1 = salt only; and M_2 = complete minerals

U_1 = no urea; and U_2 = urea supplementation seasonally

P_1 = native pasture continuously; P_2 = molasses grass, (Melinis minutiflora), continuously; and P_3 = native pasture in the dry season, molasses grass in rainy season. Within herds:

Weaning: (W_1) five cows with calves weaned at 3 months vs (W_2) 30 cows with calves weaned at 9 months.

The five cows with calves to be weaned at 3 months were randomly chosen from among the first cows to calf in each herd. That is, other cows could have been paired with them insofar as calving date was concerned. However, in the analysis, these five cows were compared with the 30 cows with calves to be weaned at 9 months of age. Larger numbers and completely random selection of cows for early weaning were not considered feasible because of concern over costs and possible management problems.

Crossbreeding: (X_s) Alternate 28 days: 8 San Martinero bulls, one per herd, rotated among the herds in alternate 28-day periods. (X_z) Alternate 28 days: 8 Zebu bulls of the Brahman breed, one per herd, rotated among the herds in alternate 28-day periods. Thus, bulls of a breed were in use 28 days and rested 28 days.

The first calf crop, making up almost one-third of the total data on calves, was not affected by early weaning or whatever cumulative effects long-term mineral and urea feeding may have had on the cow herd and subsequent calvings. They could have been affected by minerals, urea feeding, and crossbreeding.

Most of these same observations were taken on the control herd during the experiment, and the heifers allocated to the control herd were a random sample of the total heifers assigned to the experiment. (Results of this control

	MINERAL EXPERIMENT		PASTURE EXPERIMENT		
	(M_1) Salt only	(M_2) Complete mineral	(P_1) Native (continuous)	(P_2) Molasses grass (continuous)	(P_3) Native (dry season) & Molasses grass (rainy season)
(U_1) No urea supplement	Herd 3	Herd 5	Herd 5	Herd 8	Herd 6
(U_2) Urea supplement	Herd 2	Herd 4	Herd 4	Herd 9	Herd 7

<u>Mineral treatments</u>

(M_1) Salt only
vs
(M_2) Complete mineral

<u>Pasture treatments</u>

(P_1) Native (continuous)
vs
(P_2) Molasses grass (continuous)
vs
(P_3) Native grass (dry season)
and
Molasses grass (rainy season)

TREATMENTS COMMON TO BOTH EXPERIMENTS*

<u>Protein supplements</u>	(U_1) No urea supplement vs (U_2) Urea supplement in dry season
<u>Weaning dates</u>	(W_1) 3-month weaning (early) (5 cows/herd) vs W_2 9-month weaning (normal) (30 cows/herd)
<u>Sire breeds</u> (1 bull per herd, continuously, with bulls rotated among the herds in alternate 28-day periods; i.e., a bull was in use 28 days then rested 28 days.)	X_s (8 San Martinero sires) vs X_z (8 Brahman sires)

*Other effects compared for both experiments included age, season, reproductive status, and sex; particular attention was given to the relationship between nutrition and conception, abortion and calving rates as well as weights.

Figure 3. General scheme for Carimagua management system experimental design.

herd have not been analyzed within the formal experiment reported here; however, Dr. Juvenal Gomez, ICA, documented their performance.) Herd 1 was a traditional management control herd--not included in the experimental design--in which no weaning was allowed and all progeny continued with the herd on native pasture and salt until 18 months of age. Two Zebu bulls were with this herd.

Selection of Experimental Components at Carimagua

The herd systems experiment included experimental, demonstrational, and commercial types of activities.

Native pastures for the experiment were located in areas where a combination of highland and lowland could be incorporated within each of the native pastures. Empirically, 5 ha of native pasture were allocated for each animal unit. For seeded molasses grass pasture, only upland was used and this was allocated at the ratio of 1 ha per animal unit. Native pastures were further divided into three areas separated by firebreaks (disked bare soil). Each area within a pasture was purposely burned annually in a chronological pattern so as to provide a freshly burned area in each native pasture about every 4 months. On the other hand, molasses grass pastures required protection from fire, a measure that was only partially successful.

To minimize any differences in productivity of the pastures within major nonpasture treatments, the herds were exchanged between the two pastures of their experimental treatment following each weighing period. Thus, Herds 2 and 3 were alternated in use of the same two pastures, as were Herds 4 and 5, 6 and 7, 8 and 9. No pastures were exchanged between herds that received minerals vs those not receiving them; nor were there exchanges of herds requiring different types of pastures.

In the dry season, in addition to their own pasture, cows grazing molasses grass year-round had access to the molasses grass pastures vacated by Herds 6 and 7 when they were moved onto native pastures for the dry season. Thus, the stocking rate per hectare of molasses grass was approximately halved during the dry season.

Dry season was considered to be from December 15 to April 15, early rainy season from April 15 to August 15, and late rainy season from August 15 to December 15.

Cattle were purchased in late 1971 and early 1972. In the experiment itself, heifers came from only two herds in the area. These were mostly high-grade Brahman, representing about 75% Brahman breeding. The remaining 25% was probably Criollo of the Casanare type, tracing to early introductions by Spanish colonists. A few appeared to be a first-cross San Martinero x Zebu. The Criollo breed of bulls was the San Martinero; the Zebu breed was Brahman.

The experiment was begun in July 1972 after the heifers had been weighed, tested for brucellosis, vaccinated for foot and mouth disease, and sprayed for the control of ticks. Subsequent culling was based on brucellosis or tuberculosis reactions. The heifers were approximately 2½ years old, as judged from the eruption of incisors. These animals were weighed during the pre-experimental period in April, and the average weight of 178 kg indicated that they were in thin, almost emaciated, condition. Heifers were allocated at random to the different treatments within stratified weight groups, based upon their April weight.

At the outset of the experiment, color, condition, and estimated ancestry were noted. Breed of sire, birth dates, and causes of death were listed (when possible) for calves born during the experiment. There was no castration. Because of the advanced age at first estrus, bull and heifer calves were not separated before 18 months.

The life cycles of the herds were examined under a range of different beef-producing systems. When effects of the major variables began to show a high level of reliability from year to year, the experiment was terminated in May 1977. At that time, the cows were approximately 7 years old and had produced an average of about 2.7 calves per cow in 4.0 calving years. (Under the unimproved conditions that prevailed, ranchers considered that a cow would have about four calves over an average productive life.)

The reproductive status descriptions of the cow were: open and dry, 1 to 6 months pregnant, 6 to 9 months pregnant, nursing and pregnant, and nursing and dry. Stage of pregnancy was determined by the birth date of the calf. Urea supplementation began early in January and was terminated on arrival of the rainy season. Daily supplementation was: urea (80 g), cane molasses (500 g), and sulphur (4 g). The mixture was diluted with water to prevent rapid consumption. The urea-molasses solution was fed in log troughs in which a revolving wooden reel provided a licking surface.

Each treatment (complete minerals, early weaning, molasses grass pasture, urea-molasses-sulphur supplementation, and crossbreeding) could be compared with groups that did not include these treatments.

The seasonal breeding vs continual breeding was replaced by the urea supplementation treatment (during the dry season) 3 months after the experiment began.

The individual herd size of about 35 cows was based upon the reasoning that a difference in calving rate of about 5% (with a statistical significance of $P < .05$) would be a practical cutoff point. Some death loss was anticipated, but the herd sizes were not expected to drop below 30 cows during the life of the experiment. After heifers were allocated to the breeding herd, they were to remain there, without culling, for the duration of the experiment. Similarly, those cows assigned to early weaning were continued on that basis.

The original plan was to breed in 1972, but the heifers were not cycling, as judged by palpation of ovaries. All were grazed on native savannas without minerals until they were allocated to all the experimental groups on July 25, 1972. The procedures of health management are described in appendix B.

Bulls were turned in with the heifers in May 1973. Individual matings were recorded through the use of chinball markers and conception was judged by palpation. Weights were taken after an overnight stand in corrals without water.

Although other grazing trials with steers at Carimagua used a salt-bone meal mix satisfactorily, it was felt that the slight additional cost of supplying minor elements would be warranted in the herd systems life-cycle experiment. Thus, the comparison was between a complete mineral mix vs a salt-only mix. The mix formula and herd consumption data are listed in appendix table 1.

The mix for the mineral-fed animals was first prepared by ICA (later by Ganavis in Bogota) then shipped to the Carimagua station. According to Lebdosoekojo, et al. (1980), the analysis of the supplement indicated the following concentrations: sodium, 17.75%; phosphorus, 8.93%; calcium, 12.98%; copper, 397 ppm; iron, 1,097 ppm; zinc, 650 ppm; manganese, 633 ppm; and cobalt, 33.5 ppm. Although no analysis was made for iodine, the supplement contained .004% potassium iodide.

Weights of the minerals given each herd were recorded, including a weigh-back each 56 days, so that bimonthly consumption could be calculated. Mineral or salt was placed in bunks made of hollowed logs, sheltered with a roof of palm leaves.

Statistical Analysis

The least-squares and maximum-likelihood general program for fixed models (Harvey, 1960) was used for the analyses. This procedure had the advantage of allowing use of unequal subclass numbers and the establishment of unbiased estimates for main effects and some interactions. Because of some concern about the effects of the unequal subclass numbers on the magnitude of the constants, nonadjusted means also were calculated. (Agreement was close, thus these nonadjusted mean weights are not shown.)

An example of a generalized model for the mineral experiment (Herds, 2, 3, 4, and 5) was:

$$Y_{ijkr} = \mu + M_i + U_j + W_k + (M \times U)_{ij} + \ldots + e_{ijkr}$$

Where: Y_{ijkr} estimated value for number of calvings for cow, r, that received mineral, i; supplement, j; type of weaning, k.

μ = effect of overall mean

M_i = effect of i type of mineral supplementation

U_j = effect of j type of urea supplementation

W_k = effect of k type of weaning age

$(M \times U)_{ij}$ = effect of first order interaction

e_{ijkr} = experimental error based on differences among cows not attributed to treatments

Similar models were written for various observations on the cattle in the mineral as well as the pasture experiment.

Calf weights were age-adjusted by regression. Otherwise, similar least-squares equations involving treatments were written.

Two procedures were followed in obtaining the least-squares means and appropriate variance analyses of cow weights: (1) an overall analysis in which the model included year, season, minerals, urea, weaning, pastures and reproductive status; and (2) analysis only of weights taken in a given period.

Chapter III

Mineral Experiment Results

CHARACTERISTICS OF THE BREEDING HERD

Results obtained over the entire experimental period (1973-1977) are reported here in chronological order, with brief summaries of the treatment effects of minerals, weaning, urea supplementation, and crossbreeding. Other factors such as year, season, age, and reproductive status are included also. Particular attention is given to how nutrition is associated with conceptions, abortions, and calving rates. Also examined were effects on cow weights, death losses, and timing sequence of calving, calf weights, and mortality (see experimental design, page 18).

Observations on breeding cows reflect results of growth of their calves from 3 months to 18 months. At 18 months, the calves were removed from the experiment. Death losses of calves also have been documented as to probable cause.

To simplify discussion, only the adjusted means for main effects and means for significant interaction effects have been presented in this chapter. The appendices tables provide more complete analyses, including analyses of variances, main effects, and interactions.

BREEDING HEIFERS

Weights, Conceptions, Abortions, and Calving Rates

Figure 4 shows a rapid divergence of the growth curves representing purchased heifers in the mineral-fed herds vs those in the nonmineral-fed herds. By May 1973 (immediately previous to the first breeding season) the mineral-fed heifers weighed 31 kg (13%) more ($P < .01$) than did the herds fed salt only.

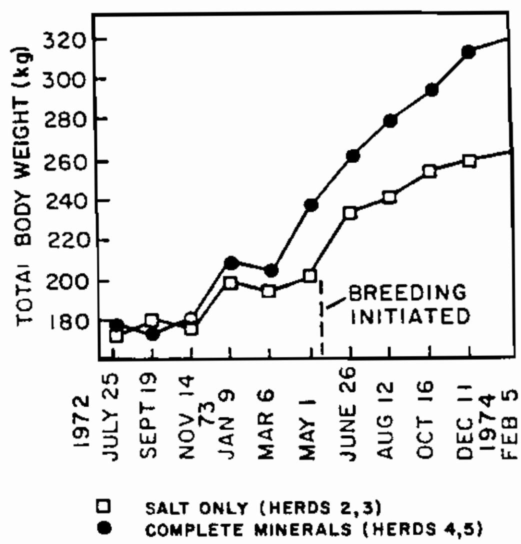


Figure 4. Weight changes of heifers on native pasture as related to mineral treatment.

The original plan was to breed the heifers at 2.5 years of age, in May 1972. However, examination at that time indicated immature ovarian development, and it was evident that the heifers were not cycling. Breeding was delayed until the following May when the heifers were 3.5 years old and those on minerals weighed 257 kg (table 1). The conception rate was high in the next months, and it was apparent that the high level of breeding in May and June of the first breeding year would affect the remainder of the experiment by partially confounding results with seasonal calving. It also caused an atypical chronological pattern of breeding and calving, particularly in the native savanna herds.

TABLE 1. LEAST-SQUARES MEANS AND ANALYSIS OF VARIANCE OF WEIGHTS OF EXPERIMENTAL HEIFERS AT BEGINNING OF BREEDING SEASON, MAY 1973 (MINERAL EXPERIMENT)

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	140	242.1	242	2.09
Salt only	71	-15.3	227	2.93
Minerals	69	15.8	257	2.97
Source	df	Mean squares	F	
Mineral	1	32773	54**	
Residual df	138	610		

**P < .01

Surveys (Stonaker et al., 1976) later indicated that, with uncontrolled breeding, there is a natural breeding season in the Llanos, usually during the dry season rather than the early wet season. As the experiment progressed through the years, the patterns of calving incidence associated with experimental procedures were diminished, and the calving dates began to cover a wider range over the other months. The distribution of births by month and year for all herds is shown in table 2. About 50% of all births occurred in the 4 months between February and May.

First Pregnancies. The mineral-fed heifers continued to outperform the nonmineral-fed herds in body weight (figure 4). The rate of conception in the first months of the breeding season was confirmed by palpation in October. Conception rates did not differ greatly between the mineral and nonmineral herds in the first year of the experiment. The large difference in calving percentage (table 3) could

TABLE 2. DISTRIBUTION OF BIRTHS OF CALVES BY MONTH AND YEAR, ALL HERDS (1-9) FROM 1974 to 1977

		Months[a]												
		1	2	3	4	5	6	7	8	9	10	11	12	Total
1974	No.	0	25	57	53	29	19	9	21	14	16	6	3	252
	%	0	3.45	7.86	7.31	4.00	2.62	1.24	2.90	1.93	2.21	0.83	0.41	34.76
1975	No.	17	18	20	14	13	11	21	13	27	14	12	16	196
	%	2.34	2.48	2.76	1.93	1.79	1.52	2.90	1.79	3.72	1.93	1.66	2.21	27.03
1976	No.	28	20	21	20	11	11	10	18	8	14	15	21	197
	%	3.86	2.76	2.90	2.76	1.52	1.52	1.38	2.48	1.10	1.93	2.07	2.90	27.17
1977	No.	12	10	26	16	16	0	0	0	0	0	0	0	80
	%	1.66	1.38	3.59	2.21	2.21	0	0	0	0	0	0	0	11.03
Total	No.	57	73	124	103	69	41	40	52	49	44	33	40	725
	%	7.86	10.07	17.10	14.21	9.52	5.66	5.52	7.17	6.76	6.07	4.55	5.52	100

[a] 1 = January, 12 = December.

TABLE 3. REPRODUCTIVE PERFORMANCE IN THE FIRST CALF CROP (CALVES BORN BETWEEN FEBRUARY AND DECEMBER 1974), BY HERD (MINERAL EXPERIMENT)

Treatment	Herd	No. of cows	No. of births	No. of abor-tions	Calving (C), %	Abortions (A), %	C+A	Time from beginning of breeding to conception, months
(M_1)Native pasture and salt	2	33	17	13	51.5	39.3	91	7.74
	3	29	15	7	51.7	24.1	75	9.78
(M_2)Native pasture and complete minerals	4	31	27	2	87.1	6.5	94	4.27
	5	33	30	1	90.9	3.0	94	4.74

be attributed to a high abortion rate in the nonmineral-fed herds, a finding that was confirmed in subsequent years of the experiment.

BREEDING COWS

Weights

The cows were weighed every 56 days throughout the life of the experiment. The least-squares means of cow weights in the mineral experiments are shown in appendix table 4. Thus, by category, the adjusted means should give the best unbiased estimate of the isolated effect of the treatment, independent of other effects. Observations were made of variations resulting from effects of dry and wet seasons, minerals, urea supplements, early weaning, and reproductive status. Table 4 shows the resultant wide range of body weights. For example, over the years, the cows increased in body weight by about 14%, plateauing at 339 kg in 1977.

TABLE 4. COW WEIGHTS (ADJUSTED) OVER ALL YEARS AS RELATED TO YEAR, REPRODUCTIVE STATUS, SEASON, UREA SUPPLEMENT, MINERALS, AND WEANING DATES (MINERAL EXPERIMENT)

Year	kg
1973	290
1974	312
1975	314
1976	332
1977	339

Reproductive status	kg
Open, dry	299
Pregnant 1-6 mo	320
Pregnant 6-9 mo	348
Pregnant, lactating	325
Open, lactating	295

Season	kg
Dry	304
Early wet	320
Late wet	329

Urea	kg
None	312
Urea	323

Minerals	kg
Salt	304
Minerals	331

Weaning	kg
3 mo	317
9 mo	317

See appendix tables 2 and 4.

Cows receiving minerals on native pastures gained approximately 9% more than did cows fed the salt-only diet. Cows fed urea supplements were about 4% heavier. Body weights of cows weaning calves at 3 months did not differ from those of cows weaning calves at 9 months. (This finding could be attributed to frequency of calving.)

Reproductive status was the environmental factor having the greatest effect on body weight of cows in the mineral experiment. At any one time, about 30% of the cows in the herd were lactating and not pregnant; these were also the lightest cows in the herd, averaging 295 kg. The heaviest cows in the herd were 6 to 9 months pregnant and were dry; they weighed 348 kg, or 18% more than the lightest group.

Appendix table 1 shows minerals consumed and the formula for the mineral supplement.

Calving Sequence Patterns

Ranchers in the Llanos Orientales commonly believe that cows calve in alternate years; thus, the chronological calving pattern was of particular interest in the experimental herds. Appendix table 3 shows the time pattern of calvings by individual cows. About half of the early-weaned cows calved in each of the years 1974, 1975, 1976, and 1977; most of the remainder produced three calves in the sequence of 1974, 1975, and 1976. Normally weaned cows in this group had lost one or more calves. Of the normally weaned cows that calved three calves, most were either in the sequence of 1974, 1975, and 1976 or in 1974, 1975, and 1977. Among those cows receiving minerals that calved only twice, the predominant pattern was to calve in 1974 and again in 1976, giving some basis for the commonly held opinion that cows in the Llanos tend to calve every other year. In nonmineral-fed Herds 2 and 3, the predominant pattern of calving during the period of the experiment was two calves born in either the sequence of 1974-1976 or 1975-1976. Six apparently normal cows did not calve during the entire experiment.

Conceptions and Abortions Over All Years

At irregular intervals, cows were palpated as a test for pregnancy. In all, nine palpations were made between October 1973 and March 1977. The correlation between predicted age of fetus and the actual age of fetus was r = .87 as determined later by birth date. Despite limitations of the data, estimates can be inferred relative to probable conceptions and abortions. The intervals between the palpation periods were 16, 24, 24, 40, 32, 16, and 8 weeks; thus a number of conceptions could have escaped detection. Estimates of abortion rates were tentative (except in 1973 and the last two palpations after August of 1976); only a portion of the calvings were detected that might have occurred before the experiment was terminated. Despite these limitations, the effects of treatments were analyzed on the overall number of conceptions detected (table 5); only the effect of early weaning was significant.

Table 6 shows treatment effects as ratios that compare the number of conceptions and number of calves born.

Abortion rates differed markedly between the two treatments. The birth rate for mineral-fed cows was 1.28 times that for nonmineral-fed cows. However, the conception rate for the same comparison was closer (1.11). For other treatments, such as urea supplementation, these ratios were similar, indicating that only minerals improved ability to maintain pregnancy.

TABLE 5. CONCEPTIONS, ABORTIONS, NUMBER OF CALVES BORN PER COW, AND CALVING-RATE INDEX AS AFFECTED BY MINERAL TREATMENT, UREA SUPPLEMENTATION, AND WEANING AGE (MINERAL EXPERIMENT)

Treatment	No. of cows N	Conceptions $\bar{x}$	Abortions $\bar{x}$	Calves born $\bar{x}$	Calving-rate index $\bar{x}$
Minerals					
Salt (M_1)	71	2.72	.37	2.34	.58
Minerals (M_2)	69	3.01	.02	2.99	.75
Urea					
None (U_1)	70	2.81	.19	2.62	.66
Urea (U_2)	70	2.92	.20	2.72	.68
Weaning					
3 mo (W_1)	20	3.45	.20	3.25	.81
9 mo (W_2)	120	2.27	.19	2.08	.52

See appendix tables 2, 6, 7, and 8 for complete listings of least-squares means and analyses of variances and appendix table 9 for calving rates for all treatments including interactions.

TABLE 6. COMPARISON OF RATIOS OF CONCEPTIONS AND CALVES BORN AS RELATED TO MINERAL TREATMENT, UREA SUPPLEMENTATION, AND DATE OF WEANING (MINERAL EXPERIMENT) SEE TABLE 5

	Conceptions	Born
Minerals		
M_2/M_1	1.11	1.28
Urea		
U_2/U_1	1.04	1.04
Weaning		
W_1/W_2	1.52	1.56

Calving-Rate Index

Cattle producers often use the term "percent calf crop" to describe the reproductive rate in the herd. It may represent the percentage of total cows calving in the herd in a season or the percentage of cows weaning calves relative to the number of cows exposed to the bulls. It is not a precise term but is useful in describing an important economic component of beef production.

In the Llanos, bulls usually are with the cows continuously. Calf-crop percentage is a widely used term; one definition is: number of calves born in a year divided by the number of breeding cows in the herd that year. Heifers would not be included as breeding cows until old enough to calve in that year. More commonly, in the Llanos, the calf crop percentage refers to the number of live calves in the herd divided by the number of cows, with a calendar year as the time period.

In commercial dairy herds, where year-round breeding also is followed, reproductive rate is almost always conveniently measured in days or months between calvings or in length of calving intervals. An average interval of 365 days would be equivalent to a calving percentage at birth of 100%; 730 days would be 50%.

In the herd systems study, although calving rate was not obligatory for presenting comparative reproductive rates (this was based on total number of calves produced per cow within each treatment as previously described), it seems appropriate to express calving rates and weaning rates in percentage terms.

Calving intervals as used in dairy studies were not applicable because much of the reproductive data came from the first calvings, which would not be included with calving intervals. Further, this experimental herd, because it was formed from purchased heifers, would be atypical of established beef herds consisting of cows of an array of ages.

To transform the calf numbers to a more understandable calving percentage or rate, the following indexing of calving rate was used. It was assumed that (in the absence of twinning) there is a maximum practical calving rate of 1.00 or 100%. This parallels a calving interval of 365 days that would accommodate a 285-day gestation period and an 80-day interval following parturition to conception. The 80-day interval was chosen to represent an acceptable average time after bulls were introduced into the herd in which virgin heifers would conceive. This interval is less than the average of about 4 months encountered in the experiment, but is longer than is biologically necessary.

In this experiment, heifers and cows had 1,195 days or 3.27 years during which it was possible to calve. If a minimum calving interval of 365 days is assumed as biologically feasible (and perhaps desirable), heifers conceiving 80 days after being first exposed to bulls and every 365 days thereafter would reproduce at the maximum possible rate of 100%. This is the index for comparative purposes.

In 1,195 days, the length of the experiment, a 100% calving rate could produce four calves with the 365-day calving interval as follows:

285th day after bulls were placed with females	Assumed day for first calving	Second calf	Third calf	Fourth calf
Day 0	Day 80	Day 445	Day 810	Day 1175

Thus, because the data on first calving heifers is included, the maximum calving rate possible is:

$$\frac{4 \text{ calves}}{3.27 \text{ years}} \text{ or } 1.22 \text{ calves/year}$$

Thus, 1.22 is indexed as the maximum calving rate of 1.00, which corresponds to a calving interval of 365 days. Accordingly, indexed calving rates in this study are presented as: average number of calves per cow per treatment divided by (3.27 x 1.22).

With this indexing, calving rate would exceed 1.0 only under unusual circumstances when calving intervals are under 1 year.

Production Ratios

In summaries and in some tables, ratios of production may be useful to indicate relative differences in production level irrespective of the basis of measurement (i.e., number of calves, kg, percentage).

Frequently, the base herd would be the low-input Herds 2 and 3, which received salt and native pasture. The production in these herds with 9-month weaning would be considered as base 1.0. Performance of other treatments would then be compared to these. If other bases for comparison are used, they are indicated.

The calving-rate-index data based on calves born contrast with the data on calves that lived to 18 months of age or to the end of the experiment (table 7). In nonmineral-fed Herds 2 and 3, total production in each herd was 49 calves (living 540 days or until the termination of the experiment). Using this total as a basis for comparing other herds, Herd 4 (which produced 76 calves) is calculated to have a ratio of 1.55, and Herd 5 (with 81 calves) has a ratio of 1.65.

The number of calves raised relative to the cow-years involved must be calculated to further compare the treatment effects. The data in table 8 indicate that the differences due to weaning age were much larger within the nonmineral-fed herds than in the herds receiving minerals (see figure 5).

TABLE 7. CALVES BORN AND RAISED[a] BETWEEN FEBRUARY 14, 1974, AND MAY 23, 1977, MINERAL EXPERIMENT

Herd/ treatment	Weaned at 9 mo					Weaned at 3 mo					Early/normal weaning ratios:	
	Born	Died	Net	Calving rate index	Calf crop index	Born	Died	Net	Calving rate index	Calf crop index	Births early/ normal	Net prod. of animals early/normal
2 (M_1)	52	13	39	.43	.33	16	6	10	.80	.50	1.86	1.52
3 (M_1)	51	15	36	.42	.30	14	1	13	.70	.65	1.67	2.17
4 (M_2)	70	11	59	.58	.49	18	1	17	.90	.85	1.55	1.73
5 (M_2)	76	6	70	.64	.58	17	6	11	.85	.55	1.32	.95

[a] Uncorrected for cow mortality; based on beginning inventories in 1972. All calf deaths included irrespective of age.

TABLE 8. CALVING-RATE INDEXES OF CALVES BORN AND RAISED, ACCORDING TO UNADJUSTED VALUES FOR WEANING TREATMENTS (MINERAL EXPERIMENT)

Herd	Treatment[a]	Calving-rate index: 9-mo weaning Born	9-mo weaning Raised	3-mo weaning Born	3-mo weaning Raised
4, 5	M_2	.61	.61	.89	.72
2, 3	M_1	.43	.31	.84	.59
2, 4	U_2	.51	.41	.89	.69
3, 5	U_1	.53	.44	.80	.78

a 2 = received.
1 = none received.
See appendix table 9 for adjusted values.

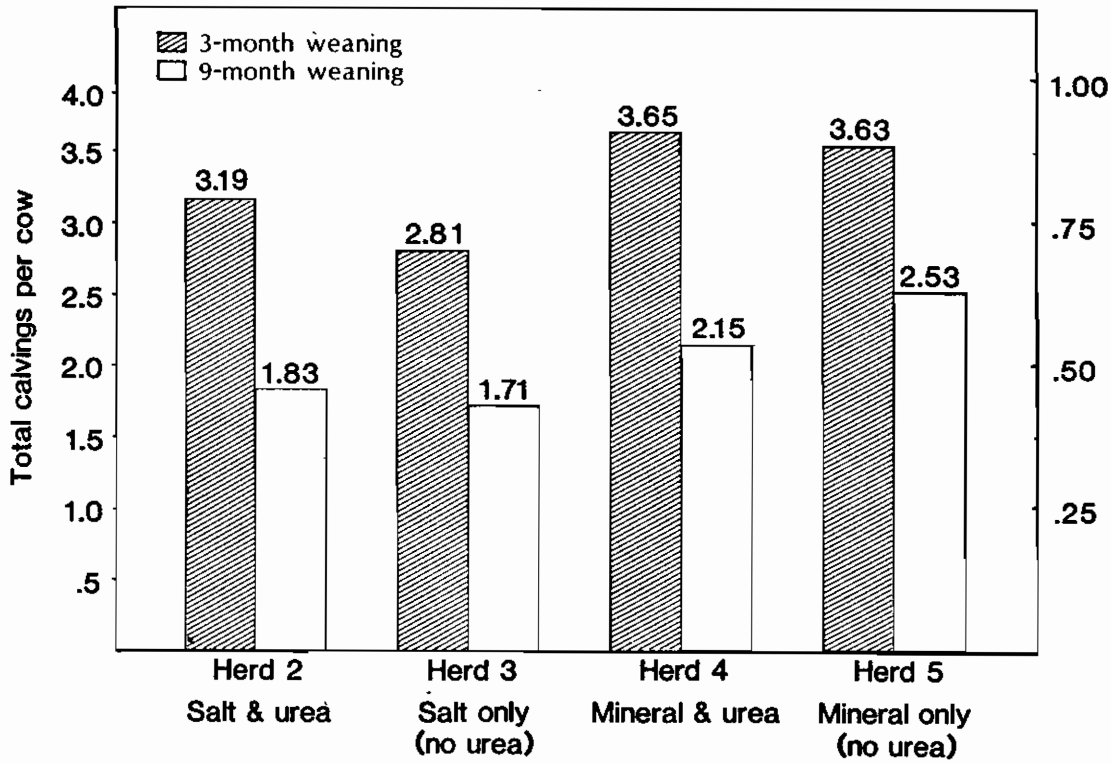


Figure 5. Number of calvings in mineral experiment herds; relative increases due to treatments; indexed calving rates (see tables 7 and 12 and appendix table 2).

Breed of Sire and Number of Progeny

Gomez et al. (1982) have observed that in the distribution of breed of calf in the mineral-fed vs nonmineral-fed herds, the Zebu bulls sired only 37% of the calves in the salt-only herds, but sired 62% in the mineral-supplemented herds (table 9). These differences were significant ($P < .05$). Overall, 52.2% of the calves were sired by Zebu bulls.

TABLE 9. NUMBER AND PERCENTAGE OF CALVES SIRED BY ZEBU VS SAN MARTINERO SIRES (MINERAL EXPERIMENT)

	Herd		Zebu-sired calves	San Martinero-sired calves	Total
Native pasture + salt	2-3	(no.)	25	45*	70
		(%)	36.6	63.4	
Native pasture + minerals	4-5	(no.)	71*	43	114
		(%)	62.3	37.7	
Total		(no.)	96	88	184
		(%)	52.2	47.8	100

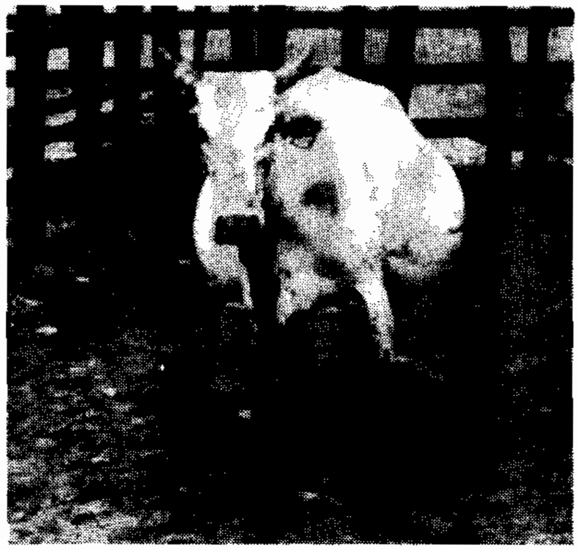
* $P < .05$.
Source: Gomez, S. J. et al., 1982.

Death Loss Among Cows

The herds that were not fed minerals had relatively greater death losses (table 10). The total cow loss (not including those eliminated for brucellosis) was about 17% in nonmineral-fed herds. In mineral-fed herds, losses were only about 2% (figure 6). Cows removed from all herds because of a positive brucellosis test were not included as death losses. Herd 1, a control herd that received no minerals and in which no calves were weaned, had substantially more bone fractures. The only other herds having cows eliminated because of bone fractures were nonmineral-fed Herds 2 and 3.

A case of vaca inflada (hydrallantois, a condition known in the Llanos and thought to be associated with phosphorus deficiency) occurred in Herd 1. Large accumulations of amniotic fluid in the affected pregnant cow occur causing excessive swelling in the abdominal region, which may be fatal to cow and fetus. (Feeding of minerals has been reported as a preventive measure for vaca inflada.)

None of the cows with early-weaned calves were lost.



<u>Vaca inflada</u> (inflated cow). Observed in Herd 1 where the treatments were native pasture without minerals or weaning. In <u>vacas infladas</u> an excess amount of amniotic fluid is produced and calves are usually stillborn. Mineral feeding is a preventive measure.

TABLE 10. COW LOSSES BY CAUSE (MINERAL EXPERIMENT)

	Herds				
Cause	2	3	4	5	Total
Brucellosis[1/]		2	2	1	-
Leptospirosis		1			1
Starvation		2			2
Bone fractures	2	1			3
Trapped in mud		1			1
Septicemia	1				1
Anaplasmosis, hemoparasites		1			1
Unknown	1				1
Lesion of knee			1		1
Total	(4	8)	(3	1)	11
Brucellosis cows deleted	(4	6)	(1	0)	11

[1/] Percentage losses (brucellosis cows deleted):
Nonmineral Herds 2 and 3 10/70 = 14% overall
or 10/60 = 17% for 9-mo weaning
Mineral Herds 4 and 5 1/70 = 1% overall
or 1/60 = 2% for 9-mo weaning

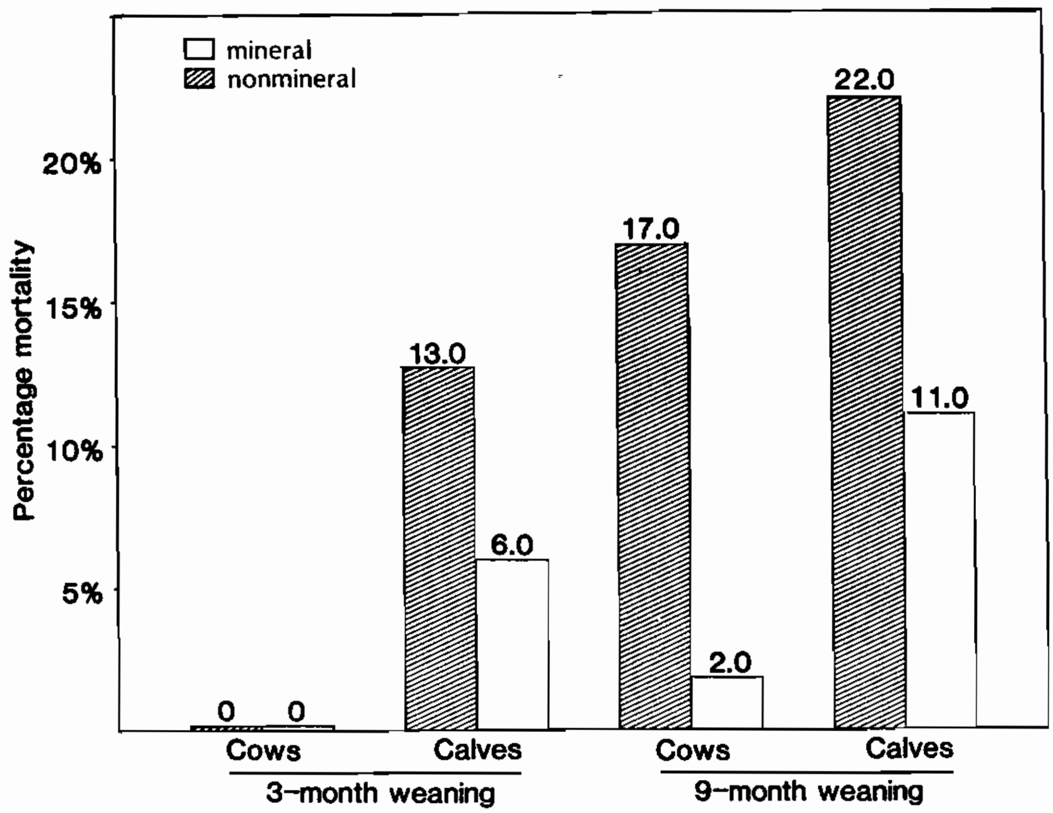


Figure 6. Calf mortality to 3 months, as related to weaning and minerals; cow mortality throughout experiment (see tables 10 and 12).

Another unusual cause of animal death in the Llanos is the result of enterradas, i.e., literally being buried in mud. During the dry season, weak cows become entrapped in the mud when going to drink from bogs or water holes. This problem also occurred in experimental herds that had access to ponds and streams. The danger can be minimized by bulldozing out a solid footing or building a log ramp to watering holes or streams in the dry season. In the rainy season, water is generally easily accessible and enterradas is not a problem.

CALVES AND YEARLINGS

Weights

In table 11, the least-squares adjusted means for weights of calves at 9 and 18 months are listed by major treatments and conditions.

The greatest differences in calf weights were associated with effects of complete mineral supplementation vs feeding a salt-only diet. Calf weights for the two treatments at various ages are shown in figure 7. Mineral supplementation showed the greatest advantage over the salt-only diet at 9 months of age (38 kg or 29%); at 18 months, the difference (32 kg or 21%) was also significant ($P < .01$).

Calves from urea-supplemented cows slightly outweighed calves from nonsupplemented cows (figure 8); however, this difference can probably be attributed to the better milking performance of the cows rather than to the actual consumption of the urea solution by the calves. The supplementation effect diminished following weaning at 9 months of age; calves from urea-supplemented cows weighed only 3% more at 18 months of age.

The differences in body weight between bulls and heifers were significant ($P < .05$) at all ages in the experiment (figure 9). The male:female ratio was about 1.06 previous to weaning at 9 months of age. After weaning, the ratio increased to 1.09 at 12 and 18 months of age. Because the heifers were relatively late in reaching puberty, the bull calves were not separated from the heifers before the age of 18 months.

Comparisons of breed of sire showed no significant differences until calves reached 9 months of age. Following weaning of the calves, the breed differences were significant ($P < .01$) and weights of the crossbred calves sired by San Martinero bulls were consistently greater than those of

TABLE 11. CALF WEIGHTS (ADJUSTED MEANS) AT 9 AND 18 MONTHS AS RELATED TO YEAR OF BIRTH, SEASON OF BIRTH, UREA SUPPLEMENTATION, MINERALS, SEX, SIRE BREED, AND MINERALS AND UREA INTERACTION (MINERAL EXPERIMENT)

Year	9 mo, kg	18 mo, kg
1974	145	175
1975	147	167
1976	149	

Season	9 mo, kg	18 mo, kg
Dry	150	178
Early wet	140	161
Late wet	160	174

Urea	9 mo, kg	18 mo, kg
None (U_1)	147	173
Urea (U_2)	153	168

Minerals	9 mo, kg	18 mo, kg
Salt (M_1)	131	155
Minerals (M_2)	169	187

Sex	9 mo, kg	18 mo, kg
Male	155	178
Female	145	168

Sire breed	9 mo, kg	18 mo, kg
Zebu	146	162
San Martinero	155	179

Significant interaction: P < .05	9 mo, kg
$M_1U_1 + M_2U_2/2$	145
$M_1U_2 + M_2U_1/2$	155

See details in appendix tables 9, 11, and 12.

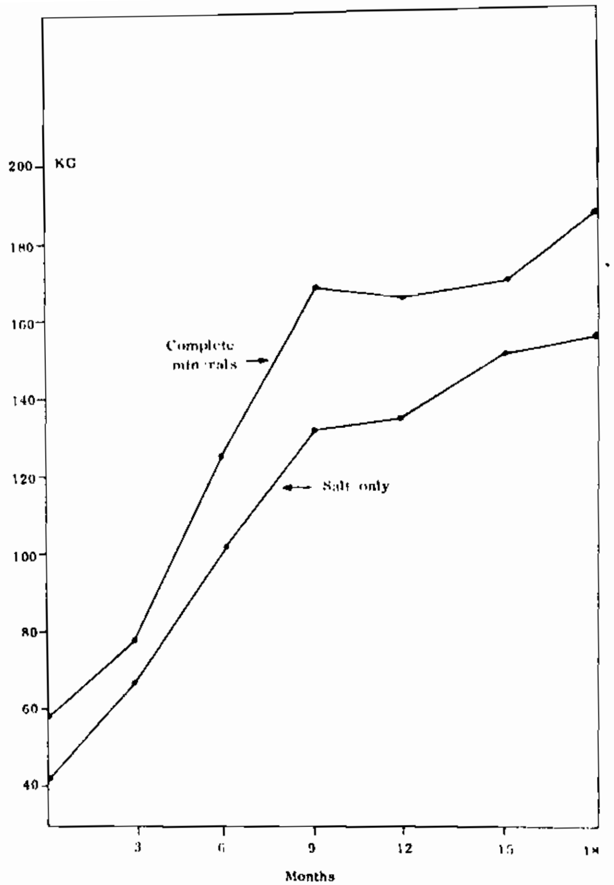


Figure 7. Effects of mineral supplementation on weights of calves weaned at 9 months (least-squares means).

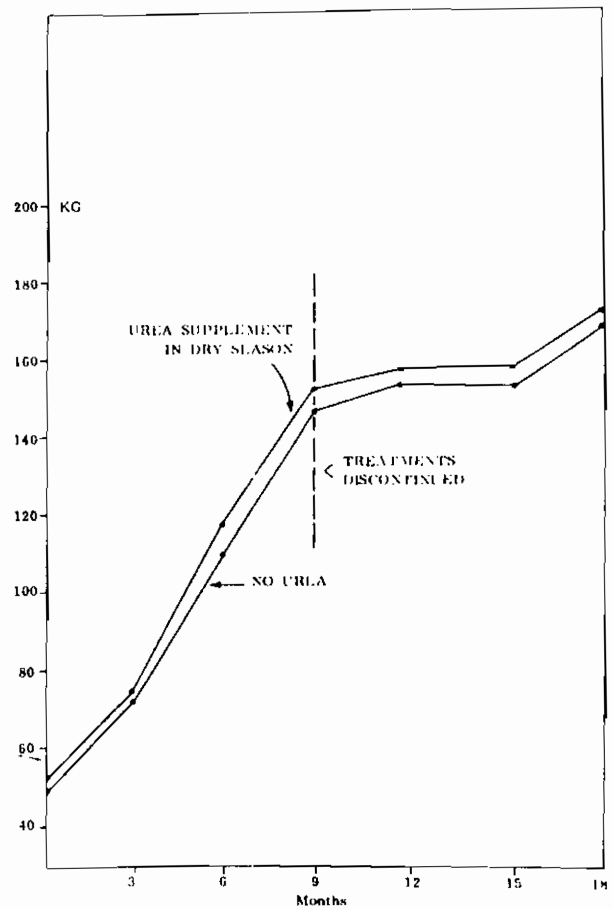


Figure 8. Effect of urea supplementation on weight of calves weaned at 9 months (mineral experiment).

grade Brahman calves. Weights differed only slightly (1%) at 3 months of age; this difference increased to 4% at 6 months, to 6% at 9 months, to 8% at 12 months, and to 10% at 18 months of age (figure 10).

Much of this difference could be attributed to a hybrid vigor effect; however, this observation would be conjecture because all of the dams were grade Zebu. An assessment of hybrid vigor could have been made had there been purebred San Martinero cows and calves in the experiment. The mature San Martinero sires weighed less than did the mature Zebu sires, even though they were in good condition and well-adapted to the environment. Thus, the greater weights of the San Martinero-sired calves were probably not caused by an additive effect. Heterosis seems to be an acceptable explanation.

Significant interaction effects were noted between minerals and urea at 9 months of age (calculated as Herd 2 [M_1U_2] + Herd 5 [M_2U_1] versus Herd 3 [M_1U_1] + Herd 4 [M_2U_2]) (appendix table 12). Calves from the urea-supplemented, nonmineral herd (Herd 2) weighed more than would be expected from the additive effects of minerals and urea. The commercial-grade molasses (in amounts providing a small energy source) contained a small percentage of minerals such as calcium. The chemical analysis for molasses was moisture, 22.0%; sugar, 62.0%; protein, 2.3%; ash, 8.81%; Ca, .64%; and P, .05% (Buitrago, 1977). The effects related to these minerals cannot be separated from those due to the effects of urea supplementation (which provides a supplemental non-protein nitrogen source for the cows that could increase their grazing capability). The interaction effects on calf weights had disappeared by 18 months of age.

Stillborn calves were 16 times more prevalent in the nonmineral-fed herds than in the herds receiving complete minerals (table 12). After calves reached 30 days of age,

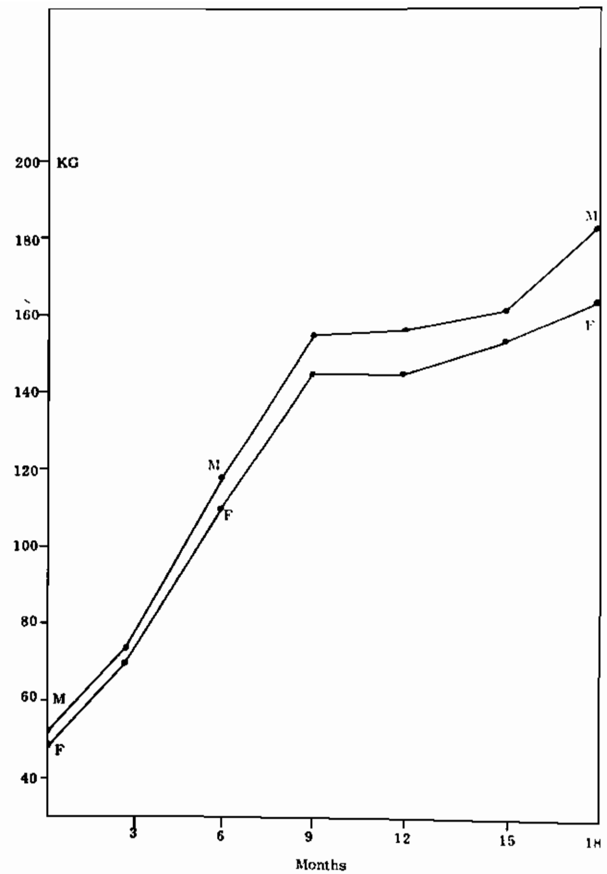


Figure 9. Weight comparisons of male (M) vs female (F) calves weaned at 9 months (mineral experiment).

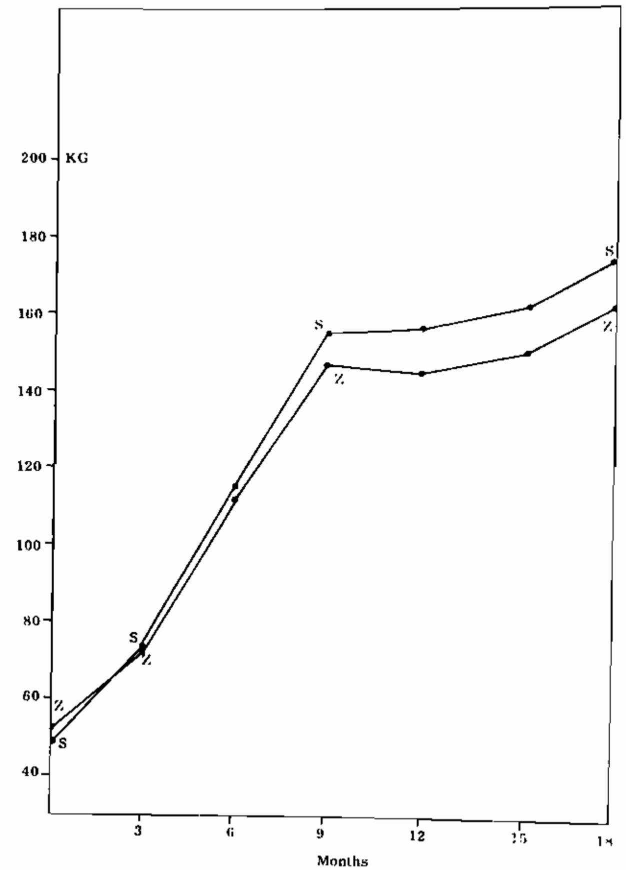


Figure 10. Effect of San Martinero (S) sires vs Zebu (Z) sires on weights of calves weaned at 9 months (mineral experiment).

death-loss rates were approximately equal in all herds until the 9-month weaning.

Death Losses Among Calves and Yearlings

The early-weaned group had a total of 65 calvings (table 12); thus, death-loss data are based on fewer numbers and are less reliable than are the data from the groups weaned at 9 months that had a total of 249 calvings. Until 90 days of age, early-weaned calves had a greater chance of survival--9% death loss vs 15% for those weaned at 9 months. However, at 18 months, death losses were essentially equal--18% for 9-month weaning and 22% for weaning at 3 months.

TABLE 12. NUMBER AND PERCENTAGE OF DEAD CALVES BY HERD AND AGE AT DEATH AND WEANING (MINERAL EXPERIMENT)

Herd	Calves born no.	Calves dead no. (%)	Days of age at death: At birth no.	0–30 no.	30–90 no.	90–270 no.	270–545 no.
			9-mo weaning				
2 (M_1)	52	13 (25)	7	2	0	4	0
3 (M_1^1)	51	15 (29)	6	7	1		1
	103	28 (27)	13 (12%)	9 (9%)	1 (1%)	4 (4%)	1 (1%)
4 (M_2)	70	11 (16)	1	7	2		1
5 (M_2^2)	76	7 (9)	0	3	2		2
	146	18 (12)	1 (1%)	10 (7%)	4 (3%)		3 (2%)
			3-mo weaning				
2 (M_1)	16	6 (38)	3	1	0	0	2
3 (M_1^1)	14	1 (7)	0	0	0	0	1
	30	7 (23)	3 (10%)	1 (3%)	0 (0%)	0 (0%)	3 (10%)
4 (M_2)	18	1 (6)	0	0	0	1	0
5 (M_2^2)	17	6 (35)	0	2	0	2	2
	35	7 (20)	0 (0%)	2 (6%)	0 (0%)	3 (9%)	2 (6%)

At ages from 90 days to 18 months, the early-weaned calves had a death loss of 12%. These calves were managed in various ways after weaning; usually about .5 kg of 25% protein dairy calf concentrate was supplied daily until they were 6 months old. At times, legume pasture (such as Stylosanthes) was available. All calves received minerals, irrespective of previous treatment. (In an independent study of early-weaned Llanos-born calves at Cali [CIAT Annual Report, 1975]--for which better pastures were available--death losses were much lower than at Carimagua.)

For calves up to 90 days old in mineral-fed herds, death loss was 9%, as compared with a 20% death loss for calves that received salt only. At 18 months, these death losses were 14% and 26%, respectively.

Fewer than 1% of calves were stillborn in mineral-fed cow herds, whereas 12% were stillborn in herds fed salt only.

Most losses of calves were either unexplained or resulted from starvation (table 13).

TABLE 13. CAUSES OF DEATH OR REMOVAL OF CALVES AND YEARLINGS IN ALL HERDS (MINERAL EXPERIMENT)

	Herds				
	(M_1)		(M_2)		
Cause of death	2	3	4	5	N
Starvation	3	5	1	5	14
Poison (urea or other)	2	1		1	4
Various reasons noted	1	1		2	4
Pneumonia			1		1
Fractures	2			1	3
Unknown	11	9	8	3	31
Total	19	16	10	12	57

Chapter IV

Pasture Experiment Results

CHARACTERISTICS OF THE BREEDING HERD

All cattle in the pasture experiment received complete minerals (appendix table 1). Thus, the average performance level was higher than in the mineral experiment. The treatments included three types of pastures: 1) native, 2) molasses grass, or 3) native in the dry season with molasses grass in the rainy season. (See experimental design, page 18.) The other treatments were repeated as in the mineral experiment, i. e., urea supplementation in dry season, early weaning, and crossbreeding.

For the most part, pasture effects on individual animal performance were negligible although carrying capacity and beef produced per hectare were increased several fold by grazing of molasses grass. Gomez et al. (1982) indicated the production per hectare of molasses grass + native pastures was 2.5 times that of native pasture alone. Production of stocker cattle fed solely on molasses grass was 3.29 times that of cattle on native pasture (table 14). Although other results from the pasture experiment generally supported the findings of the mineral experiment, an exception was the increased abortion rate from the interaction between urea supplementation and molasses grass pasture.

TABLE 14. CALF PRODUCTION AS RELATED TO TYPE OF PASTURE

Pasture treatment	N	Weaning weight $\bar{x}$, kg	Calf production, kg/ha/yr	Relative production
Native	162	130	16.0	1.00
Molasses grass and native	173	132	39.7	2.48
Molasses grass alone	157	126	52.6	3.29

Source: Gomez, S. J. et al., 1982.

BREEDING HEIFERS

Growth, Conceptions, and Calving-Rate Indexes

Figure 11 and table 15 show that one year after the experiment began (by May of 1973), breeding heifers on native pasture weighed 8% more than did those on native lowland in dry season and molasses grass pasture in rainy season. However, as shown in figure 11, the heifers' comparative rates of gain on the three types of pasture shifted greatly during the first year. The heifers on molasses grass showed a greatly increased growth rate in the late rainy season up to January 1973, as compared to heifers on native pasture. This gain was followed by a severe weight loss on molasses grass during the dry season. Such fluctuations became a pattern for the herds on molasses grass, i.e., relatively large weight gains during the rainy season and losses during the dry season.

Weight losses of herds on molasses grass were greatly modified in the herd supplemented with urea. By August 1973, however, weights of all herds on all pasture types were about the same (figure 11). Nor was there any appreciable difference among pasture groups in the first calf crop, born in 1974 (table 16). However, estimated abortion rates

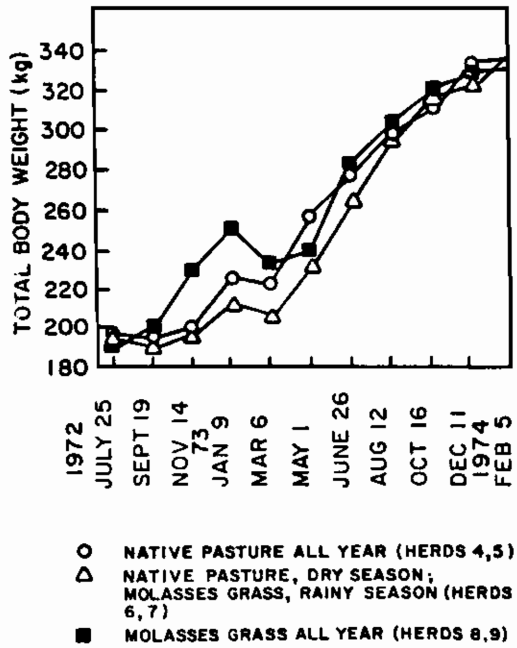


Figure 11. **Changes of weights of heifers on different pasture systems (pasture experiment).**

TABLE 15. LEAST-SQUARES MEANS AND ANALYSES OF VARIANCE OF WEIGHTS OF EXPERIMENTAL HEIFERS AT BEGINNING OF BREEDING, MAY 1973 (PASTURE EXPERIMENT)

	Herds 4, 5, 6, 7, 8, 9		
	N	Constant estimate	Least-squares mean
Mean	213	246	246
Native	69	11.6	257
Molasses grass	73	-3.6	242
Native + molasses	71	-7.9	238
Source	df	Mean squares	F
Pasture	2	7328	11**
Residual df	210	667	

** $P < .01$

TABLE 16. REPRODUCTIVE PERFORMANCE IN THE FIRST CALF CROP (CALVES BORN BETWEEN FEBRUARY AND DECEMBER 1974) (PASTURE EXPERIMENT)

Treatment	Herd	No. of cows	No. of births	No. of abor-tions	Calving (C), %	Abortions (A), %	C+A	Time from beginning of breeding to conception, months
Native pasture & complete minerals	4	31	27	2	87.1	6.5	94	4.27
	5	33	30	1	90.9	3.0	94	4.74
Native pasture & molasses grass & complete minerals	6	35	30	3	85.7	8.6	94	4.20
	7	34	31	0	91.2	0.0	91	5.15
Molasses grass & complete minerals	8	34	31	0	91.2	0.0	91	4.55
	9	32	28	3	87.5	9.4	97	3.85

were observed to be high in herds receiving urea. (This is discussed later in the overall observations on the interaction between molasses grass and urea.)

BREEDING COWS

Cow Weights

The experimental data on cow weights reflected age, physiological state, and nutritional conditions. The greatest contribution to the variance in weight was associated with reproductive status, followed by season, urea supplementation, pasture type, year, and calf-weaning age. The adjusted cow weights are shown in table 17.

TABLE 17. COW WEIGHTS (ADJUSTED) OVER ALL YEARS AS RELATED TO YEAR, REPRODUCTIVE STATUS, SEASON, UREA SUPPLEMENTATION, TYPE OF PASTURE, AND WEANING DATE (PASTURE EXPERIMENT)

Year	kg
1973	311
1974	335
1975	331
1976	339
1977	342

Reproductive status	kg
Open, dry	318
Pregnant 1-6 mo, dry	335
Pregnant 6-9 mo, dry	369
Pregnant, lactating	332
Open, lactating	303

Season	kg
Dry	316
Early wet	335
Late wet	343

Urea	kg
No	327
Yes	336

Pastures	kg
Native	336
Molasses	323
Nat/mol	335

Weaning	kg
3 mo	317
9 mo	323

See appendix tables 13 and 14.

Cow weight and associated body condition are, of course, important to the cattleman when the animal is sold; moreover, they are critical to reproductive performance of the cow and, in some cases, survival itself. The cows in this study were conceiving when they weighed between 320 kg and 335 kg. Cows with early-weaned calves on native pasture, or on the combination of native pasture and molasses grass, were heavier than those pastured solely on molasses grass. Individually, these treatments added only 3% to 5% to the body weight of the cows. Such effects are small compared to those attributed to reproductive status; for example, wet, open lactating cows weighed only 82% as much as did pregnant, dry cows. Effects associated with time (years) reflected annual fluctuations in pasture, etc., as well as the results of increasing age of the cows. Generally the molasses grass pasture and urea had little effect on average cow weights.

Seasonal Effects on Cow Weights

Seasonal variations of cow weights in the pasture experiment were analyzed over one year, beginning in August 1976 and ending March 1977 (figure 12). The results were similar to the analysis using all cow weights, demonstrating severe weight loss when the herd was on molasses grass pasture during dry season. Native pasture effects were associated with greater weights and less fluctuation. The constants are given in appendix table 15 and variance analysis in appendix table 16. Urea supplementation largely alleviated the poor nutrition from molasses grass in the dry season.

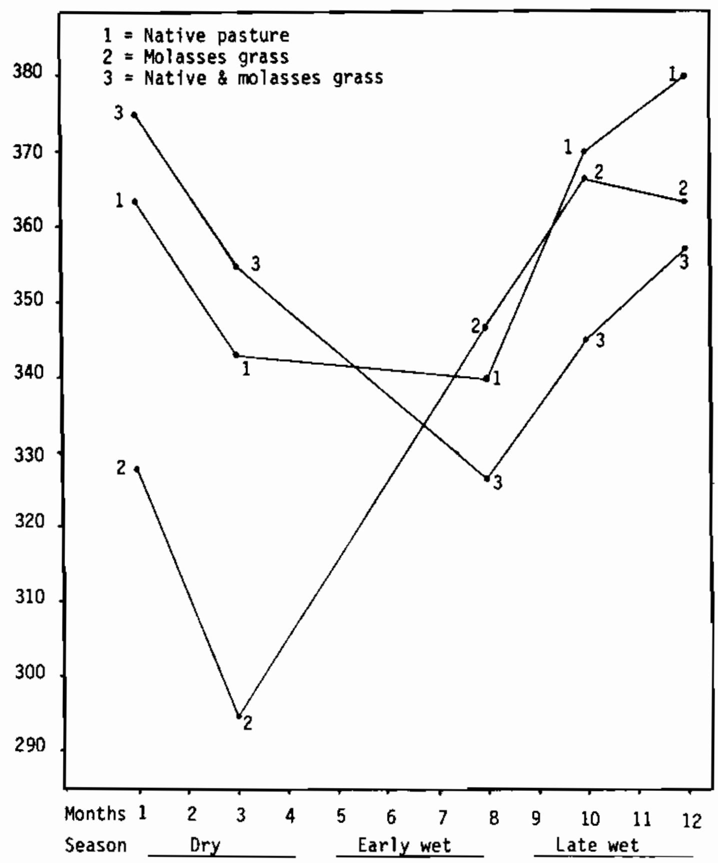


Figure 12. Relationship of wet and dry season to weight of cows on three types of pastures, 1976-1977 (pasture experiment).

From December through March, cows on native pastures were heavier; however, a 3% weight advantage was attributed to urea-supplemented cows. For cows on molasses grass, the maximum weight advantage associated with the urea supplementation was 12% in January. Pasture effects were significant in January and March during the dry season. Urea effects were significant in January and August. Weaning age and reproductive status had significant effects in all months.

Despite poor performance in the dry season, the molasses grass pastures with urea supplementation maintained about five times more animal units per hectare than did native pasture alone.

Calving Rate

The overall calving-rate index in the pasture experiment was 60% for 183 cows weaned at 9 months, compared to a rate of 84% for the 30 cows weaned at 3 months. This difference was due to shortened calving interval. These early-weaning effects were the only statistically significant effects on the calving-rate index shown in the pasture experiment. Cows fed urea supplements had a 72% calving-rate index, in contrast to a 74% index for the unsupplemented cows. Cows continuously on molasses grass pasture had a 69% calving-rate index as compared to an index of 74% for those on native pasture or native pasture with molasses grass (table 18). Table 19 shows numbers of calves born and raised.

TABLE 18. NUMBER OF CONCEPTIONS, ABORTIONS, CALVES, AND CALVING-RATE INDEX PER COW AS RELATED TO TYPE OF PASTURE, UREA TREATMENT, WEANING AGE, AND UREA-MOLASSES GRASS INTERACTION (PASTURE EXPERIMENT)

	No. of conceptions	No. of abortions	No. of calves born	Calving-rate index
Overall	2.94	.04	2.90	.72
Pastures				
1) Native	3.00	.02	2.99	.74
2) Molasses	2.82	.08	2.74	.69
3) Native + molasses	3.00	.03	2.97	.74
Urea				
None	2.96	.03	2.93	.74
Urea	2.93	.05	2.87	.72
Weaning				
3 mo	3.40	.03	3.37	.84
9 mo	2.49	.05	2.43	.60
Significant interaction				
Molasses grass with urea	2.90	.14	2.76	.65
Molasses grass without urea	2.75	.02	2.72	.69

See appendix tables 17, 18, 19, 20, 21, and 22.

TABLE 19. NUMBER OF BIRTHS AND DEATHS, CALVING-RATE AND CALF-CROP INDEXES OF CALVES RAISED[a] BETWEEN FEBRUARY 14, 1974, AND MAY 23, 1977, AND WEANED AT 3 MONTHS AND AT 9 MONTHS (PASTURE EXPERIMENT)

	Weaned at 9 mo					Weaned at 3 mo					Early/normal weaning ratios:	
Herd	Born	Died	Net	Calving-rate index	Calf-crop index	Born	Died	Net	Calving-rate index	Calf-crop index	Births early/normal	Net prod. of animals early/normal
4	70	11	59	.58	.49	18	1	17	.92	.86	1.59	1.76
5	76	6	70	.64	.58	17	6	11	.86	.57	1.34	.98
6	78	9	69	.66	.57	17	3	14	.86	.72	1.30	1.26
7	77	10	67	.65	.56	17	1	16	.86	.82	1.32	1.46
8	69	7	62	.57	.52	17	1	16	.86	.82	1.51	1.58
9	75	9	66	.63	.55	15	3	12	.77	.62	1.22	1.13

[a] Uncorrected for cow mortality; based on beginning inventories in 1972. All calf deaths included irrespective of age.

Conceptions and Abortions

The significant pasture x urea interaction term suggests that urea supplementation to cows on molasses grass pasture was more highly and positively related with conception rate than was urea supplementation to cows on other types of pasture where urea supplementation slightly decreased conceptions (table 18). However, this conception advantage of urea feeding on molasses grass was not reflected in the number of calves actually produced. The calving rate was sharply reduced by a seven-fold increase in calculated number of abortions per cow in the herd on molasses-grass that received urea as compared to those on molasses grass without urea (appendix tables 17, 18, 19, 20, 21, and 22). This was an unexpected result because studies with dairy cows have indicated no harmful effects of urea on reproduction rates (Ryder et al., 1972; Serrano, 1976). Nor have increased abortion rates been reported in other reviews on the use of urea with beef cattle in the savannas.

Although the calculation methods were indirect, and palpation data incomplete, the results indicate that there was a significant increase in the number of abortions associated with cows fed urea while on molasses grass pastures. Such increases did not occur when urea was fed to cows on native pasture. This topic merits further investigation in droughty savannas where urea is likely to be used.

Calves Raised

The percentage of calves raised attributable to the pasture treatment differed little among cows weaned at 9 months (table 20). The maximum percentage of calves raised on the molasses grass pasture was 77%, as compared to 72% raised on the native pastures. In the molasses-grass-pastured herds, the cows with urea-supplemented diets had a 6% greater calf crop at birth than did those with nonsupplemented pasture; however, this advantage dropped to 3% in terms of percentage of calves raised. Urea supplementation effects were negligible.

Cow Death Losses

Cow death losses in Herd 8 were especially heavy (34%) on the molasses grass pasture: five cows died of starvation and two cows died from urea intoxication after accidentally escaping their pasture and consuming a fatal quantity of urea (with Herd 2). In Herd 9, three cows died (one from urea intoxication). Bottles of vinegar were kept near each trough containing molasses-urea for quick administration if cows showed signs of urea toxemia. However, cows could be observed only infrequently during any given day.

Brucellosis also was a major cause for removal of animals from the experiment; however, these removals were not included in the mortality data (table 21).

None of the cows with early-weaned calves was lost.

TABLE 20. UNADJUSTED VALUES FOR CALVING-RATE INDEX AND CALF-CROP-RAISED INDEX (PASTURE EXPERIMENT)

	9-mo weaning		3-mo weaning	
	Calving-rate index	Calf-crop raised index	Calving-rate index	Calf-crop raised index
Pastures				
(P_1) Native	.62	.54	.89	.72
(P_2) Molasses	.61	.57	.89	.77
(P_3) Native + molasses	.66	.54	.82	.72
Urea				
U_1 6, 8	.61	.55	.86	.69
U_2 7, 9	.64	.56	.82	.72
Molasses grass				
U_1 8	.57	.52	.86	.82
U_2 9	.63	.55	.77	.62

TABLE 21. COW LOSSES AND CAUSES IN THE PASTURE EXPERIMENT, 1973-1977

Cause	Herd 4	5	6	7	8	9	Total
Brucellosis*	2	1	1			2	6
Starvation					5		5
Trapped in mud			2		1	1	4
Urea intoxication					2	1	3
Septicemia						1	1
Anaplasmosis, hemoparasites					1		1
Unknown					1		1
Lesion of knee	1						1
Cirrhosis of liver						1	1
Pneumonia					1		1
Total	3	1	3	0	11	6	24
*Brucellosis cows deleted	1	0	2	0	11	4	18

CALVES AND YEARLINGS

Calf Weights

Pasture treatment effects on calf weights differed little until the calves were weaned. Following weaning, all pasture-experiment calves received minerals and were pastured together on native savanna. Then, as a result of a shortage of molasses grass pasture caused by accidental burning, most of the weaned calves continued on native savanna until 18 months of age. Some calves, however, were returned to their appropriate pasture treatment (such as molasses grass alone, or molasses grass in the rainy season and native savanna in the dry season). The analysis includes all 9-month weaned calves (table 22), irrespective of pasture treatments following weaning.

Year effect at 9 months and season-of-birth effect were significant and in contrast to the findings of the mineral experiment. The calves born in the dry season weighed more at 9 months ($P < .05$) than did those born during the rainy season (table 22). The season-of-birth effect continued to be significant at 18 months of age.

Supplementation of cows with urea, molasses, and sulphur also produced heavier calves at 9 months of age ($P < .01$). After weaning, this weight difference diminished and was not significant at 18 months of age (figure 13).

Pasture effects were associated with weight differences of only 1% to 3% among calves up to 9 months of age.

Urea supplementation produced a 6% advantage in calf weights at 9 months of age, although this advantage decreased thereafter to a 3% advantage at 18 months. Figure 14 shows that most of the average differences were due to the relatively greater difference between Herd 9 (urea supplemented on molasses grass) and Herd 8 (nonsupplemented

TABLE 22. CALF WEIGHTS (ADJUSTED MEANS) AT 9 AND 18 MONTHS AS RELATED TO YEAR OF BIRTH, SEASON OF BIRTH, UREA SUPPLEMENTATION, TYPE OF PASTURE, SEX, SIRE BREED, AND MOLASSES GRASS X UREA INTERACTION (PASTURE EXPERIMENT)

Year

	9 mo, kg	18 mo, kg
1974	171	214
1975	164	184
1976	155	

Season

	9 mo, kg	18 mo, kg
Dry	174	211
Early wet	154	195
Late wet	162	189

Urea

	9 mo, kg	18 mo, kg
None	159	196
Urea	168	201

Pastures

	9 mo, kg	18 mo, kg
Native	164	186
Molasses	161	208
Native/molasses	165	202

Sex

	9 mo, kg	18 mo, kg
Male	169	205
Female	158	192

Sire breed

	9 mo, kg	18 mo, kg
Zebu	160	194
San Martinero	167	204

Significant interaction

		9 mo, kg
Molasses grass without urea	P<.01	150
Molasses grass with urea		172

See details in appendix tables 23, 24, and 25.

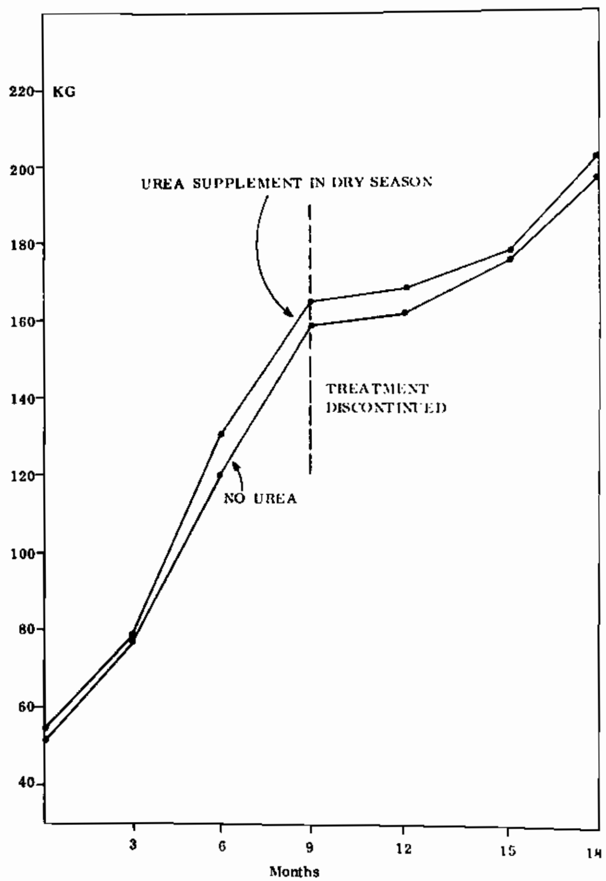


Figure 13. Relationship of urea supplementation in dry season to weights of calves weaned at 9 months (pasture experiment).

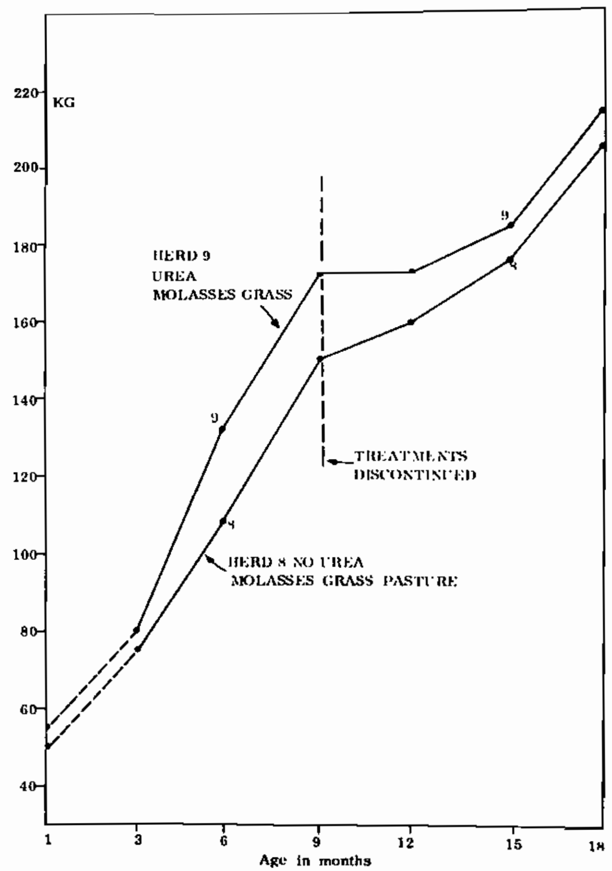


Figure 14. Relationship of calf weights to urea supplementation of cows on molasses grass (pasture experiment).

on molasses grass). The 22 kg advantage for the herd with urea supplementation represented a 15% increase over the nonsupplemented herd (P .05).

The lack of new growth and the maturity of the molasses grass pasture during the dry season seriously affected the performance of cattle on molasses grass without urea. In contrast, the cattle on the native pastures were grazing lowland, which ordinarily flooded during the rainy season but became accessible during the dry season. These lowlands were burned in February when water had receded, and several species of native forage plants showed rapid new growth.

In contrast, the species growing on the uplands (such as molasses grass) became very mature, fibrous, and low in nutritional value during the dry season. The relative lack of response of calves from urea-supplemented cows on the native lowland during the dry season reflected the opportunity for these cows to graze selectively and thus better meet protein and other requirements.

Calves born in the dry season gained more than calves born in the late-wet periods (table 22). However, the differences due to the interaction of season-of-birth effects with pasture effects were significant only for calf weights at 18 months.

Bull calves were heavier than heifers with differences ranging from 3% to 9% and a 7% advantage at 18 months of age (figure 15).

The magnitude of calf-weight differences associated with breed of sire also was not as great as that in the mineral experiment; the advantage of San Martinero sires ranged from 3% for 3-month-old calves to 5% for 18-month-old calves (figure 16). Zebus sired 53% of the calves, San Martineros, 47% (table 23). Starvation was the greatest cause of calf death loss (table 24). Table 25 shows the distribution of loss by pastures and weaning treatments.

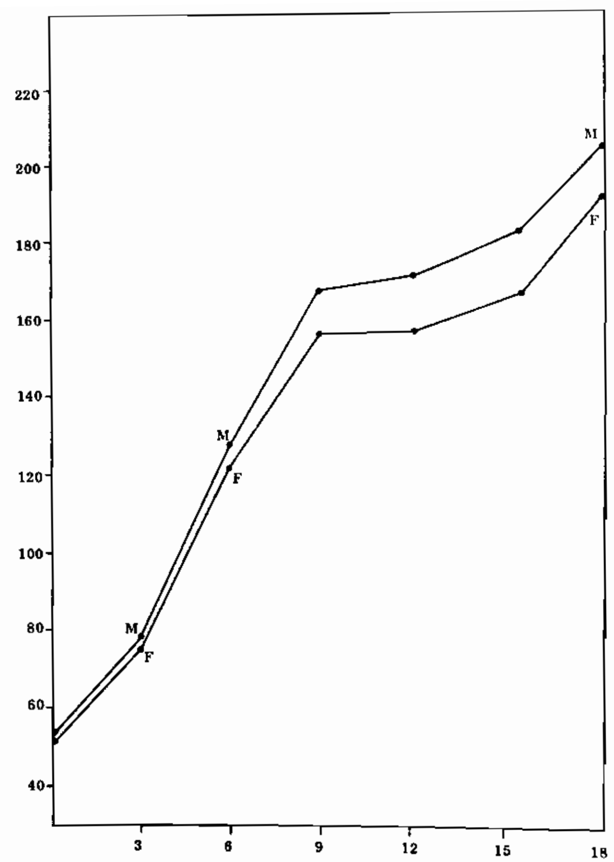


Figure 15. Weight comparisons of male (M) calves vs female (F) calves weaned at 9 months (pasture experiment).

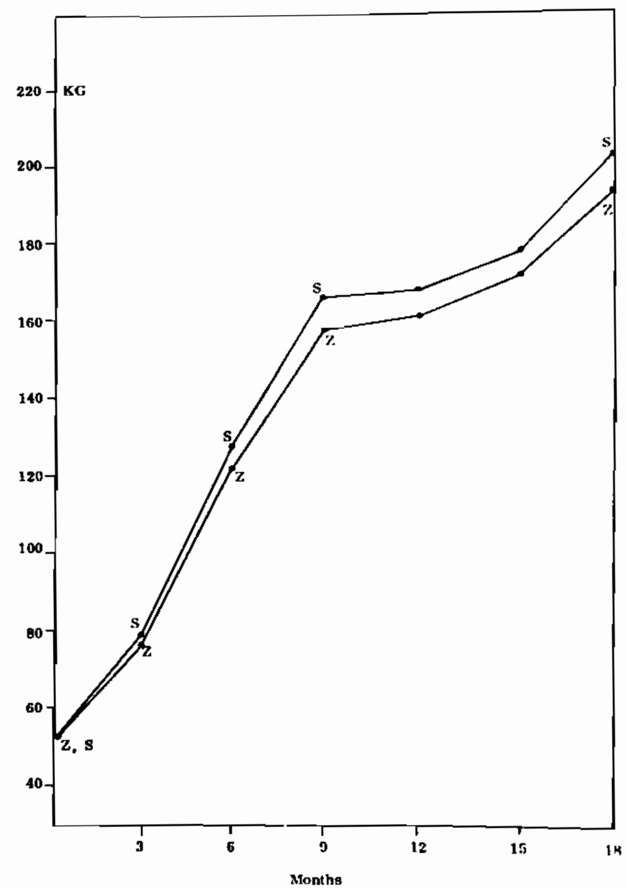


Figure 16. Effect of San Martinero (S) sires vs Zebu (Z) sires on weights of calves weaned at 9 months (pasture experiment).

TABLE 23. NUMBER AND PERCENTAGE OF CALVES SIRED BY ZEBU BULLS VS SAN MARTINERO BULLS

	Herd		Zebu-sired calves	San Martinero-sired calves	Total no.
Native pasture + minerals	4-5	(no.)	71*	43	114
		(%)	62.3	37.7	
Native pasture + molasses grass + minerals	6-7	(no.)	60	64	124
		(%)	43.4	51.6	
Molasses grass + minerals	8-9	(no.)	63	63	126
		(%)	50	50	
Total		(no.)	194	170	364
		(%)	53.3	46.7	100

Source: Gomez, S. J. et al., 1982.
* P < .05.

TABLE 24. CAUSES OF DEATH OR REMOVAL OF CALVES AND YEARLINGS BY HERD (ALL HERDS) (PASTURE EXPERIMENT)

Cause of death	Herds 4	5	6	7	8	9	Total no.
Starvation	1	5	1	1	1	2	11
Asphyxiation					1	1	2
Lost				1			1
Dead at birth no explanation			1				1
Poison (urea or other)		1		1	1		3
Various reasons noted		2	1	1	1		5
Pneumonia	1				1		2
Accidents			3		1	2	6
Fractures		1	1				2
Unknown	8	3	5	7	2	5	30
Total	10	12	12	11	8	10	63

TABLE 25. NUMBER AND PERCENTAGE OF DEAD CALVES, BY HERD, AGE WEANED, AND AGE AT DEATH (PASTURE EXPERIMENT)

Herd	Calves born, no.	Calves dead, no.	Calves dead, %	Days of age at death: At birth, no.		0–30 no.		30–90 no.		90–270 no.		270–545 no.	
				9-mo weaning									
4	70	11	16	1		7		2				1	
5	76	7	8	0		3		2				2	
6	78	9	12	2		3		2				2	
7	77	10	13	2		1		2		2		3	
8	69	7	10	2		0		2		3		0	
9	75	9	12	2		5				2		0	
	445	53	(12)	9	(2%)	19	(4%)	10	(2%)	7	(2%)	8	(2%)
				3-mo weaning									
4	18	1	6	0		0		0		1		0	
5	17	6	35	0		2		0		2		2	
6	17	3	18	0		0		0		1		2	
7	17	1	6	0		0		0		1		0	
8	17	1	6	0		0		0		1		0	
9	15	3	20	0		0		1		1		1	
	101	15	(15)	0	(0%)	2	(2%)	1	(1%)	7	(7%)	5	(5%)

Chapter V

Five-Year Production of Live Weight in the Nine Herds--A Hypothetical Commercial Ranch Analysis

In the previous chapters, the analyses of treatment effects used adjusted values based upon least-squares means, and sufficient data were available for making statistically valid conclusions. However, in a commercial ranch operation, decisions would be based on the actual beef output from the various management systems as represented in each herd. That is, the ranch manager would be looking at an unadjusted balance sheet of actual live-weight production from the herds.

The intent of this section is to approximate the rancher's analysis--making no adjustments to the data and without isolating the within-herd treatments effects (i.e., the effects of early weaning of five cows and crossbreeding with San Martinero bulls).

The gross production of live-weight beef per herd at Carimagua is shown in table 26. For comparative purposes, Carimagua data may be compared with information from the Fondo Ganadero (Meta) related to the commercial production of leased herds in the Llanos. As a working rule of thumb, the Fondo Ganadero expects a doubling of the net weight produced per herd within a 5-year period. Although results at Carimagua are not exactly comparable, weights were approximately doubled in Herd 1, the low-input (control) herd.

TABLE 26. LIVE-WEIGHT BEEF PRODUCED PER HERD, 1972-1977[a]

Herd	M[b]	U[b]	Calves no.	Calves kg	Stockers no.	Stockers kg	Cows, 1977 no.	Cows, 1977 kg	Heifers, 1972 no.	Heifers, 1972 kg	Net wt produced per herd, kg	Wt ratio relative to Herd 3
1	1	1	10	1185	21	4066	24	7363	34	6468	6146	.75
2	1	2	27	2883	20	3197	31	9900	34	6606	9374	1.14
3	1	1	21	2124	27	4280	27	8378	35	6574	8208	1.00
4	2	2	32	4235	43	7852	32	11402	34	6467	17022	2.07
5	2	1	38	4317	38	7228	33	10862	33	6408	15999	1.95
6	2	1	30	3456	51	10248	33	10389	35	6709	17384	2.12
7	2	2	36	4929	45	9044	35	11858	34	6486	19345	2.36
8	2	1	28	3064	49	10032	25	7458	36	7013	13541	1.65
9	2	2	28	3699	48	10651	32	10277	37	7093	17534	2.14

[a]Includes live weight of all cows and calves in herds May 1977 and 18-month weights of stockers leaving the experiment, less initial 1972 weights of breeding heifers entering the experiment.
[b]M = minerals, U = urea. Not fed = 1, fed = 2.
Mineral effect (M) = 7720 kg/herd
Urea effect (U) = 2036 kg/herd
Urea effect on molasses grass only = 3993 kg/herd

Table 26 lists the numbers and weights of all calves below 18 months of age at the end of the experiment in May 1977. Weights of all cows as of May 1977 were added to the calf weights. The weights of the stockers (postweaned cattle) were added when they were removed from the experiment at 18 months of age. The weights of the original heifers when they entered the experiment in May 1972 were then subtracted from these combined sums. Slight discrepancies in numbers are due to animals that were missing on the days when the herds were weighed.

The control herd performed poorly overall, and its cow survival rates were low, largely because of bone fractures. Bone fractures generally occurred when the cattle were being worked in the corrals and squeeze chute. Also, the total number of calves produced in Herd 1 was much lower than that of other herds, including the other nonmineral supplemented herds.

Interestingly, the average weight of stockers at 18 months was 194 kg in Herd 1 as compared to 159 kg in the other nonmineral supplemented herds. Natural weaning may not have occurred until the calves were 12 to 14 months of age, thus explaining the extra weight.

Herd 3, which received no mineral or urea supplement, also is useful for comparative purposes because it is representative of a number of herds under low-investment management in the Llanos. Except for Herd 8, a low-producing herd, all mineral-supplemented herds produced twice as much beef as did Herd 3. These ratios are shown in table 26. Herd 7 was the most productive, yielding 2.36 times as much beef as did Herd 3. Herd 7 received mineral and urea supplementation and was grazed on native pasture in the dry season and molasses grass pasture in the rainy season.

The total mineral effect per herd was 7,720 kg body weight (Herd 3 vs Herd 4), which could be attributed to an estimated mineral consumption of about 3,470 kg during the 5 years. Approximately 2.2 kg of beef were produced per kg of salt-mineral mix consumed (or, omitting the 47% salt, 4.2 kg of beef were produced per kg of mineral). On a market basis, the cost:benefit ratio could be as much as 1:20.

The total urea-supplementation effect per herd was associated with an additional 2,036 kg body weight per herd. Over the 4 years of urea supplementation, the total seasonal consumption per herd was estimated at approximately 5,170 kg of molasses, 820 kg of urea, and 82 kg of sulphur. The cost:benefit ratio could be as much as 1:4. The greatest response to urea supplementation was on continuously grazed molasses grass pasture, where an additional 3,993 kg live weight were produced as a result of urea supplementation in Herd 9.

Primarily as a result of heavy cow losses, Herd 8 (on molasses grass continuously, without urea) did not perform as well as did herds on all other mineral-supplemented pastures.

Chapter VI

Discussion and Conclusions

MINERAL SUPPLEMENTATION

The Carimagua experiments emphasize that mineral feeding is biologically advantageous and could be an economically sound practice.

Lack of minerals was strongly associated with a reduced calf crop. Mineral supplementation increased calving rate from 43% to 61% and calf crop from 31% to 61% (table 8). The 27% loss of calves from birth to 18 months in nonmineral-fed herds was more than double the 12% death loss in mineral-fed herds (table 12). Indications were strong that nonmineral-fed cows did not maintain their pregnancies as well, and that their low calving rate was more closely related to abortion losses than to conception failure. (Palpation at every weigh period could have identified such abortions; however, this was not done in this experiment.)

About 14% of the cows in the nonmineral-fed herds on native pasture were lost in the 5 years, whereas only 1% were lost in mineral-fed herds (table 10). Thus, the nonmineral-fed herds could scarcely reproduce and maintain themselves. (However, free-roaming cows that were not fed minerals could have a greater opportunity to obtain their mineral needs in bones, etc.)

Weight gains were markedly increased by mineral supplementation. Cows receiving minerals on native pastures weighed 9% more than those that received only salt (table 4); mineral supplemented calves weighed 29% more at 9 months of age (table 11). Calves in the control herd (Herd 1), which were weaned naturally by their mothers, weighed about the same as did calves in mineral-fed groups at 18 months. (Dr. Juvenal Gomez, long-term manager of the project at Carimagua, observed that the cows permitted the calves to nurse until they were 12 to 14 months of age, which could explain the good weights of their calves.)

Herds that received the complete mineral supplement produced approximately twice as much live weight gain as the herds that received only salt (table 26). Mineral supplementation increased annual beef production per animal unit from 51 kg to 84 kg (table 28).

MOLASSES GRASS PASTURE VS NATIVE PASTURE

In contrast to their failure to use minerals in the Llanos, many ranchers had sought to improve pastures by the establishment of at least small areas of introduced grasses--primarily Brachiaria decumbens and molasses grass (Melinis minutiflora). As indicated in this experiment, molasses grass pastures provided little improvement in individual animal performance. Although much higher productivity per hectare can be obtained with molasses grass pastures, existing pastures often are understocked and producers have little economic incentive to establish molasses grass pastures. Strategic use of improved, legume-based, pasture/protein banks to alleviate dry-season forage deficiencies could offer potential for improvement in both animal productivity and yields/hectare (CIAT, 1981).

The failure of molasses grass pasture to sustain the herd during the dry season was not anticipated at the beginning of the experiment. However, ranchers in the area often commented upon the poor performance of molasses grass pasture in the dry season. The urea supplementation of molasses grass pastures overcame the problem of weight loss, an effect that also has been observed in dry-season pastures in tropical savanna regions in Africa and Australia.

The urea supplementation of molasses grass was accompanied by a significant increase in abortions as compared to relatively few abortions in cows on native pastures. Such an effect had not been reported in the literature; however, feeding of urea in this experiment was managed very differently from that reported for dairy herds. Cows in molasses grass pastures tended to consume the molasses-urea solution much more rapidly than did those on the native pastures. More water was added to the solution to repress consumption; however, a marginally toxic urea level may have occurred that could have contributed to the higher abortion rate in the herd on molasses grass.

The low response to urea supplementation on native pastures was attributed to the availability of fresh pasture from lowlands that were burned in early February; that is, protein shortages were not so critical if cattle could graze these lowland bajos during the dry season. Blydenstein (1972) indicated that the variation in species and the fresh growth after such burning in the dry season could account for a relatively high level of performance on these native lowland pastures (particularly when contrasted to the failure of molasses grass). During the rainy season, however, this effect was reversed; the young, growing cattle (such as the calves and the heifers in the first year of the experiment) grew at a considerably faster rate when on molasses grass pasture than when on native savanna pasture.

It seems probable that other improved pastures, such as Brachiaria, would have produced different results, primarily because of its fire resistance. In the steer-grazing trials at Carimagua (CIAT, 1975), the herds on Brachiaria consistently showed less weight loss in the dry season than did those on molasses grass and upland native grass.

However, in the rainy seasons, animals on the molasses grass performed comparatively well and the grass was valuable in repressing tick infestation. The carrying capacity per hectare was greatly increased with molasses grass, even though the cows were allowed twice as much molasses grass pasture in the dry season as in the rainy season. During the dry season, irrespective of the availability of molasses grass, the cattle required native lowland pastures or some form of supplementation for satisfactory performance.

In Australia, Holroyd et al. (1977) observed that cattle grazing urea-supplemented native pasture had provided approximately the same reproductive performance as did those on legume-mixed pastures that incorporated Townsville stylo with native pasture. In the absence of urea supplementation, however, pregnancy rates dropped greatly in the native pasture--but to a much smaller degree in the Townsville (Stylosanthes humilis) stylo-mixed pastures. They also reported that cows on Townsville-based pastures had better body condition than did those on native pasture. However, the Australian experiment dealt only with lactating cows, thus differed substantially from the Carimagua experiment where comparatively few cows were lactating.

SEASONAL EFFECTS AND PASTURES

Cows continued to do well on the limited lowland native pasture available in the dry season.

Cows on improved upland pasture of molasses grass showed drastically reduced weights when kept on this pasture during dry season without urea supplementation. However, with urea supplementation, the calves of the supplemented cows had slightly greater body weights than did all others.

Cows on native pastures reached their lowest weights in the rainy season (August) and gained most rapidly during the late rainy season (independent of lactation stage).

In the Casanare, another area of the Llanos, relatively more lowland is available during the dry season, and the dry season is said to be more productive than the wet season. The abundant lowlands cannot be grazed during the flood season, and it is the period of greatest nutritional stress for the cattle because upland areas are too limited on many Casanare ranches.

Considerable progress has been made in the CIAT and ICA forage programs. The introduced African grass Andropogon gayanus appears to have considerably greater potential for the uplands than does the molasses grass or the Brachiaria decumbens. Its advantages are higher production and resistance to fire and disease. The legume possibilities also have greatly improved over those available in 1972 (CIAT, 1981). Some promising species/combinations, particularly to alleviate dry-season forage deficiencies, are Andropogon gayanus/Stylosanthes capitata, and Pueraria phaseoloides as a dry-season protein bank. Even a seasonal production of abundant high-quality pasture during peak lactation might overcome the lactational stress that prevents lactating cows from rebreeding.

At 9 months of age and continuing through 18 months of age, highest weights were noted for calves born in the dry season, followed by those born in the first half of the rainy season. Calves born in the second half of the rainy seasons had the lowest weights.

Dry-season calving had a 7% to 10% weight advantage (tables 11 and 22) at 18 months and could possibly be exploited with seasonal breeding, if calving intervals of approximately one year could be attained. However, with the current estimated calving interval of 526 days, the succeeding calf would be born at the worst time for achieving maximum body weight.

CROSSBREEDING

A considerably higher level of heterosis or hybrid vigor was indicated in the mineral experiment (half of the animals received only salt) as compared with that in the pasture experiment (all animals received minerals). The comparative weight advantage of the crossbred animals at 18 months was 10% in the mineral experiment vs 5% in the pasture experiment. This difference was attributed to greater heterosis under conditions of greater stress, such as that produced in the salt-only herds in the mineral experiment. At all ages, the crossbred calves were heavier than their grade Zebu herdmates.

These experimental results do not support the practices generally used in the region. For many years, the objective of cattle producers in the Llanos has been to decrease the percentage relationship of their cattle to the Spanish Criollo and to increase the relationship to the Indian breeds, primarily the American Brahman. Despite this effort, the Criollo influence remains apparent in many regions of the Llanos, particularly the Casanare region north of the Meta River.

Until recent years, the level of hybrid vigor or heterosis obtained by crossing the Criollo type to the Zebu type could be easily observed, thus encouraging the widespread introduction of Brahman and other Zebu breeds to the region. Apparently, however, the almost exclusive use of Zebu bulls has now outlived its logical basis. The level of grading to the Zebu has progressed so far that little heterosis occurs. Most herds could probably benefit from back-crossing to Criollo bulls such as those represented by the San Martinero in this study. Currently, this back-crossing is probably the most acceptable and least expensive of all management techniques that could increase heterosis and productivity. These conditions could change rapidly if the demand for Criollo bulls were to increase their prices--only a few herds of purebred Criollo cattle remain in the country.

Results of experimentation in Colombia, Venezuela, and Costa Rica have confirmed that a high level of heterosis is obtained between crosses of Criollo and Zebu breeds.

EARLY WEANING

Early-weaning results provided an unexpected breakthrough in understanding reproduction failures in the Llanos, providing evidence that nutrient intake is inadequate to permit the Zebu cow to regularly rebreed during the stress of lactation, even with minerals and seasonally good pasture (molasses grass). If the Zebu cow does not regularly rebreed during early lactation, her calving intervals are lengthened and the calf crop is lowered. If their calves are weaned early, Llanos cows of Zebu breeding have the potential to reproduce at a level as high as that of Zebu cows in the best pasture regions of any area of the country. Thus, lactation stress is again indicated as the major constraint to high calving rates in the Llanos.

Experimental observations were limited for early-weaning data because only five cows in each herd were allocated to the early-weaning treatment; as a result, only ten cows were in the nonmineral, early-weaning group. Although statistical significance was obtained, the group was small for development of generalizations. However, supporting data were obtained in a related experiment carried out with the _Caja Agraria_ in which early-weaned cows from commercial ranches were found to rebreed shortly after weaning (CIAT, 1975).

Early-weaned calves at Carimagua were separated from the experimental treatments at 3 months of age. Although pasture and forage conditions varied considerably between years, the concentrate ration was uniform. Thus, although data on growth of early-weaned calves are obviously not directly comparable with those of the major treatments, the weights obtained at Carimagua can be compared (figures 17 and 18). By 18 months of age, 3-month-weaned calves (all of which received minerals after 3 months) weighed almost as much as did 9-month-weaned calves that did not receive minerals (figure 17). However, with mineral supplementation (figure 18), the 9-month weaned calves had a substantial weight advantage over the early-weaned calves at 18 months of age. Also, 9-month weaned calves were considerably heavier than 3-month weaned calves (figure 19) in the pasture experiment.

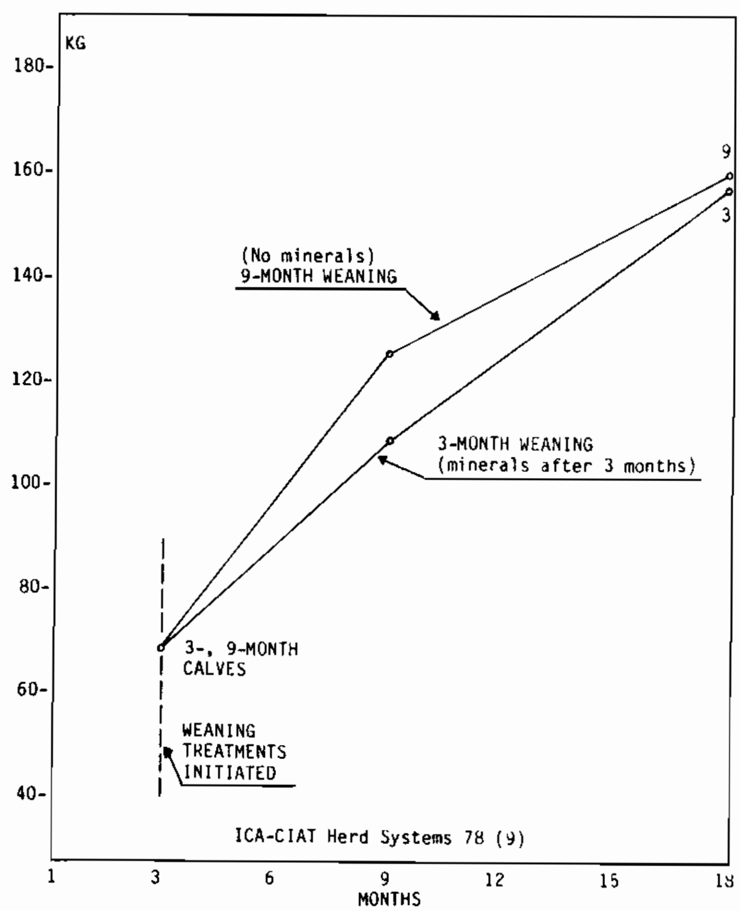


Figure 17. Effect of 3-month vs 9-month weaning on calf weights in Herds 2 and 3, without minerals (mineral experiment).

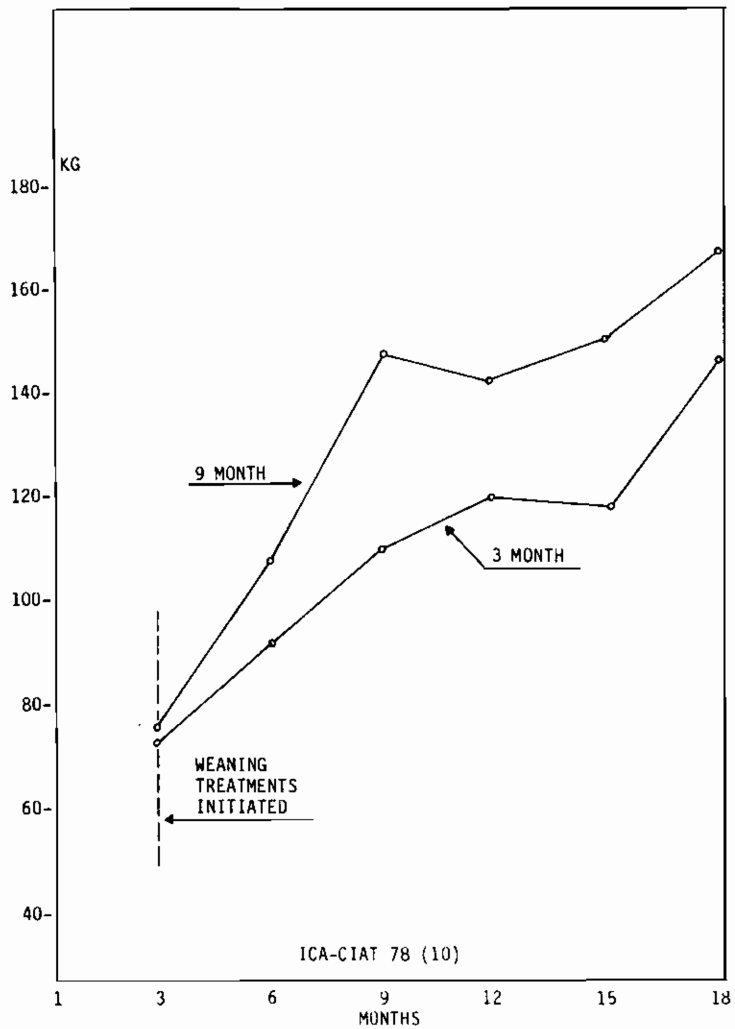


Figure 18. **Effect of 3-month vs 9-month weaning on calf weights in Herds 4 and 5 with minerals (mineral experiment).**

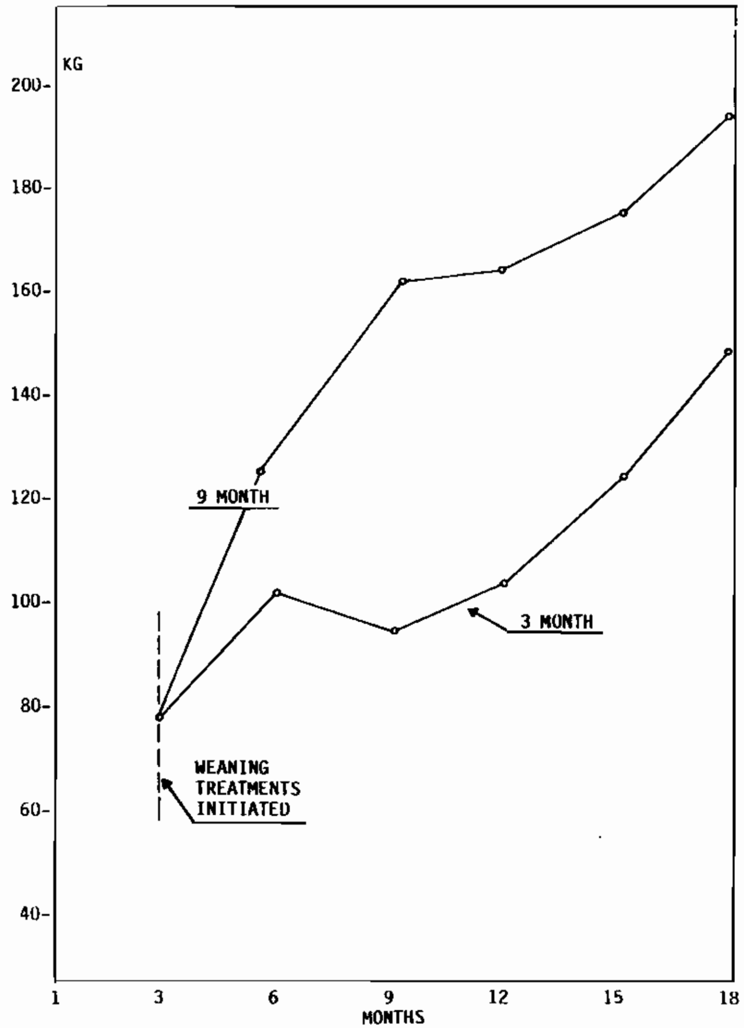


Figure 19. **Effect of 3-month vs 9-month weaning on calf weights (pasture experiment).**

TOTAL BEEF PRODUCTION ESTIMATED FOR COMBINATIONS OF MINERALS AND WEANING TREATMENTS

If the herd data for the Carimagua experiments are accumulated, total beef production can be estimated relative to combinations of mineral and weaning treatments. This differs from the herd summaries in Chapter V in that the main effects of minerals and early weaning on total beef production are presented. Using the parameters that had been developed in the study (table 27) the synthesis is shown in table 28. These data sum the increase in calving rate, the decrease in mortality of cows and calves, and the weight changes associated with addition of minerals, early weaning, or both. Herds 2 and 3, the nonmineral herds representing unimproved systems of cattle production in the Llanos, are used as the base herds for all comparisons.

A commonly accepted extraction rate for the Llanos Orientales is 11% (FAO-based values). At this rate few if any heifers can be sold if the herd is to be maintained; surviving old cows would be included in extraction rate when sold.

The percentage calf crop at birth estimated from the Fondo Ganadero study of 40 Llanos farms was higher than that observed in Herds 2 and 3. Estimates of death losses in Fondo herds were not available. The body weights of the calves at 18 months in the Carimagua experiment indicated that these cattle had grown at least as well as the original heifers that were purchased in 1972. Thus, there are indications that the base herds were reasonably representative of many herds in the Llanos at that time.

Table 28 shows kilograms of live weight produced per cow, including the cows' gains as well as death losses. Also shown are the live weights of calves at different ages; it was assumed that these calves could be sold or placed on contract at 3 months of age, 9 months of age, or 18 months of age.

TABLE 27. PARAMETERS ON MINERALS AND WEANING USED TO COMPARE PRODUCTION IN TABLE 28

	Herds 2, 3, nonmineral				Herds 4, 5, 6, 7, 8, 9, minerals			
Weaning	3 mo[a]		9 mo		3 mo		9 mo	
Calving index, %	75		43		88		64	
Mortality, %								
3 mo	11		22		3		8	
9 mo	13		26		10		10	
18 mo	23		27		15		12	
Raised, %[b]								
3 mo	67		34		85		59	
9 mo	65		32		79		58	
18 mo	58		31		75		56	
Cow mortality, %	0		16		0		12	
Calf weights, kg								
3 mo	66		68		78		81	
9 mo	112		129		112		163	
18 mo	151		160		151		199	
Cow numbers & weights, kg	no.	$\bar{x}$	no.	$\bar{x}$	no.	$\bar{x}$	no.	$\bar{x}$
1977	10	299	50	318	30	332	160	306
1972	10	178	60	178	30	178	180	178
5-year gain		121		140		154		128
Cow gain/year, kg[c]		24		18		31		19

[a]All early-weaned calves received minerals following 3 mo of age.
[b]Due to termination of experiment, death loss is underestimated.
[c]Adjusted for mortality.

TABLE 28. ANNUAL LIVE WEIGHT BEEF PRODUCTION (KG) PER COW AND ANIMAL UNIT (AU) FOR CALVES AT 3 MONTHS, 9 MONTHS, AND 18 MONTHS, AS RELATED TO MINERALS FED AND AGE AT WEANING

3-mo weaning

	Calves at 3 mo				Calves at 9 mo				Calves at 18 mo			
Minerals (M)	M_2		M_1		M_2		M_1		M_2		M_1	
Kg wt/cow and (ratio)	97	(1.43)	68	(1.00)	119	(1.75)	97	(1.43)	144	(2.12)	112	(1.65)
Kg/AU[a] and (ratio)	92	(1.80)	64	(1.25)	96	(1.88)	80	(1.57)	86	(1.67)	71	(1.39)
Animal units	No.	AU	No.	AU	No.	AU	No.	AU	No.	AU	No.	AU
Cows	100	100	100	100	100	100	100	100	100	100	100	100
Calves	-	-	-	-	76	19	65	16	76	19	65	16
Yearlings	-	-	-	-	-	-	-	-	71	43	58	35
Bulls	4	6	4	6	4	6	4	6	4	6	4	6
Total	104	106	104	106	180	125	169	122	251	168	227	157

9-mo weaning

	Calves at 9 mo M_2		Calves at 9 mo M_1		Calves at 18 mo M_2		Calves at 18 mo M_1	
Kg wt/cow and (ratio)	114	(1.68)	59	(.87)	130	(1.91)	68[b]	(1.00)
Kg/AU[a] and (ratio)	95	(1.86)	52	(1.01)	84	(1.65)	51[b]	(1.00)
Animal units	No.	AU	No.	AU	No.	AU	No.	AU
Cows	100	100	100	100	100	100	100	100
Calves	58	14	33	8	58	14	33	8
Yearlings	-	-	-	-	56	34	32	19
Bulls	4	6	4	6	4	6	4	6
Total	162	120	137	114	218	154	169	133

[a] Animal units (AU): Cow or cow with calf under 3 mo = 1 AU. Calf, 3-9 mo = .5 AU. Yearling 9-18 mo = .8 AU. Bull = 1.5 AU.

Example: Calculate annual production of weight produced per cow and per animal unit with a system of 9-mo weaning and salt only. Carry calves to 18 mo and include cow weight changes.

Given: Calf weight @ 18 mo = 160 kg
Percentage raised = 31
Cow gain = 18 kg
Animal units in the herd = 133

Thus: 160 kg x .31 = 50; 50 + 18 = 68 kg per cow; (68 x 100 cows) ÷ 133 animal units = 51 kg per animal unit.

[b] Ratios calculated relative to this value.

Comparisons were made between cattle herds that received minerals vs those that did not receive minerals, as well as between herds in which all cattle theoretically were weaned at 3 months vs herds with all cattle weaned at 9 months. All ratios of production were computed based on Herds 2 and 3 (which had normal weaning at 9 months and did not receive mineral supplements) with calves sold as stockers at 18 months of age. This low-input system produced 68 kg of body weight per cow-year and 51 kg per animal unit. In such herds, for each 100 cows, there would be a total of 169 animals (equivalent to 133 animal units). Use of the same system and selling the calves at 9 months would produce even less beef per cow and about the same per animal unit (figure 20).

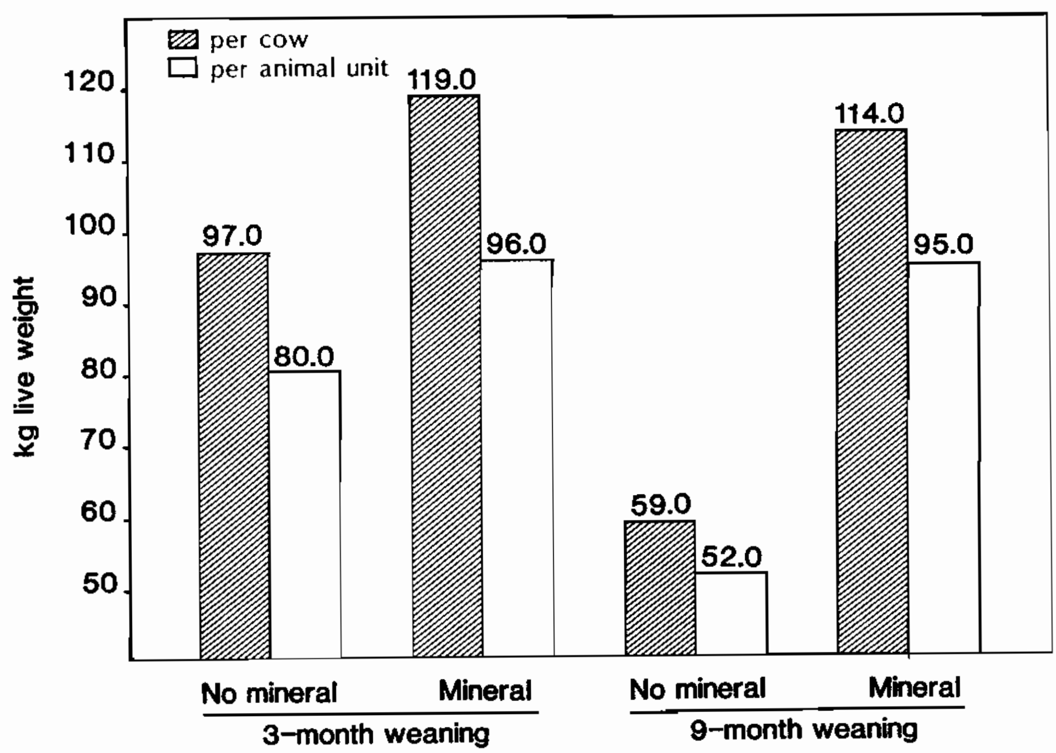


Figure 20. Annual live weight beef production per cow and per animal unit when calf production is measured at a calf age of 9 months (includes cow weight changes). Data from table 28.

In each of these comparisons, mineral feeding was shown to greatly increase the beef produced per cow and per animal unit over that produced when minerals were not fed. The system of mineral supplementation, early weaning, and selling stockers at 18 months produced the most beef per cow-year. The most beef per animal unit was obtained by selling at 9 months, with the calves receiving mineral supplementation and 3-month weaning.

Three-month weaning systems would require intensive management as is done in the early weaning of dairy calves. However, a 3-month beef calf weaned directly from its dam differs greatly from a 3-month dairy calf that has been on a dairy calf regime, with the beef calf obviously heavier and stronger.

Palmira Comparison

Although not directly a part of the Carimagua herd-system project, an experiment was done at Palmira with 3-month weaned calves from three Llanos ranches, with the assistance of the Caja Agraria (CIAT, 1975, 1976). In this experiment, 12 calves on star grass (Cynodon nlemfuensis) (either with or without concentrates), equalled growth rates of the normally weaned calves on minerals in the Carimagua experiment. Those on other regimes at Palmira weighed about the same as did the average of the 3- and 9-month-weaned calves in the mineral experiment at Carimagua (figures 19 and 21). These steers were grazed on legume-based pastures and were sold weighing 450 kg at age 33 months (B. Grof and E. Concha F., private communication, 1978). Death losses in this experiment were 6% (to age 9 months).

In the Brazilian Cerrado (CIAT, 1980), calves were weaned successfully at 3 months, without concentrates, by putting the calves directly onto a grass-legume pasture of A. gayanus + S. guianensis. When they reached 1 year of

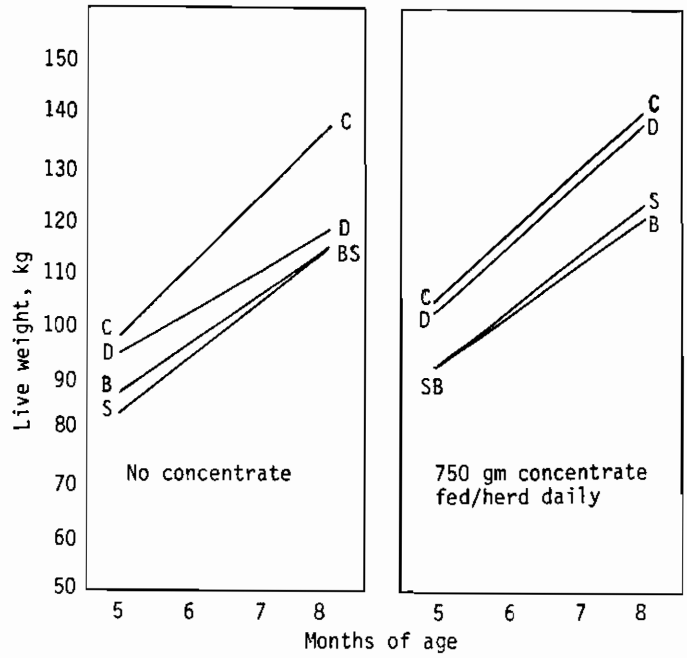


Figure 21. Weights of early-weaned calves from CIAT (Palmira) ranches at 5 and 8 months of age. C = Cynodon nlemfuensis pasture, B = Brachiaria mutica pasture, S = Stylosanthes guianensis green cut, D = Desmodium distortum green cut. (Calves were transported to CIAT at Palmira when early weaned and randomized by weight to treatments around 3 months of age.)

age, the 3-month-weaned calves were only 12 kg lighter than those weaned at 5 months. With a 90-day mating period on molasses grass pasture, 92% of the 3-month-weaned dams conceived vs 65% of the 5-month-weaned dams. Thus, as at Carimagua, a high conception rate was associated with early weaning.

An example of early weaning on a large scale is that practiced by Carlos Schenstrom in the Beni region of eastern Bolivia (Schenstrom, personal communication). The calves' diets included concentrates only until they were about 4 to 5 months of age, then the calves were put on a pasture-only diet. In 1979, Schenstrom had early weaned and raised 700 calves in one season. The calving rate was said to have been doubled by early weaning.

Additional labor costs are required in raising early-weaned calves. Although not estimated here, such costs would be highly variable, depending on the cost of labor, size, organization, etc., of the early-weaning system. In the Palmira experiment, an average of 42 kg of concentrate was fed to the early-weaned calves over a period of 56 days. A take-off was achieved of almost 1 kg of calf weight for 1 kg of concentrate and unlimited pasture.

Results at Carimagua indicate that use of minerals and early weaning can improve reproduction rates to a level approaching one calf per cow per year on native pastures of the eastern Llanos. Achievement of such reproductive levels with 9-month weaning requires the best pastures of the country. When on excellent pastures, cows normally rebreed while lactating, have high annual reproductive rates (but generally not above 70% to 80%) without early weaning, and may have nutrient intake in excess of need. These better pastures, however, have alternative uses, including fattening or milk production. Even more productive use could be made of such pastures if 1) there were more breeding cows in the Llanos, 2) their progeny were moved at younger ages to the better growing and fattening areas, and 3) there were fewer stockers in the Llanos. These concepts suggest the benefit of more extensive research on the topic of earlier weaning.

RESEARCH CONSIDERATIONS FOR THE FUTURE

The Herd Systems Project at Carimagua was designed and implemented on a scale sufficient to provide statistical reliability for results from treatments, even with rather small magnitudes of differences (about 5%). Substantial amounts of statistically reliable information were obtained in only 5 years. The study was limited, however, because an analysis was not made over a cow's complete lifetime. An average of only 2.7 calves was produced per cow; thus over one-third of the data on calving rates was from first calves. Inclusion of first-calf data undoubtedly produced an underestimation of effects of early weaning and mineral feeding over a cow's lifetime.

Thus, continuation of certain phases of the experiment could have provided a more realistic view of life cycle performance. Long-term performance is affected by such treatments and is, of course, an ultimate economic aspect of cattle production. Although all grazing experiments obviously cannot be run 10 or more years with a breeding herd, the Carimagua findings indicate that some such studies could be fruitful.

Pasture evaluation can be greatly enhanced by rate-of-gain and carrying-capacity grazing trials with steers. However, steer weight gains have limited use as direct indicators of nutritional requirements of cows for satisfactory lifetime reproductive performance. Since reproductive performance is the overwhelming determinant of animal productivity, the definitive test of pasture systems for this cattle breeding region must be with breeding herds.

There is a distinct difference between the expense of long-term livestock research and laboratory-oriented research. The net cost of life-cycle cattle experiments is basically the cost of the professional staff involved. Because of high value of product received from cattle-raising experiments, the original-data costs may be less than in the nutrition or physiology laboratory, or in the small-animal laboratory. Capital investment in land and cattle is similar for research and commercial use. Thus, transferring a cattle operation from commercial to research use, or vice versa, should have only minimal negative effect on the productivity of the capital investment.

RECOMMENDATIONS

Early weaning: As improved pastures are developed, systems should be tested for their use with early-weaned calves, with and without concentrate supplementation. Use of local supplies of concentrates should be studied, preferably those with little use for direct human consumption.

Research is needed on how replacement heifers might be produced for Llanos breeding herds under early-weaning systems.

Breeding season: If a calving interval of approximately 12 months can be obtained, breeding-season research becomes highly desirable. As indicated at Carimagua, weights of calves born in dry season exceeded weights of others by as much as 10%.

Animal breeding: Testing of the most promising adapted crossbred cows should be a fruitful area for research. The Zebu cow is generally considered to be a low-fertility cow, as compared to the Criollo breeds. Therefore, a range of cow genotypes should be explored on extensive facilities such as those at Carimagua. Such facilities should be used in the genetic improvement of the breeds well adapted for tropical savannas and(or) in the introduction of promising breeds. At Carimagua, conditions would be favorable for such important long-term endeavors. The environment is typical of many tropical savannas, and sufficient pasture land is available for developing large herds that also could be used in grazing and nutrition trials. Further, several Criollo breeds have been maintained in Colombia, and Indian (*Bos indicus*) breeds also are available.

Highly competent professionals are on hand in Colombia to conduct research like that conducted by the Roman Hruska U.S. Meat Animal Research Center in Nebraska. Continuity should be assured by providing adequate financial support for the required professional researchers.

Pastures and forages: Continued research is needed to develop improved pasture systems for early-weaned calves. Reserve pasture systems to provide supplemental protein and energy during the dry season may lead to a nutritional basis for annual reproduction without early weaning. Since costs of pasture establishment are high, particular emphasis should be placed on supplemental pasture forage needed during the dry season for critical phases of the life cycle, i. e., weaned calves, lactating cows, and fattening animals nearing market weight.

Mineral nutrition: Research is needed to determine the mineral deficiencies and antagonisms in grazed forages in representative areas of oxisol/ultisol soil regions. Whereas phosphorus deficiency is readily apparent and understood, deficiencies of other macro minerals and trace minerals, e.g., sulfur and selenium, as well as antagonisms with other minerals, are inadequately defined. Field observations strongly indicate that deficiencies and imbalances are causes of physiological and nutritional disorders that reduce productivity and livability.

Economics: Economic studies of beef systems and new technological ingredients are essential to future research. Work done in the Cerrado region in Brazil (Monteiro et al., 1981) suggests means for optimizing income by using some of the presently available technologies. Earlier analyses (CIAT, 1977), should be updated to include new technologies and economic conditions. Modelling of the probable economic impacts of improved inputs and technology should increase the effectiveness in making research choices.

CONCLUSIONS

Cattle systems in the Llanos, as elsewhere, will probably reach a level of intensification dictated by economic demands. The Carimagua study indicates that cattle and beef production can greatly increase with inputs such as improved pastures, minerals, early weaning and/or crossbreeding of Zebu stock with Criollo bulls. Should the region develop agriculturally, study of other techniques of herd management would be appropriate. If cropping increases, even larger populations of cattle will probably be needed in crop-livestock systems, as has been typical of many of the cropped regions of the world. On the other hand, economic conditions might dictate that fertilizer, irrigation, pest control, and other related inputs would continue to give greater returns on the more fertile soils than on Llanos soils.

Should the Llanos continue in its relatively undeveloped natural state, some of the low-cost practices studied at Carimagua could be implemented easily for greatly increased beef cattle production and economic development of the Llanos Orientales and similar areas in the humid tropics.

References

Bellows, R.A., R.E. Short, J.J. Urick and O.F. Pahnish. 1974. Effects of early weaning on postpartum reproduction of the dam and growth of calves born as multiples or singles. J. Anim. Sci. 39:589.

Blydenstein, J. 1972. Travel report on assistance to CIAT and ICA, Colombia. Unpublished. CIAT, Cali, Colombia.

Brunnschweiler, D. 1972. The Llanos frontier of Colombia. Latin American Studies Center. Monograph 9. Michigan State University, East Lansing.

Buitrago, J. 1977. CIAT. Series ES 23. Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1968. Agricultural and economic development in the lowland tropics. CIAT. Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1975. Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1976. Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1977. Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1978. Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1980. Annual Report. CIAT, Cali, Colombia.

Centro Internacional de Agricultura Tropical. 1981. Annual Report. CIAT, Cali, Colombia.

Conrad, J.H. 1976. Phosphorus supplementation for increasing reproduction in cattle. Ruminant Livestock Production System Seminar. Georgetown, Guyana.

Donaldson, L.E., J.B. Ritson and D.B. Copeman. 1967. The reproductive efficiency of several North Queensland beef herds. I. Physiological and management factors and embryonic neonatal losses. Australian Vet. J. 43:1.

FAO Report FAO/SF:11/COL. 1966. Reconocimiento edafologico de los Llanos Orientales de Colombia. FAO. Rome.

Frank, B.R. 1976. Lack of adoption of research results in the dry tropics. Proc. Australian Soc. Anim. Production 10:22P.

Grigg, D. 1970. The Harsh Lands. McMillan Co., New York.

Gomez, S. J., H. H. Stonaker, I. Kleinheisterkamp, O. Lozano, R. Botero, and J. Villar. 1982. Sistemas de produccion de hatos en los Llanos Orientales. Submitted to El Cebu. ICA. Tibaitata. Colombia.

Harvey, W.R. 1960. Least squares analysis of data with unequal subclass numbers. USDA, ARS 20-8.

Harwin, G.O., R.D. Lamb and J.H.R. Bisschop. 1967. Some factors affecting reproductive performance in beef females. Proc. South African Soc. Anim. Prod. 6:171.

Hernandez B. Gustavo. 1976. Ganado Romosinuano. In: Razas Criollas Colombianas. Instituto Colombiano Agropecuario. Manual 21. Bogota.

Holroyd, R.G., P.J. Allan and P.K. O'Rourke. 1977. Effect of pasture type and supplementary feeding on the reproductive performance of cattle in the dry tropics of north Queensland. Australian J. Exp. Agric. and Anim. Husb. 17:197.

Koger, M., W.L. Reynolds, W.G. Kirk, F.M. Peacock and A.G. Warnick. 1962. Reproductive performance of crossbred and straightbred cattle on different pasture programs in Florida. J. Anim. Sci. 21:14.

Lamond, D.R. 1969. Sources of variation in reproductive performance in selected herds of beef cattle in north-eastern Australia. Australian Vet. J. 45:50.

Laster, D.B., H.A. Glimp and K.E. Gregory. Effects of early weaning on postpartum reproduction of cows. 1973. J. Anim. Sci. 36:734.

Lebdosoekojo, S. 1977. Mineral supplementation of grazing beef cattle in eastern plains of Colombia. Ph.D. dissertation. Univ. of Florida, Gainesville.

Lebdosoekojo, S., C. B. Ammerman, N. S. Raun, J. Gomez, and R. C. Littel. 1980. Mineral supplementation of beef cattle grazing native pastures on the eastern plains of Colombia. J. Anim. Sci. 51:1249.

Monteiro, L. A., A. L. Gardner, and P. D. Chudleigh. 1981. Beef production in the Cerrado region of Brazil. A bioeconomic analysis of ranch improvement schemes. World Anim. Rev. 37:37.

Morley, F.H.W., A. Axelsen and R.B. Cunningham. 1976. Liveweight at joining and fertility in beef cattle. Proc. Australian Soc. Anim. Prod. 10:201.

Niekirk, van, B.D.H. 1975. Supplementation of grazing cattle. Proc. Seminar on Potential to Increase Beef Production in Tropical America. CIAT. Cali, Colombia.

Paladines, O. 1975. Management and utilization of native tropical pastures in America. Proc. Seminar on Potential to Increase Beef Production in Tropical America. CIAT. Cali, Colombia.

Plasse, D. 1976. The possibility of genetic improvement of beef cattle in developing countries with particular reference to Latin America. In: A.J. Smith (Ed.) Beef Cattle in Developing Countries. Univ. of Edinburgh. Edinburgh.

Raun, N.S. 1976. Beef cattle production practices in the lowland American tropics. World Anim. Rev. 19:18.

Ryder, W.L., D. Hillman and J.T. Huber. 1972. Effect of feeding urea on reproductive efficiency in Michigan dairy herd improvement association herds. J. Dairy Sci. 55:1290.

Salazar, J.J. 1973. Effects of crossing Brahman and Charolais bulls in native breeds in Colombia. In: T.J. Cunha, M. Koger and A.C. Warnick (Ed.) Crossbreeding Beef Cattle: Series 2. Univ. of Florida Press, Gainesville.

Sanchez, P. A. and R. R. Isbell. 1978. A comparison of the soils of tropical Latin America and tropical Australia. In Seminario sobre produccion y utilizacion de forrajes en suelos acidos e infertiles del tropico. CIAT. Cali, Colombia.

Serrano, Q.A. 1976. Reproductive performance in milking cows fed different levels of urea. Dissertation Abstr. Int'l. B 37 (1) p 110.

Spain, J. M. 1975. In: Sanchez. P.A. and A.R. Isbell. 1978. A comparison of the soils of tropical Latin America and tropical Australia. Seminario sobre produccion y utilizacion de forrajes en suelos acidos e infertiles del tropico. Centro Internacional de Agricultura tropical. Cali, Colombia.

Stonaker, H.H. 1971. Animal breeding in the tropics of Latin America. J. Anim. Sci. 33:1:1.

Stonaker, H.H., J. Villar, G. Osorio and J. Salazar. 1976. Differences among cattle and farms as related to beef cow reproduction in the eastern plains of Colombia. Trop. Anim. Health and Prod. 8:147.

Theiler, A., H.H. Green and P.J. du Toit. 1928. Studies in mineral matabolism. III Breeding of cattle on phosphorus deficient pasture. J. Agr. Sci. 18:369.

Vaccaro, L. de, M. Garcia, O. Bazan and E. Bardales. 1977. Fertility and body weight at first mating of Zebu cattle grazing cleared jungle land in the Amazon. Trop. Agr. (Trinidad). 54:3:223.

Word, J.D., L.C. Martin, D.L. Williams, E.I. Williams, R.J. Panciera, T.E. Nelson and A.D. Tillman. 1969. Urea toxicity in the bovine. J. Anim. Sci. 29:786-791.

Appendices

APPENDIX A

FORAGE PLANTS

In describing major native forage plant species at Carimagua, Blydenstein (unpublished data) noted: "About 6,500 ha are covered by *Trachypogon vestitus* savanna on level land, with an additional 4,500 ha with *Paspalum pectinatum* savanna on the very gentle slopes down to the rivers and streams, with gallery forest or moriche palms. At the centre of the station is located the Carimagua lake, a permanent body of open water surrounded by inundable low-lands covered with *Scleria* and other sedge-dominated vegetation, but with short grass cover (*Leersia hexandra*) at the time the waters recede. The eastern part of the station reaches more dissected area of the high Llanos and is covered with a *Paspalum pectinatum* savanna, tending to *Paspalum carinatum*-type savanna. This part covers about 4,000 ha."

In sampling the upland savanna (Pasture 7), 21 species were observed; the most frequent were *Trachypogon vestitus*, *Axonopus pulcher*, *Panicum versicolor*, and *Cyperaceae*. Forty species were observed in a lower, inundated area (pasture 3), including *Axonopus*, *Sedge*, *Andropogon virgatus*, *Scleria hirtella*, *Elocharis sp.*, *Cuphea graciles*, *Pasto morado*, *Cyprus cayennensis*, and *Pasto pelo largo*. Some species were not identified or were identified by local names.

APPENDIX B

Health measures were as follows:

- Before the experiment began--All bulls were examined three times for evidence of trichomoniasis and vibriosis by washings from the prepuce. No trichomonas or vibrio were found by direct examination or by culturing. Bulls were not subjected to herd treatments, except for the time they were with the cows. They were kept in appropriate physical condition for high fertility. Thus, treatments affecting reproduction should primarily reflect the cows' reproductive capabilities. All heifers and bulls were serologically examined for brucellosis; the few animals with positive reactions were excluded from the experiment.
- During the experiment--
  - (1) Preventive medicine included the following:
    - (a) All animals over 6 months of age were vaccinated against foot and mouth disease every 4 months using an inactivated product.
    - (b) All females between 6 and 8 months of age were vaccinated with strain 19 to prevent brucellosis.
    - (c) All animals 6 months or older were vaccinated yearly to prevent blackleg and malignant edema.
  - (2) Routine checkups and treatments included:
    - (a) All animals were checked for gastrointestinal parasites, using fecal worm-egg counts every 4 months. All

animals were dewormed when a substantial number were found to have total egg counts of 300 eggs per gram or more. These animals were treated at least every 6 months.

(b) All animals were monitored for development of antibodies against blood parasites: anaplasmosis and babesiosis.

(c) All animals were monitored for tick loads, with half-body counts of engorged female ticks every 2 months. All herds were sprayed with an acaricide (according to seasonal loads) to reduce infestations.

(d) All animals were monitored for *Dermatobia hominis* (nuche) infestations by whole-body counts every 2 months. Herds were sprayed to control nuche when loads were considered as deleterious.

(e) All herds were monitored for development of brucellosis infections by blood-serum analysis performed 2 months apart. Animals that reacted positively in two examinations were culled from the experiment.

(f) All herds were monitored for incidence of granular vaginitis every 2 months. No preventive medicine or control measures were taken.

(g) All animals were bled every 2 months and the serum used to monitor incidence of leptospirosis and IBR infections. No measures were taken to control these infections.

(h) All herds were monitored for wounds, fractures, poisoning, and abnormal conditions or syndromes.

(i) Health and abnormal conditions of all animals were monitored by analysis of blood parameters during the last year of the experiment.

APPENDIX TABLE 1. THE CONSUMPTION OF SALT OR COMPLETE MINERAL SUPPLEMENT BY HERDS FROM MARCH 5, 1975, TO MARCH 4, 1976

Herd	Type of supplement	Total consumption per herd, kg	Average daily consumption per cow, g
2	Salt	449	36
3	Salt	508	42
4	Complete mineral	611	51
5	Complete mineral	668	53
6	Complete mineral	918	70
7	Complete mineral	1116	85
8	Complete mineral	1069	81
9	Complete mineral	997	81

Source: S. Lebdosoekojo, 1977.

The formula for the mineral mix was: 47% salt, 47% dicalcium phosphate, 5.3% wheat bran, .3000% ferrous sulfate, .1854% manganese sulfate, .1170% copper sulfate, .0744% zinx oxide .0120% cobalt sulfate, .0042% potassium iodide.

APPENDIX TABLE 2. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF NUMBER OF CALVES PRODUCED PER COW ALL YEARS AND TREATMENTS IN THE MINERAL EXPERIMENT

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	140	2.67	2.67	.09
Minerals (M)				
(1) Salt	71	-.32	2.34	.12
(2) Complete	69	.32	2.99	.12
Supplement (U)				
(1) None	70	-.05	2.62	.12
(2) Urea	70	.05	2.72	.12
Weaning (W)				
(1) 3 mo	20	.58	3.25	.16
(2) 9 mo	120	-.58	2.08	.07
$M_1 \times U_1$	36	-.09	2.21	.16
$M_1 \times U_2$	35	.09	2.48	.16
$M_2 \times U_1$	34	.09	3.03	.16
$M_2 \times U_2$	35	-.09	2.95	.16
$M_1 \times W_1$	10	.07	3.00	.23
$M_1 \times W_2$	61	-.07	1.69	.09
$M_2 \times W_1$	10	-.07	3.50	.23
$M_2 \times W_2$	59	.07	2.48	.09
$U_1 \times W_1$	10	-.10	3.10	.23
$U_1 \times W_2$	60	.10	2.13	.09
$U_2 \times W_1$	10	.10	3.40	.23
$U_2 \times W_2$	60	-.10	2.03	.09

APPENDIX TABLE 3. ANNUAL SEQUENCE PATTERN OF CALVINGS 1974-1977 (INCLUSIVE) BY INDIVIDUAL COWS IN ALL HERDS

Years of calving	74 75 76 77		74 75 76 -		74 75 - 77		74 - 76 77		- 75 76 77		74 75 - -		74 - 76 -		- 75 76 -		74 - - 77		- 75 - 77		- - 76 77		74 - - -		- 75 - -		- - 76 -		- - - 77	
	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW	N	EW
Herd 1	0	0	2	0	1	0	0	0	0	0	5	0	4	0	0	0	2	0	0	0	0	0	9	0	5	0	3	0	0	0
Herd 2	1	1	4	3	1	0	1	1	1	0	1	0	8	0	7	0	0	0	2	0	0	0	3	0	1	0	1	0	2	0
Herd 3	0	0	2	1	0	0	0	0	0	0	1	0	1	0	2	0	1	0	0	0	0	0	0	0	6	0	1	0	0	0
Herd 4	4	3	10	2	5	0	0	0	0	0	3	0	7	0	2	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0
Herd 5	3	2	7	3	9	0	4	0	0	0	1	0	6	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Herd 6	2	2	14	3	6	0	1	0	0	0	2	0	5	0	3	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Herd 7	3	2	10	2	5	0	3	0	0	0	4	0	7	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Herd 8	2	2	6	3	5	0	1	0	0	0	4	0	14	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Herd 9	3	2	10	1	5	0	1	0	0	0	3	1	9	1	1	0	0	0	0	0	1	0	3	0	1	0	0	0	0	0
Total	18	14	65	18	37	0	11	1	1	0	24	1	61	1	19	0	3	0	5	0	1	0	21	0	15	0	5	0	2	0

N = Number of cows.
EW = Number of cows early weaned.

APPENDIX TABLE 4. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF COW WEIGHTS (KG) ALL YEARS FOR THE MINERAL EXPERIMENT

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	3086	317	317	1.6
Year (Y)				
1973	270	-28	290	3.2
1974	792	-5	312	1.9
1975	892	-3	314	1.9
1976	765	15	332	1.9
1977	367	21	339	2.6
Season (T)				
(1) Dry	1026	-13	304	2.1
(2) Early wet	1016	2	320	1.9
(3) Late wet	1044	11	329	2.1
Minerals (M)				
(1) Salt	1529	-13	304	1.9
(2) Complete	1557	13	331	1.8
Supplement (U)				
(1) None	1554	-5	312	1.8
(2) Urea	1532	5	323	1.8
Weaning (W)				
(1) 3 mo	476	0	317	3.0
(2) 9 mo	2610	0	317	1.0
Reproductive status (R)				
(1) Open dry	694	-18	299	2.1
(2) Preg 1-6 dry	761	3	320	1.7
(3) Preg 6-9 dry	537	31	348	2.0
(4) Preg wet	161	8	325	6.9
(5) Open wet	933	-23	295	2.2
$T_1 \times R_1$	238	-4	281	3.0
$T_1 \times R_2$	194	1	307	3.0
$T_1 \times R_3$	217	3	338	2.7
$T_1 \times R_4$	43	-2	310	8.3
$T_1 \times R_5$	334	3	284	2.7
$T_2 \times R_1$	193	7	309	3.1
$T_2 \times R_2$	270	-2	320	2.6
$T_2 \times R_3$	148	-1	349	3.4
$T_2 \times R_4$	71	-6	322	7.2
$T_2 \times R_5$	334	2	299	2.6
$T_3 \times R_1$	263	-3	308	2.9

APPENDIX TABLE 4 (CONTINUED)

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
T_3 x R_2	297	1	333	2.3
T_3 x R_3	172	-2	357	3.1
T_3 x R_4	47	8	345	8.7
T_3 x R_5	265	-5	301	3.1
M_1 x R_1	483	-1	284	2.2
M_1 x R_2	356	1	308	2.2
M_1 x R_3	232	-4	331	2.7
M_1 x R_4	51	6	318	7.8
M_1 x R_5	407	-1	280	2.6
M_2 x R_1	211	1	314	2.9
M_2 x R_2	405	-1	332	2.1
M_2 x R_3	305	4	366	2.5
M_2 x R_4	110	-6	333	7.3
M_2 x R_5	526	1	309	2.5
W_1 x R_1	99	-5	294	3.8
W_1 x R_2	169	-1	319	2.9
W_1 x R_3	117	-1	347	3.5
W_1 x R_4	8	3	328	13.2
W_1 x R_5	83	5	300	4.1
W_2 x R_1	595	5	304	1.6
W_2 x R_2	592	1	321	1.6
W_2 x R_3	420	1	349	1.9
W_2 x R_4	153	-3	323	3.3
W_2 x R_5	850	-5	290	1.4
T_1 x M_1	506	0	290	2.5
T_1 x M_2	520	0	318	2.4
T_2 x M_1	504	1	307	2.3
T_2 x M_2	512	-1	332	2.3
T_3 x M_1	519	-1	315	2.5
T_3 x M_2	525	1	343	2.4

APPENDIX TABLE 5. ANALYSIS OF VARIANCE OF COW WEIGHTS ALL YEARS AND TREATMENTS, MINERAL EXPERIMENT

Source	Herds 2, 3, 4, 5 df	Mean squares	F	F[a] comparison
Year (Y)	4	105239	78.9**	59.52**
Season (T)	2	88264	66.2**	49.58**
Minerals (M)	1	328599	246.3**	184.00**
Urea (U)	1	91985	68.9**	51.67**
Weaning (W)	1	10	.008	.006
Reproductive status (R)	4	142145	106.5**	79.85**
T x R	8	3927	2.9*	2.21
M x R	4	3594	2.7*	2.02
W x R	4	3830	2.9*	2.15
T x M	2	826	.6	.96
Residual	3054	1334		
(Cows)[a]	(181)[a]	(1780)[a]		

F[a] Using pooled variance and df of (cows)[a] as error from appendix table 11.
Included for comparison because restrictions to the model superimposed by computer capacity did not isolate a variance for cows.
*P < .05
**P < .01

APPENDIX TABLE 6. ANALYSIS OF VARIANCE OF CALVES PRODUCED PER COW ALL YEARS IN THE MINERAL EXPERIMENT

Source	Herds 2, 3, 4, 5 df	Mean squares	F
Minerals (M)	1	7.11	13.41**
Supplement Urea (U)	1	.17	.33
Weaning (W)	1	23.34	44.05**
M x U	1	1.07	2.03
M x W	1	.35	.67
U x W	1	.68	1.29
Residual	133	.53	-

**P < .01

APPENDIX TABLE 7. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF NUMBER OF CONCEPTIONS PER COW ALL YEARS AND TREATMENTS (1973 - 1977, 3.84 YEARS), MINERAL EXPERIMENT

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	140	2.86	2.86	.09
Minerals (M)				
(1) Salt	71	-.14	2.72	.13
(2) Complete	69	.14	3.01	.13
Supplement (U)				
(1) None	70	-.06	2.81	.13
(2) Urea	70	.06	2.92	.13
Weaning (W)				
(1) 3 mo	20	.59	3.45	.17
(2) 9 mo	120	-.59	2.27	.07
$M_1 \times U_1$	36	-.10	2.60	.17
$M_1 \times U_2$	35	.10	2.90	.17
$M_2 \times U_1$	34	.10	3.00	.17
$M_2 \times U_2$	35	-.10	3.00	.17
$M_1 \times W_1$	10	.09	3.40	.24
$M_1 \times W_2$	61	-.09	2.00	.10
$M_2 \times W_1$	10	-.09	3.50	.24
$M_2 \times W_2$	59	.09	2.50	.10
$U_1 \times W_1$	10	-.09	3.30	.24
$U_1 \times W_2$	60	.09	2.30	.10
$U_2 \times W_1$	10	.09	3.60	.24
$U_2 \times W_2$	60	-.09	2.20	.10

APPENDIX TABLE 8. ANALYSIS OF VARIANCE OF ESTIMATED NUMBER OF CONCEPTIONS PER COW, MINERAL EXPERIMENT

Source	Number of conceptions per cow df	Mean squares	F
Minerals (M)	1	1.43	2.5
Supplement (U)	1	.21	
Weaning (W)	1	23.78	41.7**
M x U	1	1.32	2.3
M x W	1	.61	1.1
U x W	1	.61	1.1
Residual df	133	.57	-

**P < .01

APPENDIX TABLE 9. ANNUAL INDEXED CALVING RATES AS CALCULATED FROM NUMBERS OF CALVES BORN DURING 3.27 YEARS IN THE MINERAL EXPERIMENT

	Herds 2, 3, 4, 5 Means
Mean (MU)	.67
Minerals (M)	
(1) Salt	.59
(2) Complete	.75
Supplement (U)	
(1) None	.66
(2) Urea	.68
Weaning (W)	
(1) 3 mo	.81
(2) 9 mo	.53
$M_1 \times U_1$	.56
$M_1 \times U_2$	.62
$M_2 \times U_1$	.76
$M_2 \times U_2$	.74
$M_1 \times W_1$	.75
$M_1 \times W_2$	.43
$M_2 \times W_1$	.88
$M_2 \times W_2$	.64
$U_1 \times W_1$	.78
$U_1 \times W_2$	.54
$U_2 \times W_1$	.85
$U_2 \times W_2$	.51

APPENDIX TABLE 10. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF CALF WEIGHTS (KG) AT 9 MONTHS (AGE ADJUSTED), MINERAL EXPERIMENT

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	153	150	150	3.1
Year (Y)				
(4) 1974	61	-5	145	3.1
(5) 1975	55	-3	147	3.6
(6) 1976	37	8	159	7.8
Season (T)				
(1) Dry	75	0	150	2.7
(2) Early wet	42	-10	140	4.0
(3) Late wet	36	10	160	7.8
Minerals (M)				
(1) Salt only	52	-19	131	4.3
(2) Complete	101	19	169	3.2
Supplement (U)				
(1) None	80	-3	147	3.7
(2) Urea	73	3	153	3.7
Sex (S)				
(1) Male	82	5	155	3.5
(2) Female	71	-5	145	3.7
Breed (B)				
(1) Zebu	77	-5	146	3.7
(2) San Martinero	76	5	155	3.5
$Y_4 \times T_1$	27	3	148	4.7
$Y_4 \times T_2$	21	5	140	5.2
$Y_4 \times T_3$	13	-8	147	6.0
$Y_5 \times T_1$	26	7	154	4.3
$Y_5 \times T_2$	7	-4	133	8.6
$Y_5 \times T_3$	22	-3	154	4.9
$Y_6 \times T_1$	22	-10	149	4.9
$Y_6 \times T_2$	14	-2	146	6.0
$Y_6 \times T_3$	1	11	180	22.2
$T_1 \times M_1$	24	0	131	4.7
$T_1 \times M_2$	51	0	169	3.2
$T_2 \times M_1$	15	-1	120	6.5
$T_2 \times M_2$	27	1	160	4.4
$T_3 \times M_1$	13	1	142	9.6
$T_3 \times M_2$	23	-1	179	8.0
$T_1 \times U_1$	37	-4	143	3.8
$T_1 \times U_2$	38	4	157	3.7
$T_2 \times U_1$	23	-1	135	5.1
$T_2 \times U_2$	19	1	144	5.9
$T_3 \times U_1$	20	5	162	9.1
$T_3 \times U_2$	16	-5	159	8.2
$M_1 \times U_1$	29	-5	123	5.1
$M_1 \times U_2$	23	5	139	5.7
$M_2 \times U_1$	51	5	171	4.1
$M_2 \times U_2$	50	-5	168	3.8

APPENDIX TABLE 11. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF CALF WEIGHTS (KG) AT 18 MONTHS (AGE ADJUSTED) FOR THE MINERAL EXPERIMENT

	Herds 2, 3, 4, 5			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	108	171	171	2.8
Year (Y)				
1974	61	4	175	3.7
1975	47	-4	167	3.9
1976	-	-	-	-
1977	-	-	-	-
Season (T)				
(1) Dry	52	7	178	3.7
(2) Early wet	25	-10	161	6.4
(3) Late wet	31	3	174	4.6
Minerals (M)				
(1) Salt only	38	-16	155	4.9
(2) Complete	70	16	187	3.4
Supplement (U)				
(1) None	55	2	173	3.6
(2) Urea	53	-2	168	4.6
Sex (S)				
(1) Male	44	7	178	4.1
(2) Female	64	-7	163	3.4
Breed (B)				
(1) Zebu	53	-9	162	4.0
(2) San Martinero	55	9	179	3.6

APPENDIX TABLE 12. ANALYSIS OF VARIANCE OF WEIGHTS OF 9-MONTH-WEANED CALVES; SIGNIFICANCE OF RESULTS AS INDICATED BY F VALUES, CURVILINEAR ADJUSTMENT FOR AGE, MINERAL EXPERIMENT

	Herds 2, 3, 4, 5 Ages of calves	
Source	9 mo	18 mo
Year of birth (Y)	1.30	2.03
Season of birth (T)	3.70	2.38
Minerals (M)	75.30**	25.09**
Urea (U)	2.44	.64
Sex (S)	7.03**	8.60**
Breed of sire (B)	5.53*	10.95**
Y x T	1.00	1.77
T x M	.07	3.41*
T x U	1.97	1.28
M x U	5.82*	.11
Residual df	135	93

*P < .05
**P < .01

APPENDIX TABLE 13. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF COW WEIGHTS (KG) ALL YEARS FOR THE PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	4806	331	331	1.6
Year (Y)				
(3) 1973	422	-21	311	2.9
(4) 1974	1222	4	335	1.8
(5) 1975	1407	0	331	1.8
(6) 1976	1181	7	339	1.8
(7) 1977	574	10	342	2.4
Season (T)				
(1) Dry	1599	-15	316	1.9
(2) Wet	1584	4	335	1.9
(3) Wet	1623	12	343	1.9
Pastures (P)				
(1) Native	1557	4	336	1.8
(2) Molasses	1574	-8	323	1.9
(3) Native+molasses	1675	4	335	1.8
Supplement (U)				
(1) None	2413	-4	327	1.7
(2) Urea	2393	4	336	1.7
Weaning (W)				
(1) 3 mo	716	8	339	3.1
(2) 9 mo	4090	-8	323	.8
Reproductive status (R)				
(1) Open dry	691	-13	318	2.0
(2) Preg 1-6 dry	1219	4	335	1.4
(3) Preg 6-9 dry	903	38	369	1.8
(4) Preg wet	341	0	332	7.0
(5) Open wet	1652	-29	303	1.8
$T_1 \times R_1$	267	-4	299	2.9
$T_1 \times R_2$	302	0	320	2.6
$T_1 \times R_3$	407	-1	353	2.1
$T_1 \times R_4$	88	3	320	7.7
$T_1 \times R_5$	535	1	289	2.3
$T_2 \times R_1$	200	9	330	3.1
$T_2 \times R_2$	389	-4	334	2.3
$T_2 \times R_3$	243	-5	368	2.9
$T_2 \times R_4$	127	-3	333	7.3
$T_2 \times R_5$	625	3	310	2.1

APPENDIX TABLE 13. (CONTINUED)

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
$T_3 \times R_1$	224	-5	325	2.9
$T_3 \times R_2$	528	4	351	2.0
$T_3 \times R_3$	253	6	387	2.8
$T_3 \times R_4$	126	-1	343	7.8
$T_3 \times R_5$	492	-5	310	2.5
$T_1 \times P_1$	520	5	326	2.4
$T_1 \times P_2$	520	-6	302	2.4
$T_1 \times P_3$	559	1	321	2.3
$T_2 \times P_1$	512	-2	338	2.3
$T_2 \times P_2$	517	3	330	2.4
$T_2 \times P_3$	555	-2	337	2.3
$T_3 \times P_1$	525	-3	344	2.4
$T_3 \times P_2$	537	3	338	2.4
$T_3 \times P_3$	561	1	347	2.3
$W_1 \times R_1$	126	2	328	3.5
$W_1 \times R_2$	260	-3	341	2.5
$W_1 \times R_3$	177	-2	376	3.0
$W_1 \times R_4$	8	2	342	13.8
$W_1 \times R_5$	145	0	311	3.3
$W_2 \times R_1$	565	-2	308	1.7
$W_2 \times R_2$	959	3	330	1.3
$W_2 \times R_3$	726	2	363	1.5
$W_2 \times R_4$	333	-2	322	2.3
$W_2 \times R_5$	1507	0	295	1.1
$P_1 \times R_1$	211	4	327	3.0
$P_1 \times R_2$	405	-6	333	2.2
$P_1 \times R_3$	305	-5	368	2.5
$P_1 \times R_4$	110	3	339	7.6
$P_1 \times R_5$	526	5	312	2.3
$P_2 \times R_1$	253	-8	302	2.7
$P_2 \times R_2$	390	7	334	2.2
$P_2 \times R_3$	296	4	366	2.6
$P_2 \times R_4$	89	5	329	7.8
$P_2 \times R_5$	546	-8	287	2.3
$P_3 \times R_1$	227	4	325	2.9
$P_3 \times R_2$	424	0	338	2.1
$P_3 \times R_3$	302	1	374	2.6
$P_3 \times R_4$	142	-8	328	7.5
$P_3 \times R_5$	580	4	310	2.2

APPENDIX TABLE 14. ANALYSIS OF VARIANCE OF COW WEIGHTS (KG) ALL YEARS AND TREATMENTS, PASTURE EXPERIMENT

Source	Herds 4, 5, 6, 7, 8, 9			F^a comparison
	df	Mean squares	F	
Year (Y)	4	44886	30.1**	25**
Season (T)	2	181765	121.8**	102**
Pastures (P)	2	54293	36.4**	30**
Urea (U)	1	96882	64.9**	54**
Weaning (W)	1	39605	26.5**	22**
Reproductive status (R)	4	297192	199.1**	167**
T x R	8	8423	5.6**	4.73**
P x R	8	16196	10.8**	9.1**
W x R	4	1818	1.2	1.0
T x P	4	13227	8.9**	7.43**
Residual df	4767	1493		
(Cow)	(181)[a]	(1780)[a]		

[a]Using variance and df of (Cow)[a] as error.
See appendix table 5.
**P < .01

APPENDIX TABLE 15. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF COW WEIGHTS (KG) IN 1976-1977, PASTURE EXPERIMENT

Date	August 2, 1976				October 2, 1976			
Source	N	Constants	Least-squares means	Standard errors	N	Constants	Least-squares means	Standard errors
Mean (MU)	196	341	341	5.0	196	364	364	5.4
Pastures (P)								
(1) Native	65	-4	338	8.1	65	4	369	8.0
(2) Molasses grass	61	2	343	9.1	61	3	368	10.3
(3) Native+molasses	70	2	343	8.5	70	-7	357	8.0
Supplement (U)								
(1) None	97	-8	333	7.0	97	-2	362	7.9
(2) Urea	99	8	350	6.7	99	2	366	6.7
Weaning (W)								
(1) 3 mo	30	13	355	9.0	30	16	380	9.7
(2) 9 mo	166	-13	328	3.9	166	-16	348	4.1
Reproductive (R) status								
(1) Pregnant	71	26	368	8.1	55	32	397	9.7
(2) Open	125	-26	315	6.0	141	-32	332	5.0
$P_1 \times U_1$	33	4	333	10.5	33	-1	366	10.1
$P_1 \times U_2$	32	-4	342	10.5	32	1	372	10.3
$P_2 \times U_1$	29	-6	329	11.9	29	-3	363	14.6
$P_2 \times U_2$	32	6	358	11.0	32	3	372	10.7
$P_3 \times U_1$	35	2	338	10.9	35	3	358	10.6
$P_3 \times U_2$	35	-2	349	10.8	35	-3	356	9.8
$P_1 \times W_1$	10	-7	344	14.8	10	-1	384	14.5
$P_1 \times W_2$	55	7	331	6.3	55	1	353	6.2
$P_2 \times W_1$	10	15	372	16.2	10	15	399	17.2
$P_2 \times W_2$	51	-15	315	7.2	51	-15	336	8.2
$P_3 \times W_1$	10	-9	348	15.3	10	-14	359	14.5
$P_3 \times W_2$	60	9	339	6.9	60	14	355	6.1
$P_1 \times R_1$	36	0	364	9.8	21	-10	391	12.1
$P_1 \times R_2$	29	0	311	-11.3	44	10	346	8.6
$P_2 \times R_1$	17	14	384	14.4	12	18	418	17.9
$P_2 \times R_2$	44	-14	303	8.8	49	-18	317	7.9
$P_3 \times R_1$	18	-14	356	13.1	22	-8	381	12.2
$P_3 \times R_2$	52	14	331	9.0	48	8	333	8.6
$U_1 \times W_1$	15	4	350	12.6	15	1	379	13.3
$U_1 \times W_2$	82	-4	316	5.6	82	-1	345	6.5
$U_2 \times W_1$	15	-4	359	12.2	15	-1	382	12.3
$U_2 \times W_2$	84	4	341	5.4	84	1	351	4.9
$U_1 \times R_1$	36	-2	358	10.8	20	-2	393	13.7
$U_1 \times R_2$	61	2	309	7.9	77	2	332	6.7
$U_2 \times R_1$	35	2	378	10.1	35	2	401	10.6
$U_2 \times R_2$	64	-2	321	8.1	64	-2	332	7.1
$W_1 \times R_1$	11	6	387	14.8	7	-1	412	17.3
$W_1 \times R_2$	19	-6	322	11.0	23	1	349	9.2
$W_2 \times R_1$	60	-6	349	6.3	48	1	381	7.1
$W_2 \times R_2$	106	6	308	4.7	118	-1	315	4.0

APPENDIX TABLE 15. (CONTINUED)

Date	December 2, 1976				January 2, 1977			
Source	N	Constants	Least-squares means	Standard errors	N	Constants	Least-squares means	Standard errors
Mean (MU)	196	370	370	5.2	196	350	350	4.1
Pastures (P)								
(1) Native	65	6	377	7.5	65	14	364	7.2
(2) Molasses grass	61	-10	360	9.1	61	-21	329	7.0
(3) Native+molasses	70	4	374	9.2	70	7	356	7.3
Supplement(U)								
(1) None	97	-2	368	7.8	97	-9	341	5.8
(2) Urea	99	2	372	6.6	99	9	359	6.0
Weaning (W)								
(1) 3 mo	30	19	389	9.4	30	18	367	7.4
(2) 9 mo	166	-19	351	4.0	166	-18	332	3.8
Reproductive (R) status								
(1) Pregnant	48	31	401	9.4	49	28	377	6.8
(2) Open	148	-31	339	4.8	147	-28	322	4.8
$P_1 \times U_1$	33	-3	372	9.6	33	5	360	9.0
$P_1 \times U_2$	32	3	381	10.1	32	-5	368	9.4
$P_2 \times U_1$	29	-12	346	11.5	29	-12	308	9.2
$P_2 \times U_2$	32	12	374	11.0	32	12	350	9.0
$P_3 \times U_1$	35	14	386	13.6	35	7	354	8.9
$P_3 \times U_2$	35	-14	362	9.6	35	-7	359	9.8
$P_1 \times W_1$	10	-7	388	13.5	10	1	382	12.9
$P_1 \times W_2$	55	7	365	6.4	55	-1	346	6.0
$P_2 \times W_1$	10	17	396	16.2	10	10	356	12.5
$P_2 \times W_2$	51	-17	324	6.9	51	-10	302	6.2
$P_3 \times W_1$	10	-10	383	15.3	10	-10	364	12.5
$P_3 \times W_2$	60	10	365	7.5	60	10	349	7.0
$P_1 \times R_1$	19	-9	399	11.3	19	-9	383	11.0
$P_1 \times R_2$	46	9	354	8.7	46	9	345	7.6
$P_2 \times R_1$	14	3	394	15.2	17	6	362	10.5
$P_2 \times R_2$	47	-3	326	7.7	44	-6	296	8.0
$P_3 \times R_1$	15	6	411	15.9	13	3	387	11.6
$P_3 \times R_2$	55	-6	337	7.9	57	-3	326	7.8
$U_1 \times W_1$	15	1	388	12.9	15	3	362	10.5
$U_1 \times W_2$	82	-1	348	6.6	82	-3	320	4.7
$U_2 \times W_1$	15	-1	390	12.0	15	-3	373	10.2
$U_2 \times W_2$	84	1	355	5.1	84	3	345	5.9
$U_1 \times R_1$	18	2	401	13.7	30	2	370	8.9
$U_1 \times R_2$	79	-2	335	6.5	67	-2	311	6.4
$U_2 \times R_1$	30	-2	402	10.8	19	-2	385	9.6
$U_2 \times R_2$	69	2	343	6.8	80	2	333	6.6
$W_1 \times R_1$	7	1	422	17.0	11	0	395	11.9
$W_1 \times R_2$	23	-1	356	8.9	19	0	340	9.0
$W_2 \times R_1$	41	-1	381	7.2	38	0	360	6.9
$W_2 \times R_2$	125	1	322	3.8	128	0	304	3.5

APPENDIX TABLE 15. (CONTINUED)

Date	March 2, 1977			
Source	N	Con-stants	Least-squares means	Standard errors
Mean (MU)	188	319	319	6.0
Pastures (P)				
(1) Native	64	23	342	8.7
(2) Molasses grass	56	-26	293	9.8
(3) Native + molasses	68	3	323	10.3
Supplement(U)				
(1) None	90	-5	315	7.8
(2) Urea	98	5	324	8.8
Weaning (W)				
(1) 3 mo	29	13	332	10.7
(2) 9 mo	159	-13	306	5.1
Reproductive status (R)				
(1) Pregnant	26	24	343	11.2
(2) Open	162	-24	295	4.3
$P_1 \times U_1$	32	3	340	10.2
$P_1 \times U_2$	32	-3	344	12.2
$P_2 \times U_1$	25	-4	285	13.1
$P_2 \times U_2$	31	4	302	10.9
$P_3 \times U_1$	33	1	319	10.7
$P_3 \times U_2$	35	-1	326	14.3
$P_1 \times W_1$	9	3	358	14.7
$P_1 \times W_2$	55	-3	326	8.0
$P_2 \times W_1$	10	9	315	16.4
$P_2 \times W_2$	46	-9	272	8.0
$P_3 \times W_1$	10	-12	324	16.3
$P_3 \times W_2$	58	12	321	9.1
$P_1 \times R_1$	11	-4	363	14.8
$P_1 \times R_2$	53	4	321	7.8
$P_2 \times R_1$	8	-2	315	17.3
$P_2 \times R_2$	48	2	271	7.2
$P_3 \times R_1$	7	6	352	18.6
$P_3 \times R_2$	61	-6	293	7.0
$U_1 \times W_1$	14	6	334	13.7
$U_1 \times W_2$	76	-6	296	5.7
$U_2 \times W_1$	15	-6	331	13.5
$U_2 \times W_2$	83	6	317	8.6
$U_1 \times R_1$	18	1	340	13.7
$U_1 \times R_2$	72	-1	290	6.2
$U_2 \times R_1$	8	-1	347	16.3
$U_2 \times R_2$	90	1	301	5.8
$W_1 \times R_1$	4	-2	354	20.1
$W_1 \times R_2$	25	2	310	7.9
$W_2 \times R_1$	22	2	333	9.6
$W_2 \times R_2$	137	-2	280	3.4

APPENDIX TABLE 16. ANALYSIS OF VARIANCE OF COW WEIGHTS (KG), 1976-1977, PASTURE EXPERIMENT

Source	Aug. 2, 1976		Oct. 2, 1976		Dec. 12, 1976		Jan. 2, 1977		March 2, 1977	
	df	Mean squares	df	Mean squares	df	Mean squares	df	Mean squares	df	Mean squares
MU-YM	1	151320	1	270632	1	321777	1	219752	1	16064
Pasture (P)	2	289	2	1263	2	1974	2	10254**	2	10990**
Supplement (U)	1	6601	1	350	1	334	1	7394*	1	1016
Weaning (W)	1	16086**	1	18907**	1	24508**	1	26789**	1	7366*
Reproductive status (R)	1	57495**	1	66136**	1	59158**	1	66583**	1	24737**
P x U	2	1763	2	568	2	9729**	2	6749*	2	694
P x W	2	5689	2	7135*	2	7030*	2	3272	2	3711
P x R	2	9780*	2	8795*	2	2379	2	2908	2	635
U x W	1	1595	1	106	1	109	1	1145	1	3526
U x R	1	579	1	384	1	303	1	490	1	41
W x R	1	3098	1	50	1	146	1	2	1	235
Residual	181	2160	181	1905	181	1771	181	1524	173	1545

*$P < .05$

**$P < .01$

APPENDIX TABLE 17. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF NUMBER OF CALVES PRODUCED PER COW ALL YEARS AND TREATMENTS, PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	213	2.90	2.90	.07
Supplement (U)				
(1) None	106	.03	2.93	.10
(2) Urea	107	-.03	2.87	.10
Weaning (W)				
(1) 3 mo	30	.47	3.37	.13
(2) 9 mo	183	-.47	2.43	.05
Pastures (P)				
(1) Native	69	.09	2.99	.12
(2) Molasses	73	-.16	2.74	.12
(3) Native+molasses	71	.07	2.97	.12
$U_1 \times W_1$	15	.01	3.40	.18
$U_1 \times W_2$	91	-.01	2.45	.07
$U_2 \times W_1$	15	-.01	3.33	.18
$U_2 \times W_2$	92	.01	2.42	.07
$P_1 \times U_1$	34	.09	3.10	.15
$P_1 \times U_2$	35	-.09	2.87	.15
$P_2 \times U_1$	36	-.04	2.72	.15
$P_2 \times U_2$	37	.04	2.76	.15
$P_3 \times U_1$	36	-.04	2.95	.15
$P_3 \times U_2$	35	.04	2.99	.15
$P_1 \times W_1$	10	.05	3.50	.22
$P_1 \times W_2$	59	-.05	2.47	.09
$P_2 \times W_1$	10	-.01	3.20	.22
$P_2 \times W_2$	63	.01	2.29	.09
$P_3 \times W_1$	10	-.04	3.40	.22
$P_3 \times W_2$	61	.04	2.54	.09

APPENDIX TABLE 18. ANALYSIS OF VARIANCE OF CALVES PRODUCED PER COW FOR ALL YEARS AND TREATMENTS IN THE PASTURE EXPERIMENT

Source	Herds 4, 5, 6, 7, 8, 9		
	df	Mean squares	F
Pastures (P)	2	.65	1.36
Supplement			
Urea (U)	1	.07	.15
Weaning (W)	1	22.40	47.21**
P x U	2	.40	.84
P x W	2	.06	.13
U x W	1	.01	.01
Residual df	203	.47	-

$^{**}P < .01$

APPENDIX TABLE 19. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF NUMBER OF CONCEPTIONS PER COW, ALL YEARS AND TREATMENTS (1973 TO 1977, 3.84 YEARS), PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	213	2.94	2.94	.07
Pastures (P)				
(1) Native	69	.06	3.00	.11
(2) Molasses	73	-.12	2.82	.11
(3) Native+molasses	71	.06	3.00	.11
Supplement (U)				
(1) None	106	.02	2.96	.09
(2) Urea	107	-.02	2.93	.09
Weaning (W)				
(1) 3 mo	30	.46	3.40	.12
(2) 9 mo	183	-.46	2.49	.05
$U_1 \times W_1$	15	-.02	3.40	.17
$U_1 \times W_2$	91	.02	2.52	.07
$U_2 \times W_1$	15	.02	3.40	.17
$U_2 \times W_2$	92	-.02	2.46	.07
$P_1 \times U_1$	34	.08	3.10	.15
$P_1 \times U_2$	35	-.08	2.91	.15
$P_2 \times U_1$	36	-.09	2.75	.15
$P_2 \times U_2$	37	.09	2.90	.15
$P_3 \times U_1$	36	.01	3.03	.15
$P_3 \times U_2$	35	-.01	3.00	.15
$P_1 \times W_1$	10	.04	3.50	.21
$P_1 \times W_2$	59	-.04	2.51	.09
$P_2 \times W_1$	10	.02	3.30	.21
$P_2 \times W_1$	63	-.02	2.35	.08
$P_3 \times W_1$	10	-.06	3.40	.21
$P_3 \times W_2$	61	.06	2.61	.09

APPENDIX TABLE 20. ANALYSIS OF VARIANCE OF ESTIMATED NUMBER OF CONCEPTIONS PER COW, PASTURE EXPERIMENT

	Number of conceptions per cow		
Source	df	Mean squares	F
Pasture (P)	2	.37	
Supplement (U)	1	.02	
Weaning (W)	1	21.43	47.6**
P x U	2	.54	1.2
P x W	2	.09	
U x W	1	.02	
Residual df	203	.45	

**P < .01

APPENDIX TABLE 21. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF ESTIMATED ABORTIONS PER COW ALL YEARS AND TREATMENTS, PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	213	.04	.04	.02
Pastures (P)				
(1) Native	69	-.03	.02	.04
(2) Molasses	73	.04	.08	.04
(3) Native+molasses	71	-.01	.03	.04
Supplement (U)				
(1) None	106	-.01	.03	.03
(2) Urea	107	.01	.05	.03
Weaning (W)				
(1) 3 mo	30	-.01	.03	.04
(2) 9 mo	183	.01	.05	.02
$P_1 \times U_1$	34	.00	.00	.05
$P_1 \times U_2$	35	.00	.03	.05
$P_2 \times U_1$	36	-.05	.02	.05
$P_2 \times U_2$	37	.05	.14	.05
$P_3 \times U_1$	36	.05	.07	.05
$P_3 \times U_2$	35	-.05	-.01	.05
$P_1 \times W_1$	10	-.01	.00	.07
$P_1 \times W_2$	59	.01	.03	.03
$P_2 \times W_1$	10	.03	.10	.07
$P_2 \times W_2$	63	-.03	.06	.03
$P_3 \times W_1$	10	-.02	.00	.07
$P_3 \times W_2$	61	.02	.06	.03
$U_1 \times W_1$	15	-.02	.00	.06
$U_1 \times W_2$	91	.02	.07	.02
$U_2 \times W_1$	15	.02	.07	.06
$U_2 \times W_2$	92	-.02	.04	.02

APPENDIX TABLE 22. ANALYSIS OF VARIANCE OF NUMBER OF ABORTIONS ALL YEARS AND TREATMENTS IN THE PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9 Number of abortions		
Source	df	Mean squares	F
Pastures (P)	2	.04	-
Supplement (U)	1	.01	-
Weaning (W)	1	.01	-
P x U	2	.17	3.4*
P x W	2	.02	-
U x W	1	.05	1.1
Residual df	203	.05	-

* $P < .05$

APPENDIX TABLE 23. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF CALF WEIGHTS (KG) AT 9 MONTHS (AGE ADJUSTED) FOR THE PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	319	163	163	2.3
Year (Y)				
(4) 1974	139	8	171	2.4
(5) 1975	102	0	164	2.5
(6) 1976	78	-8	155	6.1
Season (T)				
(1) Dry	151	11	174	2.1
(2) Early wet	106	-9	154	2.6
(3) Late wet	62	-2	162	6.2
Supplement (U)				
(1) None	163	-5	159	2.8
(2) Urea	156	5	168	2.8
Sex (S)				
(1) Male	165	6	169	2.7
(2) Female	154	-6	158	2.8
Breed (B)				
(1) Zebu	166	-3	160	2.7
(2) San Martinero	153	3	167	2.8
Pastures (P)				
(1) Native	101	1	164	3.1
(2) Molasses	106	-3	161	3.2
(3) Native+molasses	112	2	165	3.2
$Y_4 \times T_1$	72	0	182	2.9
$Y_4 \times T_2$	48	-5	157	3.5
$Y_4 \times T_3$	19	5	175	5.6
$Y_5 \times T_1$	27	-1	174	4.8
$Y_5 \times T_2$	34	-4	151	4.3
$Y_5 \times T_3$	41	4	167	3.9
$Y_6 \times T_1$	52	0	166	3.4
$Y_6 \times T_2$	24	9	155	5.0
$Y_6 \times T_3$	2	-9	144	17.3
$T_1 \times U_1$	74	0	169	2.9
$T_1 \times U_2$	77	0	179	2.9
$T_2 \times U_1$	56	-2	147	3.4
$T_2 \times U_2$	50	2	161	3.6
$T_3 \times U_1$	33	2	160	7.0
$T_3 \times U_2$	29	-2	164	6.9
$T_1 \times P_1$	51	-8	167	3.5
$T_1 \times P_2$	56	1	172	3.6
$T_1 \times P_3$	44	7	183	3.7
$T_2 \times P_1$	27	4	159	4.7
$T_2 \times P_2$	31	-3	149	4.5
$T_2 \times P_3$	48	-2	154	3.6
$T_3 \times P_1$	23	3	166	7.3
$T_3 \times P_2$	19	2	161	7.5
$T_3 \times P_3$	20	-5	158	8.1
$P_1 \times U_1$	51	4	163	4.1
$P_1 \times U_2$	50	-4	165	4.0
$P_2 \times U_1$	55	-6	150	3.8
$P_2 \times U_2$	51	6	172	4.3
$P_3 \times U_1$	57	2	163	4.0
$P_3 \times U_2$	55	-2	168	3.9

APPENDIX TABLE 24. LEAST-SQUARES MEANS, CONSTANTS, AND STANDARD ERRORS OF CALF WEIGHTS (KG) AT 18 MONTHS (AGE ADJUSTED), PASTURE EXPERIMENT

	Herds 4, 5, 6, 7, 8, 9			
	N	Constants	Least-squares means	Standard errors
Mean (MU)	237	199	199	2.0
Year (Y)				
1974	146	15	214	2.8
1975	91	-15	184	2.9
Season (T)				
(1) Dry	111	13	211	3.1
(2) Early wet	73	-3	195	3.2
(3) Late wet	53	-9	189	4.1
Supplement (U)				
(1) None	116	-2	196	2.7
(2) Urea	121	2	201	2.7
Sex (S)				
(1) Male	113	7	205	2.7
(2) Female	124	-7	192	2.7
Breed (B)				
(1) Zebu	119	-5	194	2.6
(2) San Martinero	118	5	204	2.8
Pastures (P)				
(1) Native	70	-13	186	3.6
(2) Molasses	86	10	208	3.3
(3) Native+molasses	81	3	202	3.0

APPENDIX TABLE 25. F VALUES FROM ANALYSES OF VARIANCE OF 9- AND 18-MONTH-WEANED CALVES, PASTURE EXPERIMENT

Source	Herds 4, 5, 6, 7, 8, 9 Ages of calves	
	9 mo	18 mo
Year of birth (Y)	4.39	54.34**
Season of birth (T)	18.15**	11.14**
Pastures (P)	.77	12.40**
Urea (U)	10.14**	1.43
Sex (S)	17.15**	14.51**
Breed of sire (B)	4.96**	7.82**
Y x T	1.23	6.39**
T x P	2.71	2.90
T x U	.73	.39
P x U	5.52**	.41
Residual df	297	218

**P < .01