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AID MINERAL RESEARCH PROJECT

Contract number AID/ta-c-1153 Reg
Fla.

RESEARCH IN MINERAL DEFICIENCIES FOR GRAZING RUMINANTS

UNIVERSITY OF FLORIDA
Institute of Food and Agricultural Sciences
Center for Tropical Agriculture
Department of Animal Science

ANNUAL REPORT

November 1, 1975 through November 1, 1976

Prepared by: Joe H. Conrad and Lee R. McDowell

REPORT SUMMARY

A. Statistical Information

1. Project Title and Contract Number:

   Research in Mineral Deficiencies for Grazing Ruminants

   AID/ta-c-1153

2. Principal Investigator, Contractor, and Mailing Address:

   Contractor's Project Officer: Dr. Hugh L. Popenoe

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   Cooperative Animal Nutritionists at University of Florida:

   H. D. Wallace, Chairman
   C. B. Ammerman
   John Bell, Technician
   H. L. Chapman
   J. F. Easley
   K. R. Fick
   R. H. Houser
   J. K. Loosli
   J. E. Moore
   R. L. Shirley

   Cooperating Graduate Students at University of Florida: Kiatoko Mangeye, Zaire; Soekanto Lebdosoekojo, Indonesia; Marcelo Mendes, Brazil; and Julio Cesar de Sousa, Brazil.

   Cooperating Animal Nutritionists from Latin American Countries: Listed in Appendix.

3. Contract Period (as amended): from November 1, 1974, to November 1, 1977.

4. Period covered by report: from November 1, 1975, to November 1, 1976.
5. Total A.I.D. funding of contract to date: $300,000.
6. Total expenditures and obligations through previous contract year: $106,700.69 (Actual to 12/31/75).
7. Total expenditures and obligations for current year: $190,000 (approximate to 12/31/76).
8. Estimated expenditures for next contract year: $153,300.

B. Narrative Summary of Accomplishments and Utilization

1. Reconnaissance and Recruitment Phase

a. Literature related to mineral analyses of soils-plants-animals in Latin America has been extensively reviewed. A summary of the information found in the published articles and a list of 269 references can be found in the appendix.

The majority of the Latin American papers established sporadic mineral deficiencies or toxicities on the basis of mineral response, levels of minerals in animal tissues, or forage mineral concentration. A brief review is as follows: All minerals for grazing ruminants have been infrequently and sporadically studied. Phosphorus is the most widely deficient mineral followed by cobalt and copper, but the extent of these deficiencies has not been defined because of inadequate research. Calcium deficiencies, except during peak lactation periods, appear to be rare. Inadequacies of magnesium, sodium, iodine, selenium, and zinc and toxicities of molybdenum, selenium, and fluorine have been encountered in widely diverse areas of Latin America, but all have been infrequently studied.

b. Personal contacts have been made through visits and correspondence with interested personnel in several Latin American countries. Active research is in progress in the Bahamas, Brazil Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, and Venezuela. Discussions are underway with interested personnel in Bolivia, Perú, and Uruguay. Visits to cooperating laboratories twice annually are necessary for stimulating mineral research.

c. A list of research personnel, country by country contracts, and research institutions are presented in the appendix. Linkages

and collaboration with other A.I.D. contracts, and national and international institutions include: in the Bahamas, BARTAD; in Brazil, EMBRAPA, EPAMIG, institutions in the states of Ceará, Minas Gerais, Mato Grosso, São Paulo, Rio Grande do Sul, and the Amazon Cattlemen's Association; in Colombia, ICA, CIAT, and Caja de Crédito Agrario; in Costa Rica, the University of Costa Rica and CONICIT; in Ecuador, INIAP; in El Salvador, Ministry of Agriculture (Ganadería), Universidad de El Salvador, and Centa; in Guatemala, INCAP; in Venezuela, Centro de Investigaciones Agronómicas, Universidad Central, Universidad de Oriente, and Universidad del Zulia.

d. Specific contributions of Latin American institutions compared to AID/Florida inputs are estimated to be 15-20:1. The project is conducting difficult analyses and is contributing professional expertise for design, implementation, and conduct of research, as well as interpretation of research data and also securing difficult to obtain chemicals, laboratory supplies, and expendable supplies for collection, preservation, and analysis of samples (details are given in the appendix).

2. Experimentation Phase

Experiments designed to pinpoint mineral deficiencies and toxicities for specific farms and regions are in progress in all participating countries. Three experiments completed in Costa Rica indicated that phosphorus was the mineral most frequently deficient. Blood serum phosphorus analyses showed that 61% of the steers from 15 farms were phosphorus deficient in one experiment and in another region 98% of the cattle from 17 farms were found to be phosphorus deficient. Of the total livers analyzed from the latter study, 23 and 27% were

borderline to deficient in copper (<75 ppm) and cobalt (<0.07 ppm), respectively. Liver iron (<180 ppm), zinc (<84 ppm) and Mn (<10 ppm) were lower than the reported normal levels for 63, 16, and 96%, respectively, of the total animals studied. New research data are being generated through experiments in all cooperating countries which are designed to determine the mineral deficiencies and toxicities and the mineral relationships between levels in soils, plants, and grazing ruminants.

In previous research, phosphorus supplementation has been shown to dramatically improve the low reproductive performance (i.e., Bolivia, Brazil, Colombia, Panamá, Perú, and Uruguay). Phosphorus supplementation as bonemeal in a two-year study in south Texas resulted in a weaned calf crop of 81% as compared to 58% for the controls. A study in Brazil resulted in a 77% calf crop when bonemeal was fed compared to 55% for the controls. Recent trials in the Colombian llanos demonstrated that the pregnancy rate was increased from 50% for the controls up to 84% when complete minerals were fed. Benefit to cost ratios have been at least 2:1 when phosphorus has been supplied to deficient cattle with low reproductive rates. Research is underway to verify the effect of phosphorus on reproduction under conditions existing in other regions and countries.

3. Distribution and Application of Results Phase

The "Latin American Symposium on Mineral Research with Grazing Ruminants" was held in Belo Horizonte, Brazil, on March 22-26, 1976. This symposium was jointly sponsored by Brazilian universities, research organizations, and the Florida/AID mineral project and each of the 250 participants from 10 countries received a copy of the proceedings in Portuguese at the beginning of the meeting. Brazilians presented

11 papers, University of Florida personnel 12 papers, and invited speakers 4 papers. This symposium was a major effort to stimulate research and update the available information on mineral deficiencies and toxicities in Latin America. The proceedings have been published in Portuguese and will soon be published in English and Spanish. Nearly 1500 copies of a manual on "Methods of Mineral Analysis for Plant and Animal Tissues" have been widely distributed in English Spanish, and Portuguese.

Articles on mineral deficiencies and toxicities have been presented at national and international scientific meetings. Limited research results have been published, but the majority of research is in progress.

4. Extension Phase

Three years of mineral research are insufficient to scientifically establish the mineral status of the major ruminant livestock producing regions of Latin America. Below are some of the reasons why a mineral research project for three more years is desirable:

a. Continue to determine the location of mineral deficiencies, adequacies and toxicites in selected areas of Latin America where grazing ruminants predominate.

b. Test the mineral research methodology by extending mineral research programs into one or two countries of Africa and Southeast Asia using those principles which have proven to be best in Latin America.

c. Continue research on soil-plant-animal mineral relationships for diagnosis of mineral status of grazing ruminants.

d. Determine the cost/benefit ratio from the effect of supplemental phosphorus and other minerals on reproduction and gains.

e. Continue research to determine validity of different methodologies for establishing mineral status of grazing ruminant animals.

f. Continue to improve Latin American institutions capacities to carry out mineral research.

g. Continue a few well controlled mineral supplementation studies at experiment stations.

h. Determine effect of phosphorus supplementation during the rainy season and the carryover effect from periodic mineral supplementation especially phosphorus.

i. Continue field trials to determine best methods to counteract molybdenum and selenium toxicity.

j. Continue to generate accurate data which can be used to designed adequate mineral supplements for different regions where grazing ruminants are important.

k. Continue to improve a systematic approach for standardizing sample collections, analyses, and methods of reporting data.

l. Continue to publish and distribute research information in order to stimulate the widespread use of mineral supplements.

m. Continue to evaluate mineral supplements and to encourage mineral supplement companies, researchers, and ranchers to formulate, produce, and use high quality and nutritionally adequate mineral supplements.

n. Publish producer oriented extension bulletins on mineral deficiencies and toxicities for grazing ruminants (in Spanish, Portuguese, and English).

5. Research Methodology

Research methodology is being studied which will permit rapid

determination of the mineral status of ruminant livestock populations. An accurate review of the mineral status in a specific region will permit prescribing mineral supplements for correcting deficiencies and toxicities. Mineral status varies with soil type, forage species, age, and physiological function of animal.

The following research techniques are being studied as integral parts of the research methodology.

a. Tissue collection and analyses

Kinds of material: soil, plant, and animal tissues

Physiological state of plants and animals

Kinds of animal tissue: blood, liver, bone, milk, saliva, feces

Sampling technique: liver biopsy of live animal or slaughter animal for liver sample

Locations: farms and centralized commercial slaughterhouses

Season of Year: wet, dry

b. Mineral supplementation

The duration of the majority of mineral supplementation experiments is at least 2 years. Phosphorus supplementation to increase low reproductive rates is being emphasized. Some isolated experiments have shown that a 50 to 55% calf crop can be increased to 75 to 80% by correcting the phosphorus deficiency. Supplementation studies are the most important for the livestock producer, but they are also the most difficult to control and conduct. A few well controlled experiments on experiment stations along with a number of trials on cooperating ranches are being conducted.

6. <u>Contribution to Institution Building</u>

This project has made and is continuing to make excellent progress toward increasing cooperating laboratories' capability to do mineral

analyses. A manual on "Methods of Mineral Analysis for Plant and Animal Tissues" has been distributed to all cooperating laboratories in one of three languages - English, Spanish or Portuguese. This publication standarizes procedures for sample collection, identification, and analysis. Two visiting scientists have spent 3 months each studying mineral research techniques at the University of Florida. Three technicians have spent two weeks each at University of Florida specifically on laboratory techniques. Project personnel have visited all cooperating laboratories for periods of from one day to one week to discuss and demonstrate laboratory techniques. One or more laboratories in each country are currently conducting all mineral analyses, except cobalt and selenium, and these laboratories are serving as training centers for laboratory technicians throughout the country.

Several different experimental designs have been prepared and discussed with cooperating country personnel. From these, a satisfactory experimental design has been developed for each of their experimental situations.

All phases of this project have been conducted in complete cooperation with indigenous and international research organizations. These have been listed under section 1c and a list of the cooperating personnel can be found in the appendix.

7. Utilization Plans

The ultimate objective is to have livestock producers use nutritionally formulated mineral supplements to correct mineral deficiencies. Results of the research to date have been presented at ALPA (Latin American Society of Animal Production), American Society of Animal Science, Latin American Livestock and Poultry Conference, Symposium on Mineral

Research in Latin America, and at numerous national livestock meetings. Popular articles are being written regarding the value of using mineral supplements.

Mineral supplements are being evaluated and we are finding that few, if any, contain proper amounts of all of the required minerals. Phosphorus is the most deficient and also the most expensive. Therefore, many mineral manufacturers formulate phosphorus deficient supplements. Livestock producers are being informed concerning nutritionally adequate mineral supplements and how they should be used.

ANNUAL RESEARCH REPORT

A. General Background

Mineral deficiencies have been identified as one of the major factors limiting cattle production throughout Latin America. Although Latin America has 21% of the world's cattle, the annual slaughter rate is about 12% compared to 38% in the United States.

Many of the reasons for the low levels of cattle production are nutritionally related.

1. Reproductive performance of cattle is low and average calving rates are usually between 35 and 50% compared to 85% average in the U.S. Research in Brazil showed that the controls had an average calf crop of 55% as compared to 77% for those fed bonemeal, an increase of 22% from the feeding of phosphorus from bonemeal.

2. Most evidence indicates that the mortality rate for beef cattle in Latin America is at least 12 to 15% compared to 5 to 6% in the U.S. These high mortality rates occur primarily during the first 3 months of life and during the first dry period post weaning. Mineral and other nutritional deficiencies are directly and indirectly a major cause of mortality.

3. Slow development of cattle to market weight is illustrated by the fact that they reach 400-450 kgs in approximately five years. Numerous studies have shown increased gains, from mineral supplementation in Latin America. A recent study in the high altitude grasslands of Ecuador showed daily gains of 80 g. per day prior to mineral supplementation as compared to 212 g. per day after.

Chemical analyses of feedstuffs gathered under the University of Florida Latin American Feed Composition Project (AID/csd-2498) have

revealed that an extremely small number of laboratories are actively engaged in performing trace mineral determinations.

B. Statement of Project Objectives as Stated in the Contract

The objective of this research contract is to determine the essential mineral supplements for grazing animal diets to increase the efficiency of Lesser Developed Countries' (LDC) meat and milk production systems with a resultant increase in quality and quantity of LDC diets and a subsequent increase in employment and income levels.

The Contractor shall establish collaborative research activities in Latin American countries that have institutional and scientific capability to carry out this research project. These countries shall include Brazil (Empresa Brasileira de Pesquisa Agropecuria, Brasília, and Belo Horizonte); Ecuador (Instituto Nacional de Investigaciones Agropecuarias, Santa Catalina); Colombia (Centro Internacional de Agricultura Tropical, Cali, and Instituto Colombiano Agropecuario, Bogotá); and Costa Rica.

Selection of additional countries shall be made in consultation with the AID/W Project Officer and not limited to those countries specified in the foregoing.

This research will be carried out 1) to experimentally determine the locations of mineral deficiencies, adequacies and toxicities in selected areas of Latin America where grazing livestock predominate; 2) to establish by experimentation the biological response and economic benefit of mineral supplementation to grazing animals; 3) to experimentally evaluate methods of mineral supplement administration for grazing cattle; and 4) to publish and distribute research information in order to stimulate the widespread use of mineral supplements. The work to be undertaken has been separated into the following phases:

1) Reconnaissance and Recruitment Phase, 2) Experimentation Phase, and 3) Distribution and Application of Results Phase as follows:

1. Reconnaissance and Recruitment Phase

To carry out the Reconnaissance and Recruitment Phase, the literature on grazing cattle must be evaluated and, also, contacts in participating countries must be established by both correspondence and personal visits. In each country under consideration, previous research on mineral concentrations of soils, forages, and animal tissues, in addition to reports of clinical signs of plant and animal mineral deficiencies at specific locations, will be evaluated to determine the highest priority for cooperative mineral research projects.

Research institutions and personnel shall be located that have the ability and desire to carry out the proposed mineral research. Laboratory equipment and the methods of analysis for each mineral shall be determined by the contractor. The specific contributions of both the Latin American institutions and the University of Florida to the mineral research program shall be clearly established. This phase shall be completed and AID advised within 4 months from initiation.

2. Experimentation Phase

The experimental field work shall be initiated and carried out during this phase. The experimentation phase shall consist of two separate phases; the Tissue Collection Phase and the Mineral Supplement Phase. During the Tissue Collection Phase, tissue samples (liver, blood, and bone) shall be collected from cattle ranches and slaughterhouses. Analyses of these tissues shall pinpoint mineral deficiencies and toxicities for specific farms and regions within the participating countries. Soil and forage analyses on farms and

ranches from which the animals originate shall permit development of soil-plant-animal relationships with respect to minerals and other nutrients as well as toxic elements. Following the Tissue Collection Phase, a Mineral Supplement Phase shall clearly demonstrate production and economic benefits from mineral supplementation. In addition to establishing appropriate mineral supplement mixtures, methods of mineral administration in specific cattle producing regions shall be investigated. Both the Tissue Collection Phase and the Mineral Supplement Phase shall be initiated in Brazil, followed by Ecuador and Colombia. The exact sites for experimentation within each country shall be decided in cooperation with the Ministry of Agriculture of Brazil, INIAP (Instituto Nacional de Investigaciones Agropecuarias) of Ecuador, and ICA (Instituto Colombiano Agropecuario), and CIAT (Centro Internacional de Agricultura Tropical) of Colombia, based on criteria established in the Reconnaissance and Recruitment Phase. It is anticipated that a large percentage of the analyses required herein will be carried out at the University of Florida

3. Distribution and Application of Results Phase

Experimental results shall be distributed to farmers, government officials and scientists. Results shall be published in both scientific journals and in one- to two-page summaries suitable for distribution to farmers through local livestock organizations where available in each country and through other means considered appropriate by the Contractor and/or the A.I.D. Research Specialist. Publications reporting this research shall be based on maps that establish mineral status of cattle producing regions within participating countries. In addition, publications shall recommend mineral mixtures suitable for specific areas.

Results of the experimental findings shall be presented at local Latin American short courses in conjunction with annual and semi-annual livestock meetings in each country in addition to national and international scientific meetings.

C. Continued Relevance of Objectives

The project objectives as stated in the contract are still relevant. Many individuals and institutions recognize the importance of mineral research. However, a large number of organizations lack equipment, methods, or techniques of analysis and technicians that can carry out mineral research programs. In order to improve the institution capacity to carry out mineral research, the AID-Florida contract is providing various types of assistance. Publication of the manual entitled "Methods of Mineral Analysis for Plant and Animal Tissues" has provided a systematic approach for standardizing sample collections, analysis and methods of reporting data.

An overall objective of the mineral research program is to encourage the use of mineral supplements. It is increasingly clear, however, that it is not enough to stimulate the widespread use of mineral supplements, but to insure that these supplements are adequate to meet the requirements of grazing animals. Often farmers believe that they are providing adequate mineral supplements for their livestock, but in reality the mineral supplements used are extremely inadequate.

More emphasis needs to be given to training people to do mineral research. People are frequently available who have nutritional and laboratory experience. However, these people often need short-term training in mineral research techniques. More of this kind of training is needed.

D. Accomplishments to Date

1. Findings: The activities under this research project were separated

into three phases and the findings will be discussed as follows:

a. Reconnaissance and Recruitment Phase:

1) A complete search of the literature on mineral research in Latin America was conducted at the Hume Library, University of Florida, Inter-American Center for Agricultural Documentation and Information (CIDIA) located at CATIE, Turrrialba, Costa Rica. Visits were made to a number of research organizations throughout Latin America. A total of 269 articles from journals or other publications were reviewed.

Mineral research information has been summarized in two major publications. "Mineral Deficiencies and Toxicities and their Effect on Beef Production in Developing Countries"was presented at a conference in Edinburgh, Scotland, and published in the proceedings, Beef Cattle Production in Developing Countries, edited by A. J. Smith. This publication contained 176 references concerning the incidence of mineral deficiencies or toxicities in the tropical countries. A second publication "Current Status of Mineral Research in Latin America" was presented at the Latin American Symposium on Mineral Research with Grazing Ruminants. This paper contained 269 references and summarized all the published mineral research pertinent to grazing ruminants in Latin America. The proceedings were published in Portuguese and will be published in English and Spanish.

Brief summary of review of literature: The most widespread mineral deficiency for grazing livestock is that of phosphorus. Calcium deficiencies are rare under grazing conditions. This fact is especially important since many old texts used in Latin America have given greater importance

to calcium than experimental evidence indicates.

Copper and cobalt deficient areas are likely to extend over wide areas of Latin America, but their limits are impossible to define because of inadequate research. Inadequacies of magnesium, sodium, iodine, selenium, and zinc and toxicities of molybdenum, selenium and fluorine have been encountered in widely diverse areas of Latin America but all have been infrequently studied.

Forages rarely provide all the mineral requirements of grazing cattle. Therefore, it is a highly recommended practice to provide adequate mineral mixtures to assure the necessary intake of the elements needed.

2) Project personnel made frequent trips to visit interested research people in several Latin American countries. Currently active research is in progress in Bahamas, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, and Venezuela. Discussions are in progress with Bolivia and Uruguay. Project personnel have been discouraged from stimulating mineral research in Paraguay because of AID project priorities.

During most of the time covered by this report, project personnel were as follows:

3 full time Animal Nutritionists

8 part-time Animal Nutritionists

1 full time laboratory technician

1.5 bilingual secretary equivalents

4 graduate students

b. Experimentation phase: a brief discussion of the research program in each country is as follows:

Bahamas

AID/TAB Washington requested that we cooperate with Dr. Frank Madden at the Bahamas Agricultural Research Training and Development Project (BARTAD), San Andros P.O., North Andros Island, Bahamas. We have sent polyethylene bottles containing 10% formaldehyde along with copies of the manual on "Methods of Mineral Analysis for Plant and Animal Tissues." Dr. Madden is collecting the liver samples and sending them to Florida where they will be analyzed for cobalt, copper, selenium, and manganese.

Brazil

The Latin American Synposium on Mineral Research with Grazing Ruminants was held at Belo Horizonte on March 22-26, 1976. This symposium was jointly sponsored by the Federal Universities of Minas Gerais and Viçosa, the state research institution for Minas Gerais (EPAMIG), the School of Agriculture at Lavaras, and the University of Florida/USAID Mineral Research Project. Twenty-seven papers as outlined in the Appendix were presented at this conference. University of Florida faculty wrote 12 papers, Brazilians wrote 11 papers, Dr. D. J. Thompson, International Minerals and Chemical, wrote three papers and the final paper was presented by Dr. B. D. H. Van Niekerk, Voermol Products, South Africa.

Travel and per diem for all speakers outside of Brazil other than Dr. Thompson were paid for from project funds and all papers written in English were translated to Portuguese by Brazilian students at the University of Florida. Each of the 250 participants received a copy of the proceedings in Portuguese at the beginning of the symposium. Participants

were from Brazil, El Salvador, Perú, México, Argentina, Paraguay, Colombia, Chile, South Africa, and the United States.

The success of the symposium was summarized by Dr. William Ferguson of FAO in his report to the Acting Regional Representative for Latin America. Quotations from his report are as follows: "This symposium achieved a high level of success regarding: (a) It succeeded in bringing together for the first time a very substantial quantity of information on the subject of mineral deficiencies and toxicities in Latin America and provided some of the guidelines needed for effectively correcting some of these; (b) It clearly contributed to generating the keen interest necessary to stimulate mineralization needs and strategies in the region; (c) It has already yielded a volume of printed proceedings, which will make an important contribution to Animal Science teaching throughout Latin America."

The AID/Florida Mineral Research Project is cooperating with several different research groups in Brazil and these will be briefly outlined below.

The Amazon Cattlemen's association in cooperation with the Biological Institute and Secretary of Agriculture in São Paulo are collecting samples, conducting research, and analyzing plant and animal tissue, samples from 35 ranches in the Amazon region.

Marcelo Mendes and Julio Cesar de Sousa with the cooperation of EMBRAPA and The Amazon Cattlemen's Association have made two trips to Brazil to collect soil, forage, and animal tissue samples from 6 ranches in the Amazon region. Both students are analyzing these samples to be used in their Ph.D.

dissertations here at the University of Florida.

Dr. Jorge Lopes and Dra. Olga Gavillon of the Secretary of Agriculture and Dr. Enio Prates of the Federal University are developing a cooperative mineral research project in Rio Grande do Sul.

Dr. George Hall of the Federal University of Santa Maria and his collaborators are studying the effects of selenium-vitamin E injections on sheep and cattle in the Livramento area of Rio Grande do Sul.

Drs. Carneiro Viana, Roberto da Silva and Norberto Rodríguez are developing a mineral research emphasis at the Veterinary School at Belo Horizonte. The latter two men have each spent 3 months at the University of Florida developing research and analytical techniques. They are concentrating their mineral research effort in central Brazil.

Dr. José Adalberto Gadêlha at the Federal University of Ceará, Fortaleza, and his group are collecting and analyzing forage and animal tissue samples from five different areas of the state of Ceará in northeast Brazil. Cobalt deficiency is thought to be widespread, but no supplemental trials have been conducted. Dr. Karl Fick, University of Florida, spent one week at Fortaleza instructing the group there on mineral analysis techniques.

Colombia

A research program between CIAT and the University of Florida has been in progress since March, 1975. Mr. Soekanto Lebdosoekojo has been working on a Ph.D. research program at the Carimagua Experiment Station entitled, "Mineral Supplemen-

tation of Breeding Cattle in the Colombian Llanos." Soil, animal and forage samples were collected from the Herd System Project and they are currently being analyzed.

A cooperative mineral research program between ICA and the AID/University of Florida contract has been in progress since July, 1975. Mineral research is in progress at each of eight ICA experiment stations. Two treatment groups are being used which are with and without mineral supplement and every three months liver biopsy, blood, and forage samples are collected. Todate, some 500 liver samples have been analyzed for copper, iron, magnesium, manganese, and zinc and 900 blood samples have been analyzed for calcium, copper, magnesium, phosphorus, and zinc. Final conclusions cannot be drawn at this time, but it appears that copper is borderline to deficient.

A selenium toxic region outside of Bogotá near Puerto Boyaca is being studied. Cattle receiving a mineral supplement containing arsenic and sulfate have average daily gains twice that of the control animals.

Four mineral supplementation experiments are in progress or proposed, two are in the Medellin Region of Colombia and two are in the Montería (Caucasia) Region. The three treatments are control (salt only), salt + phosphorus and a complete mineral mixture. All experiments are with pregnant heifers and will be for 1 1/2 to 2 years. Samples to be collected are liver biopsy, blood, forage, soil, and minerals fed.

Costa Rica

The mineral research program in Costa Rica has been one of the most active todate. One thesis by Carlos Lang entitled, "Phosphorus and Trace Mineral Status of Beef Cattle in the Guanacaste Region of Costa Rica," has been completed. Blood and liver samples were taken from 3 to 4 year old steers sold from 15 farms located in five counties of the Guanacaste region. Sixty-one percent of the blood samples had serum phosphorus values which were borderline to deficient. Approximately 40, 21, 63, 33, and 24 percent of the livers analized were borderline to deficient in copper, iron, manganese, selenium, and zinc, respectively.

Another M.S. thesis was completed in June, 1976, by Kiatoko Mangeye. Ten liver and five blood samples were collected from steers on each of 12 farms in four districts with two soil type regions. Mean serum phosphorus concentrations were deficient (<4.5 mg %) for all farms. Of the total livers analyzed, 23, 5, 63, 96, and 38% were borderline to deficient in Cu (<75 ppm), Zn (<84 ppm), Fe (<180 ppm), Mn (<10 ppm), and Co (<.06 ppm), respectively. Research also suggested that low mineral intake was partially responsible for the adverse effects of oxalate from *Setaria sphacelata* pasture.

The Agronomy Faculty recently received funds from CONICET which are to be used for the mineral research program. In addition, twelve Peace Corps volunteers will devote a great deal of time to collecting liver, blood, and forage samples from selected regions of Costa Rica. Professor Hernán Fonseca plans to conduct mineral studies of the major regions of Costa Rica.

University of Florida/AID is contributing $7,000 per year for two years to assist with the mineral analyses.

Ecuador

INIAP is in charge of all research in Ecuador and we have been working closely with their personnel. They are interested in five specific types of studies as follows:

1) Determination of the chemical and nutritive value of the principle forage species in the inter-andean region. Recent research showed that cattle gained 80 g/day before mineral supplementation and 212 g/day after mineral supplementation.

2) Determination of the levels of macroelements in relation to reproduction in cattle in the Machachi Valley and the Santa Catalina Experiment Station. Limited data indicates that manganese blood levels were significantly lower for cattle with reproductive problems. Further experiments with improved design were suggested to verify this observation.

3) Sulfur research at Santa Catalina. Response to sulfur fertilization has been obtained, but the sulfur effect on animals needs to be studied. Limited research has indicated improvement following the feeding of sulfurized salt blocks.

4) Mineral status of cattle in the coastal region. Four farms were selected in the Pichilingue area, three of which do not use mineral supplements.

5) Response to selenium - vitamin E injections in the Santo Domingo region. Six farms were selected in this area because of the widespread incidence of "white muscle" disease. Injections will be given to between 50 to 100 cows on each

farm.

El Salvador

The mineral research program in El Salvador was very slow in starting, but currently considerable progress is being made. Dr. Ferdinando Perla, Ministry of Agriculture, is chairman of the mineral research program in El Salvador.

The University of El Salvador has the responsibility for analyzing the animal tissues because they have the experience and a Perkin-Elmer 303 Atomic Absorption Spectophotometer. The technician responsible, Lic. Margoth Oldemia Palma, spent two weeks in August at the University of Florida studying the most recent techniques.

CENTA has the responsibility for all of the forage and soil analyses because they have the experience and a Perkin-Elmer 303, but will receive a Perkin-Elmer 500 series soon with a graphite furnace attachment.

During the next two years, the research organizations of Ganaderia, CENTA, and the University of El Salvador will dedicate a considerable portion of these resources to mineral research. As many as 10-12 man years may be put into this program during the next 2 years. Research is currently being concentrated on 12 ranches where 120 liver biopsies had been obtained as of August 23, 1976, without any problems.

The University of Florida is supplying difficult to obtain expendable laboratory materials plus $4,000 per year.

Guatemala

The mineral research program in Guatemala started in January, 1976, which involves collecting animal tissues and

forage samples from two ranches. One ranch is located on the southeastern coast of Guatemala and one near Sonsonate, El Salvador. Both ranches have some problems which appear to be minerally related and involves both beef and dairy cattle.

Our contacts are with INCAP: Their laboratory has a Perkin-Elmer 305 Atomic Absorption Spectrophotometer with a graphite furnace and a fluorometer for conducting selenium analyses. The Florida/AID program is providing $6,000 per year for two years. Dr. Marco Tulio Cabezas is in charge of the mineral research program and Ing. J. Antonio Flores, a recent M.S. graduate from INCAP, is working full time on the program.

Venezuela

Contacts were not made until December, 1975, concerning cooperative mineral research. Three research groups are interested in investigating the mineral status of cattle in Venezuela. Dr. Claudio Chicco and his research group at Maracay plan to study the central region of Venezuela, which include four distinct areas in the llanos in which the efficiency of production is low.

Ing. David Morillo plans to use these results toward a M.S. degree at the University of Florida.

The veterinary and agronomy faculties at the University of Zulia are interested in studying the mineral status of cattle in the Lake Maracaibo region. They plan to collect soil. forage, and animal tissue samples from three ranches each in four different regions.

Dr. José a Velasquez at the Universidad de Oriente,

Jusepin, plans to study the mineral status during different physiological states of cattle in three states of eastern Venezuela.

Difficult to obtain supplies for conducting this research has been forwarded to them.

2. Interpretation of Data and Supporting Evidence: Available research data indicates that phosphorus is the most widespread mineral deficiency for grazing livestock. Calcium deficiencies are rare under grazing conditions and this is an important fact because many older textbooks in Latin America emphasize calcium deficiencies rather than phosphorus.

Copper and cobalt deficient regions extend over wide areas of Latin America, but these areas are poorly defined. Inadequacies of magnesium, sodium, iodine, selenium, and zinc, and toxicities of molybdenum, selenium, and flourine are encountered in diverse areas of Latin America.

The soil-plant-animal relationship helps to make the interpretation of mineral research data complex. In addition, the many soil types and forage species necessitate an intensive mineral research effort. The mineral papers in the Appendix emphasize the data which is available and the need for more specific data.

3. Research Design: Currently we are cooperating with mineral research in eight countries and each country has a number of different regions. Research people in these countries have certain problems and priorities. We are making a major effort to assist each country in developing and applying acceptable mineral research design and scientifically based research techniques.

Research emphasis is being placed on regions where reported "problem" areas exist which suggest mineral deficiencies or toxicities. This approach is more feasible than attempting to map large areas where deficiencies or toxicities are not apparent. As a result, em-

phasis has been placed on the following "problem" areas:

a. Costa Rica, Guanacaste (low production) and San Carlos high forage oxalates.

b. Colombia, central selenium toxic and llanos (low production).

c. Ecuador, highlands sulfur deficient and western selenium deficiency.

d. Brazil, Mato Grosso apparent mineral deficiency or toxicity and Ceará cobalt deficiency.

e. Venezuela, llanos low production.

Sample collection and preservation under field conditions are problems. Separation of the serum or plasma from whole blood without hemolysis under field conditions is difficult. Collecting forage samples which represent what the animals consume is nearly impossible. Logistics of carrying on field research at locations distant from research institutions is complicated. However, we were aware of these at the beginning and better methods of improving sample collection, storage, and analysis are constantly being evaluated. Many worthwhile research publications in Latin America such as theses and symposia proceedings are not readily available to libraries and abstracting journals.

E. Dissemination and Utilization of Research Results

More than 1000 copies of the manual entitled "Methods of Mineral Analysis for Plant and Animal Tissues" are being distributed in English, Spanish, and Portuguese throughout Latin America and other regions of the world.

Nearly 500 copies of the proceedings entitled "Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants" have been distributed in Portuguese throughout Brazil. As soon as the translations to English and Spanish are complete, 2000 to 3000 copies

will be printed for distribution. Other articles have been presented at symposia and scientific meetings and have been widely distributed.

1. This project has stimulated tremendous interest in the mineral problems of grazing ruminants in the Latin American countries in which we have cooperated. Research, extension, producers and commercial personnel have known they had problems, now they see the possibility of finding the correct solution to these problems.

All personnel directly associated with the mineral project are constantly answering questions concerning formulation of mineral mixtures and the correct use of mineral mixtures.

It is significant and noteworthy that organizations not directly involved with the AID/Florida contract request information on methods and procedures for mineral research.

Most of the information which is being distributed has direct application and we see evidence that this information is being applied as we travel within the cooperating countries.

2. A cooperative mineral research symposium attended by 250 people was our most effective way to expand the use of research results. For five days these participants heard and discussed mineral research results and mineral problems. Many people are interested in finding the solution to mineral problems. This project has encouraged them, provided standard techniques and provided some materials for them to get started. We frequently find the following situation: They have the interest and many of the materials for doing mineral research Governmental personnel recognize that minerals are limiting, but this is not a top priority. Research reviews and sample research designs are provided by the University of Florida. This information along with personal visits is often sufficient to stimulate an incountry mineral research program. By starting with the areas where mineral

problems are clearly evident, there is a good possibility that the solution can be found and that it will be applied by the livestock producers in the area.

Mineral research in Latin America is an extremely ambitious program. We are currently working in only eight countries and some of these programs are just beginning to gather momentum. We would like to expand this program into other countries as time, personnel and funds permit. It requires several years of concentrated effort to identify and correct these mineral problems. Consequently, we consider the greatest priority to be an extension in time of the current contract.

3. All research in progress is in full cooperation with LDC personnel and institutions within the respective countries. During the reconnaissance and recruitment phase of this contract only interested personnel at institutions capable of supporting mineral research were selected. The majority of both human and physical resources for mineral research are provided by the cooperating countries.

a. Planning the project. This mineral research program does not have a standard research plan that can be used in every country. However, we do have models which personnel can modify to best coincide with their specific conditions in their own country.

b. The execution of the field work. Limited human and financial resources are available within the framework of this project. What is available is used primarily to supply technical information and ideas, expendable materials which are difficult to obtain within the cooperating country and seed money with which to initiate mineral programs.

c. The analysis and reporting of results. Data generated within each country is the property of this country. The University of Florida assists with the analysis, interpretation, and

summary of data as requested. Permission must be obtained in writing and credit given as co-author and cooperating agency when applicable.

4. Representative publications and abstracts of the research program can be found in the Appendix. Under separate cover four copies of other publications are being forwarded.

G. Work Plan and Budget Forecast for Coming Year

1. Each of the eight cooperating countries are in a different stage of their mineral research programs. Comparatively speaking the most effort in relation to size of country is in Costa Rica and Colombia. Cooperating with eight countries is a modest beginning, yet significant progress has been made.

Anticipated accomplishments for the coming year include initiating research programs in other countries, analyzing samples for mineral concentrations, analyzing and interpreting data, and publishing results. At least two trips are needed to each country annually in order to adequately supervise and encourage the mineral program.

2. Procedures to be used and activities to be carried out include the following: Publish the symposium proceedings "Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants" in English and Spanish.

Distribute the manual "Methods of Mineral Analysis for Plant and Animal Tissues" in Spanish to appropriate persons and institutions.

Provide personnel and facilities at the University of Florida tohelp train 4 to 6 technicians during 1 to 3 months in analytical procedures for mineral analyses.

Continue to improve analytical methods for analysis of selenium, cobalt, molybdenum and sulfur and update laboratory manual.

Encourage and assist cooperating country personnel to publish result and write publications for the producers.

Work with producers and companies in the formulation and feeding of mineral supplements.

Continue to stimulate mineral research through correspondence, publication of popular articles and the attendance at conferences,

seminars, and workshops.

Make personal visits to cooperating countries twice annually and provide limited financial resources and difficult to obtain expendable materials.

3. Cooperating country personnel and the degree of commitment by their governments are the principle factors which will promote or impede accomplishments. Mineral programs in the cooperating countries will progress in relationship to the number of dedicated scientists working in the mineral program and the support which they obtain from their host governments and industry.

4. Dissemination and utilization of expected research results will continue to be emphasized through publications, field days, conferences, seminars and workshops. Approximately 2,500 copies of the Latin American Symposium on Mineral Research with Grazing Ruminants will be distributed in Spanish and English. The manual "Methods of Mineral Analysis for Plant and Animal Tissue" will continue to be distributed in Latin America and other parts of the world in English, Spanish, and Portuguese.

The majority of the individual country research information will be written in Spanish and Portuguese which will be published locally and regionally. It is anticipated that this information will be presented at meetings of ranchers and producers whenever appropriate.

Producers are seeking economical ways of increasing the level of production and correcting mineral deficiencies has been shown to return at least $2.00 for every dollar invested in many studies.

5. Budget Statement:

Cost Proposal for Mineral Deficiencies and Toxicities for Grazing Ruminants in Latin America
November 2. 1976 - November 1, 1977

		Man-Months	Estimated Cost
I.	Salaries		
	A. U. S. Personnel		
	Home Office Personnel		
	Assistant Professor	12	$ 21,600.00
	Short Term	2	4,000.00
	Home Office Nonprofessional		
	Laboratory Technician	12	8,220.00
	Secretary	12	6,500.00
	Research Associate (1/2 Time)	6	4,840.00
	Total U.S. Salaries		$ 45,160.00
	B. Cooperating or Third Country Nationals		
	Field Staff Nonprofessional		
	Latin American Technician	24	14,000.00
	Total Salaries		$ 59,160.00
III.	Fringe Benefits		
	State Retirement (9.0% x 40,320)		$ 3,629.00
	Unemployment Compensation (.6% x 45,160)		271.00
	Social Security (5.85% x 32,220)		1,885.00
	Medical Insurance (13.50/mo x 36)		486.00
	Total Fringe Benefits		$ 6,271.00
IV.	Overhead		
	Home Office (51% x 51,431)		$ 26,230.00
	Field Staff (29% x -0-)		-0-
	Total Overhead		$ 26,230.00
V.	Travel and Transportation		
	U.S. Travel (1 RT ticket)		$ 300.00
	International (13 RT @ 750 average/trip)		9,750.00
	Total Travel and Transportation		$ 10,050.00
VI.	Allowances		
	Per diem - U.S. (15 days @ $33/day)		$ 495.00
	- International (130 days @ various rates)		5,200.00
	Total Allowances		$ 5,695.00
VII.	Other Direct Costs		
	Bilingual Secretary (Contractual Agreement)		$ 5,000.00
	Total Other Direct Costs		$ 5,000.00
VIII.	Equipment, Vehicles, Materials and Supplies		
	Material and Supplies		
	Postage, phone & Misc. office supplies		$ 5,000.00
	Computer rental		1,000.00
	Chemical supplies		10,594.00
	Publishing & Printing Costs (2 books)		21,000.00
	Total Equipment, Vehicles, Materials and Supplies		$ 37,594.00
	GRAND TOTAL		$ 150,000.00

H. Appendix

1. Contacts visited in Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, and Venezuela.
2. Titles and authors of papers presented at the Latin American Symposium on Mineral Research with Grazing Ruminants, Belo Horizonte, Brazil, March 22-26, 1976.
3. Bibliographic list of abstracts of papers and publications other than symposium papers.
4. Loosli, J. K. 1976. Mineral problems as related to tropical climates presented at the Latin American Symposium on Mineral Research with Grazing Ruminants, Belo Horizonte, Brazil, March 22-26, 1976.
5. Mangeye, K., L. R. McDowell, K. R. Fick, H. Fonseca, J. A. Camacho, J. K. Loosli, J. H. Conrad, and R. H. Houser. 1976. Mineral status of cattle in San Carlos, Costa Rica. J. Anim. Sci. 43:328.
6. Lang, C. E., L. R. McDowell, and J. H. Conrad. 1975. Estado mineral del ganado en Guanacaste, Costa Rica. 5a Reunión Latino Americana de Producción Animal, Maracay, Venezuela, Dic., 1975.
7. Fick, K. R., L. R. McDowell, and R. H. Houser. 1976. Current status of mineral research in Latin America. Latin American Symposium on Mineral Research with Grazing Ruminants, Belo Horizonte, Brazil, March 22-26, 1976.
8. McDowell, L. R., K. R. Fick, R. H. Houser, J. H. Conrad, and J. K. Loosli. 1976. Meeting mineral requirements for grazing livestock in the tropics. Symposium on Feed Composition, Animal Nutrient Requirements and Computarization of Diets, Logan, Utah, July 11-16, 1976.

9. Conrad, J. H., 1976. Phosphorus supplementation for increasing reproduction in cattle. Ruminant Livestock Production System Seminar, Georgetown, Guyana, March 1, 1976.

10. Annual Estimated Cost of Mineral Reserach in Latin American Countries.

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Latin American Symposium on Mineral Research with Grazing Ruminants

Belo Horizonte, Brazil
March 22-26, 1976
(Listed in Order of Presentation)

1. Mineral Problems as Related to Tropical Climates, J. K. Loosli (Florida) and Antonio Carlos Guedes (UF Santa Maria).

2. Classification and Distribution of Tropical Soils, Raimundo Costa de Lemos (OESA and SEEBIA - Rio de Janeiro).

3. Methods of Analyzing Soil Fertility, José Mario Braga (UF Viçosa).

4. Properties of Soil which Affect the Availability of Minerals for Plants and Animals, S. J. Volkweiss (UFRGS - Porto Alegre).

5. Mineral Composition of Tropical Grasses and Forage Legumes, José Alberto Gomide (UF Viçosa).

6. Water as a Source of Minerals, R. L. Shirley (Florida) and Jose Herculano de Carvalho (MA, Teresina, PI).

7. Magnesium in Ruminant Nutrition, J. A. Carneiro Viana, (UF Minas Gerais).

8. Copper and Molybdenum in Ruminant Nutrition, José Fernando Coelho da Silva, (UF Viçosa).

9. Sample Preparation and the Analysis of Animal Tissues, R. M. Silva (UF Minas Gerais).

10. Calcium, Phosphorus, and Fluorine in Ruminant Nutrition, D. J. Thompson (International Minerals and Chemical Corp. Joaquim C. Werner (Nova Odessa, S.P.).

11. Sodium and Chlorine in Ruminant Nutrition, J. K. Loosli (Florida) and José Ribeiro (UFRGS - Porto Alegre).

12. Sample Preparation and Soil Analyses, Victor Gonçalves Bahia, (USP - Piracicaba).

13. Potassium and Iodine in Ruminant Nutrition, D. J. Thompson (International Minerals and Chemical Corporation) and João M.S. Andrade (EPAMIG - Belo Horizonte).

14. Sulfur in Ruminant Nutrition, R. L. Shirley (Florida) and Artur Mariante (EMBRAPA-Brasília).

15. Selenium in Ruminant Nutrition, C. B. Ammerman (Florida), S. M. Miller (Florida), L. R. McDowell (Florida) and Edvaldo Correca de Araujo (EMBRAPA-Recibe).

16. Iron, Manganese and Zinc in Ruminant Nutrition, L. R. McDowell (Florida), R. H. Houser (Florida), K. R. Fick (Florida) and Marcelo O. Mendes (EMBRAPA - Rio de Janeiro).

17. Cobalt in Ruminant Nutrition, R. H. Houser (Florida), K. R. Fick (Florida), L. R. McDowell (Florida) and José Herculano de Carvalho (MA - Teresina - PI).

18. Newer Elements, Essential and Toxic, in Mineral Nutrition, L. R. McDowell, K. R. Fick, C. B. Ammerman, S. M. Miller, R. H. Houser (Florida) and Júlio Cesar de Sousa (EMBRAPA - Sete Lagoos).

19. Biological Availability of Macro Elements, D. J. Thompson (International Minerals and Chemical Corporation) and Marcelo O. Mendes (EMBRAPA - Rio de Janeiro).

20. Biological Availability of Micro Elements - A review, C. B. Ammerman, S. M. Miller (Florida) and José Herculano de Carvalho (MA - Teresina - PI).

21. Soil, Plant, and Animal Tissue as Predictors of the Mineral Status of Ruminants, J. H. Conrad (Florida) and Júlio Cesar de Sousa (EMBRAPA - Sete Lagoos).

22. Evaluation of Mineral Supplements for Ruminants, R. H. Houser (Florida) and Leonidas Valle (EMBRAPA - Brasília).

23. Current Status of Mineral Research in Latin America, K. R. Fick, L. R. McDowell, R. H. Houser (Florida), and Hamilton da Silva (UFMG - Belo Horizonte).

24. Mineral Deficiencies of Cattle under Range Conditions in Brazil, Carlos Hubinger Tokarnia (UFF - Niteroi) and Jürgen Dobereiner (EMBRAPA - Rio de Janeiro).

25. Mineral Research Studies of Ruminants in the Amazon Region, Nelson S. Fernandes and Waldemar V. Camargo (Biological Institute, São Paulo).

26. What Type of Information Do the Mineral Companies Need from the Researchers, João Soares Veiga (TORTUGA - São Paulo).

27. Identification and Supplementation of Limiting Nutrients for Grazing Ruminants B. D. H. Van Niekerk (Voermol Products - South Africa) and E. Adilson S. Serrão (EMBRAPA, Belém).

List of Publications from Nov. 1, 1975 through Nov. 30, 1976
(Other than Brazil Conference)

Conrad, J. H. 1976. Phosphorus supplementation for increasing reproduction in cattle. Ruminant Livestock Production System Seminar, Georgetown, Guyana, March 1, 1976.

Fick, Karl, Sarah M. Miller, John D. Funk, Lee R. McDowell, and Richard H. Houser. 1976. Methods of Mineral Analysis for Plant and Animal Tissues. University of Florida, Gainesville, Florida. 60 p. (In English, Spanish and Portuguese.)

Gil, Arturo, Lee R. McDowell and Joseph Tritschler. 1975. Deficiencias y Toxicidades de Minerales para Bovinos en las Principales Areas Ganaderas del País. p. 111-115. Programa Nacional de Nutrición Animal, ICA-Tibaitatá, Informe Anual.

Lang, Carlos E., L. R. McDowell, J. H. Conrad, and Hernán Fonseca. 1975. Estado Mineral del Ganado en Guanacaste, Costa Rica. ALPA. 1975. 5a Reunión Latino Americana de Producción Animal. p. R2. Maracay-Venezuela, Nov. 30-Dic. 4. (Abstract, accepted for publication).

Mangeye, Kiatoko. 1976. Mineral Status of Cattle in the San Carlos Region of Costa Rica. Thesis, University of Florida, Gainesville.

Mangeye, K., L. R. McDowell, K. R. Fick, H. Fonseca, J. A. Camacho, and J. K. Loosli. 1976. Mineral Status of Cattle in San Carlos, Costa Rica. J. Anim. Sci. 43:328 (Abstract).

McDowell, L. R. 1976. Mineral Deficiencies and Toxicities and their Effect on Beef Production in Developing Countries. p. 216-241. Beef Cattle Production in Developing Countries, Edited by A. J. Smith, Edinburgh, Scotland.

McDowell, L. R., K. R. Fick, R. H. Houser, J. H. Conrad, and J. K. Loosli. 1976. Meeting Mineral Requirements for Grazing Livestock in the Tropics. Symposium on Feed Composition, Animal Nutrient Requirements and Computarization of Diets. July 11-16, 1976. Utah State University, Logan.

Mineral Problems as Related to Tropical Climates

by

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I feel greatly honored to be invited to present the first paper on minerals at this symposium. It was easy to accept the assignment months ago, but my difficulties arose in trying to decide exactly what should be selected from the countless publications to illustrate the critical importance of mineral nutrition problems of grazing animals. This symposium was planned to summarize the present status of knowledge about the mineral elements which influence productivity of grazing ruminants in tropical areas and to stimulate critically needed research on unsolved problems which still greatly limit productivity. Everyone recognizes that an understanding of the specific areas where mineral deficiencies or excesses occur is necessary before producers can effectively and economically correct existing limitations. Hopefully, the discussions at this symposium will help to disseminate present knowledge and stimulate needed research to solve the remaining problems.

The primary usefulness of ruminants is that they contribute to man's food supply, not only directly as meat and milk but also to provide power to produce and transport food supplies. It has been estimated that ruminants in the developing countries (largely in the tropics) produce only 12% as much milk, 20% as much beef and veal and 57% as much sheep and goat meat per animal yearly as animals in developed countries. It is the low productivity per animal that accounts for the limited supplies of animal protein in the tropics and not shortage of animals. The developing countries have 70% of the world's cattle and water buffaloes, but they produce only 22% of the milk and 34% of the beef supplies. They also have 64% of the sheep and goats to produce 50% of the meat from these species. There is uncertainty about the relative importance of nutrition, genetic capacity of the animals, parasites and diseases, climatic stress and other factors have upon animal productivity in the widely diverse regions within the tropics. All are important; the failure of any one factor causes complete failure of the system. Thus, it is logical to consider that after critical diseases are controlled, providing any supplemental minerals needed is usually the easiest and cheapest way to maximize productivity of grazing ruminants.

If I may seek your indulgence, I would like to mention a few basic principles of which you are all at least as familiar as I am and which might be considered an imposition upon so elete an audience as this one, but which may be helpful to some less well informed people who may read the proceedings of this symposium.

Ruminants, like all other animals, must receive all of the essential dietary nutrients including water in optimum amounts (not only the mineral elements) to maintain health and to grow and reproduce at their nupotential levels. Climatic factors may modify the amounts of certain nu-

trients animals require and affect the responses to adequate diets, but possible differences in requirements have not been well defined. The producer and researcher should recognize that the response to any supplement will depend upon whether or not other essential nutrients are adequately supplied and whether animal management practices will allow a response. For example, feeding mineral supplements to cattle will not increase growth if protein or energy is lacking.

The proof that a mineral element (or any nutrient) is essential in the diet depends upon feeding a diet low enough in that nutrient to cause structural or functional injury. Addition of the pure nutrient alone to the deficient diet must correct the deficiency signs and restore the animal to normal health. Some trace elements function either as constituents or as activators of enzymes, and they are needed in very minute amounts to sustain metabolic functions. Some elements can be recycled within the body so that the daily requirements are extremely small and long periods of time may be required to demonstrate a deficiency in animals, or the deficiency signs may be so mild or non-specific they cannot be easily recognized. Often too, there are multiple deficiencies which complicate accurate diagnosis. It is almost impossible to procure a diet for ruminants which is totally lacking in a specific mineral element. As a result, it is likely that trace elements not yet recognized as essential may later be proven to be important.

The Essential Mineral Elements

In Table 1 is listed the mineral elements which are presently considered to be essential in the diet and those which have caused toxicity in animals. Of these, Ca, P, Mg, Na, I, Fe, Cu, Co, Zn, Mn and Se are most likely to be deficient for ruminants, but Ca deficiency has not been reported in ruminants grazing native grasses even without legumes, which are reliably high-calcium sources. While calcium deficiency can easily be produced in young growing animals and lactating dairy cows fed native forages supplemented with concentrates, the deficiency has not been reported in grazing beef cattle even during lactation. Potassium deficiency is not likely to occur in grazing ruminants because most forages are rich in this element. Details will be covered later in the symposium.

Of the trace elements, Cr, Si, V, Sn, and Ni have been shown to be essential for one or more small animal species and it is likely that they are essential for ruminants. However, deficiencies have not been produced in any ruminant and there is no information to suggest that these might cause practical problems. Toxicity of Pb, Cd, Hg and As are caused by animals eating lead paints, motor oil or discarded batteries, or from contaminated feeds or waste materials. While one should recognize the potential danger, the likelihood of problems arising among grazing ruminants is so small the matter is not considered in the symposium. The current knowledge about the essential mineral elements will be summarized in later papers.

Table 1. Nutritional Classification of Mineral Elements

Essential				Toxic	
Calcium	(Ca)	Manganese	(Mn)	Sodium	(Na)
Phosphorus	(P)	Zinc	(Zn)	Iodine	(I)
Magnesium	(Mg)	Selenium	(Se)	Copper	(Cu)
Potassium	(K)	Molybdenum	(Mo)	Cobalt	(Co)
Sodium	(Na)	Fluorine	(F)	Zinc	(Zn)
Chlorine	(Cl)	Chromium	(Cr)	Selenium	(Se)
Sulfur	(S)	Silicon	(Si)	Molybdenum	(Mo)
Iodine	(I)	Vanadium	(V)	Fluorine	(F)
Iron	(Fe)	Nickel	(Ni)	Lead	(Pb)
Copper	(Cu)	Tin	(Sn)	Cadmium	(Cd)
Cobalt	(Co)	Others ?		Mercury	(Hg)
				Arsenic	(As)
				Others ?	

Early Research on Minerals

While we are concerned in this conference with mineral deficiencies and toxicities of grazing ruminants, many basic discoveries about mineral requirements were made with birds, rats, dogs or people. A brief summary of some classical discoveries will be helpful in understanding methods for solving present problems.

The history of the development of knowledge about the essential nature of certain mineral elements is presented by McCollum (1956), while the more practical aspects of these discoveries were summarized by Maynard and Loosli (1962). One should recognize that only when methods were devised to identify and measure mineral elements in body tissues and feeds and to characterize responses to pure elements, was it possible to replace supposition with facts about the essential nature of any nutrient. Much of our earlier knowledge about nutrition resulted from systematic observations stimulated by a need to solve critical health problems with people and their domestic animals. Often a new scientific discovery has proven to be a confirmation of common beliefs of native people and an explanation of why the beliefs are true.

It seems likely that much information about mineral needs of animals gained by trial and error over centuries was never recorded and there is no way of learning what was practiced. French cites reports of views that the "fall of Thebes was hastened by heavy livestock mortalities caused by unidentified agents, when grazing apparently luxuriant pastures" (Underwood, 1966). Feeding "salts" to domestic animals can be traced to the time of Plutarch (40-120? A.D.). Virgil and Pliny (23-79A.D.) recommended salts for milk production. There are many references to the feeding of salt in Britain after 1750 following land enclosure. In the early 1800s, mineral constituents of plants were shown to vary with soil type, stage of maturity of forages and these changes were considered

to be important for animals, a view Boussingault later demonstrated to be true. Bone chewing by cattle was recorded in Africa in 1780 and in Paraguay in 1838, but the relation of osteophagia to phosphorus deficiency in cattle was not clarified until Theiler et al. (1924) of South Africa published their classical experiments showing that the dried grasses were critically low in phosphorus and that phosphorus supplements corrected bone chewing, overcame death losses from botulism and markedly increased growth rates and reproductive levels.

Phosphorus had been isolated from urine in 1669 by Brand and it was shown to be a constituent of bones by Gahn in 1748, along with calcium. In 1842, Chossat demonstrated that calcium was a necessary supplement to a cereal diet for bone development in birds. Many experiments were carried out in Europe and North America during the following 50 years on calcium and phosphorus metabolism and requirements as reviewed by Forbes and Keith (1914). After the importance of the Ca:P ratio became recognized, as well as the actual levels of these elements in the diet and the discovery of vitamin D in 1922, it became possible to prevent or cure rickets, which had been a serious disease of children and young animals and birds produced in the winter in buildings to protect them from the cold, and which also prevented any exposure to sunlight. Rickets was never an important disease in the tropics because of natural ultraviolet irradiation of animals and food products.

It was reported in the early 1800s that in some areas of South America cattle regularly drank naturally mineralized waters and that health was impaired when this was not possible. I have been unable to learn which minerals were present in these waters. More recent studies have shown, however, that water may carry essential, as well as harmful amounts of mineral elements. Because of the high need and critical nature of water for animals as well as people, the matter is very important. The effective utilization of many areas is markedly limited by the lack of suitable water supplies. The research on nutrients and toxic substances in water has been reviewed by Shirley et al.(1974) and will be presented at this symposium. An excellent example of the usefulness of common practices relates to iodine in South America. In 1824, Alexander Humboldt described goiter in Colombia and stated that native Indians knew of a salt deposit that was an effective remedy, which was not true for other salt sources. A sample taken to France was shown by Boussingault to contain iodine, which was absent from the other salt. In 1831, Boussingault advised the Colombian Government to provide general distribution of the naturally iodized salt to the population. Iodine had been discovered by Courtois in 1811 and nine years later he began prescribing it as a cure for goiter. Overdosages of iodine caused injury to some patients and its use was condemned by physicians. It was a hundred years later before the general use of iodized salt was started in the U.S.A. with medical authority support (McCollum, 1956).

One might expect that once we know the way to prevent something as simple to identify as goiter at a cost as low as a little iodized salt, this disease would quickly be eliminated, but goiter still exists among people and animals. What can we do about it?

Iron was shown to be present in blood by Menghini in 1747. Sydenham

is credited with having treated anemia with iron solutions prepared by steeping steel filings in wine before 1680 but he did not know why it was effective. This process resulted in the formation of ferrous potassium tartrate. In 1867, Boussingault published data showing the iron content of a number of different animals and various foods and beverages, since it was generally accepted by that date to be an essential element.

Except for iron and iodine, the trace elements were not studied until about 1926 when Leroy showed that magnesium increased the growth of mice. McCollum and associates reported in 1931 that magnesium deficiency caused tetany in rats and Duncan and Huffman observed similar signs in 1935 in calves fed milk as the only food. Low blood magnesium and death loss from grass tetany is a serious problem in lactating beef cows in some areas. Copper was shown to be essential for hemoglobin formation and iron utilization in rats by Hart and Elvehjem in 1928. Following this discovery, there was more than a decade of intensive research interest which resulted in the discovery of other essential elements. Sjollema reported copper deficiency in cattle and sheep in the Netherlands in 1933. Cobalt deficiency was first identified as the cause of a "wasting disease" and anemia in cattle and sheep in Australia in 1935 by Filmer and Underwood and Marston and Lines. Manganese stimulated growth of mice and reproduction of rats in studies by Kemerer and McCollum et al. in 1931, but its importance in cattle was not known until about three decades later. A similar situation existed with zinc, which was shown to be essential for growth and hair development of mice and rats in 1922, but its need by pigs was not shown until 1955 and for calves not until 1960.

Evidence that fluoride is essential is limited to recent reports showing that a deficiency causes impaired fertility in female mice and depressed growth in rats. Earlier tests demonstrated that traces in the drinking water (0.7 to 1.0 ppm) helps to prevent dental caries in children, but 2.0 ppm or more causes mottling of the teeth enamel. Higher intakes (4 to 6 ppm in water) increases bone density and helps to prevent osteoporosis and associated incidence of collapsed or distorted vertebrae in people over 55 years of age. There is also evidence that extra fluorine decreases the aorta calification often seen in low-fluorine areas. However, it is the toxicity of fluoride that is of greatest importance in ruminant nutrition (Shupe et al., 1974).

Many of the essential mineral elements can have detrimental effects or cause toxicity if fed in sufficiently large amounts. The approximate requirement and harmful levels of the more toxic essential trace elements are shown in Table 2.

Table 2. Requirements and Toxicities of Trace Mineral Elements

Element	Species	Requirement	Toxic level
		mg/kg ration	
Copper	Cattle	5-7	115
	Sheep	10	?
	Swine	6	250+
Cobalt	Cattle	0.05-0.07	60
	Sheep	0.08	120
	Horses	5-8	?
Iodine	Livestock	0.1	?
	Swine	0.2	?
Manganese	Cattle	16-25	2000
	Swine	10	4000
Zinc	Cattle	9	900->1200
	Sheep	18-22	1000
	Swine	50	2000
Selenium	Cattle	0.1	3-4
	Sheep	0.1	10
	Horses	?	5-40
	Swine	0.1	5-8

Advances in Analytical Methods

In 1937, Maynard listed only 12 mineral elements in his book, Animal Nutrition, as proven dietary essentials (Ca, P, Na, K, Cl, S, Mg, Fe, I, Mn, Cu and Zn), several having been recently discovered. He stated "cobalt appears to be essential according to very recent work." He pointed out the commonly held view that in practice "most of them are supplied so abundantly in the commonly fed rations that no thought need be given to them." We now know that at least 6 of the above 12 are very often so deficient they must be supplemented to support optimal growth, reproduction or lactation of grazing ruminants. Furthermore, since that time eight additional trace mineral elements have been shown to be dietary essentials for some species of animals and two (Se, Mo) are important for grazing ruminants under some conditions.

I should like to mention again that knowledge about the need for mineral elements depended upon the development of methods for measuring the amounts in feeds and animal tissues and the availability of pure compounds to evaluate requirements. In the 1960s improved technical equipment and newer methods have made it possible to analyze many more samples for mineral elements and the accuracy has been greatly increased. In the industrial countries, surveys have been made to evaluate the mineral content of soils, food and feed crops and animal tissues. The areas where deficiencies and excesses of mineral elements exist have been determined so that corrective supplements can be used to maximize animal productivity and land utilization.

Some recent studies using modern techniques have been made in tropical countries to evaluate the status of mineral elements in soils and plants, and some animal studies have been reported. In 1958, de Alba cited the occurrence of phosphorus deficiency in northern Mexico, Venezuela, Colombia, Brazil, Argentina, Paraguay and Chile; cobalt deficiency in Brazil and Argentina, copper deficiency in Peru, Brazil and Argentina; ~~and selenium deficiency in Mexico~~. Other summaries have also been published (McDowell, 1974; Mills, 1970; Russell and Duncan, 1956; Underwood, 1971; Van Niekerk, 1974).

Problems and Questions Needing Solutions

There is no doubt that there are many areas where mineral deficiencies limit productivity of grazing ruminants. We need to know what and where these are. Specific research is necessary before any deficiencies can be corrected in a reasonable and economic way. There is no justification for providing extra minerals unless they are really needed. They must be offered in such a way that they can be utilized to give economic returns.

There are a number of questions that should receive special attention in planning research, among which are the following. Do the nutrient requirements of ruminants in the tropics differ from animals in the temperate zones? It has been speculated that the requirement for sodium and other minerals lost in perspiration may be higher in hot dry areas, but there are no comparative data. There is evidence that genetic variation exists among breeds of sheep in the incidence of swayback and in copper metabolism and susceptibility to copper poisoning (Terrill, 1974). There are also significant genetic differences in blood concentrations of several mineral elements. Genetic-environmental interactions involving growth and energy utilization have been reported for sheep and cattle, but these probably do not modify mineral nutrition, except as would be expected from differences in feed utilization, growth rates, body size and levels of productivity. Until data are obtained to the contrary, it seems safe to assume that any differences in mineral requirements between tropical and temperate cattle and sheep are small.

What is the best and most economical way to provide the mineral supplements needed? Self feeding minerals to grazing cattle and sheep to provide needed minerals or insurance against possible deficiencies is the common practice in the developed countries. The view that the body's need for a mineral will regulate the amount eaten has not been confirmed in controlled studies. Some animals eat very little or none of the free-choice minerals, while others eat several times more than needed. Economics in each situation should determine how the nutrient requirements will be met. Research should be carried out to define the specific needs in various locations to provide the basis for correct management decisions. Many other questions also need to be answered. This symposium will review the known information on mineral nutrition of ruminants in the tropics, define the unanswered questions and outline procedures for research which will obtain the critical information needed to increase the production of animal products.

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ABSTRACT FOR AMERICAN SOCIETY OF ANIMAL SCIENCE

Title: Mineral Status of Cattle in San Carlos, Costa Rica
(Limit to 48 letters or typewritten spaces)

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Section Preference: 1. Ruminant Nutrition 2. International Animal Agriculture 3. _____

(Program Sections are: Animal Behavior, Animal Waste Management, Breeding and Genetics, Environment and Livestock Production, Extension, International Animal Agriculture, Meat Science and Muscle Biology, Non-Ruminant Nutrition, Pastures and Forages, Physiology, Ruminant Nutrition, and Teaching).

Experiments were designed to determine the mineral status of grazing dairy and beef cattle in San Carlos, Costa Rica. Ten liver and five blood samples of steers (mostly 3-4 years old) were collected from each of 12 farms in four districts with two soil type regions. Two districts were selected in each region, with 2 to 4 farms in each district. Liver was analyzed for Cu, Zn, Fe, Mn, and Co, and plasma for Ca, P and Mg. Of the total livers analyzed, 23, 5, 63, 96, and 38% were borderline to deficient in Cu (<75 ppm), Zn (<84 ppm), Fe (<180 ppm), Mn (<10 ppm) and Co (<.06 ppm), respectively. Copper, Fe, Mn and Co were borderline to deficient in 1, 7, 12, and 3 farms, respectively. Plasma Ca and Mg were in the normal range in all animals studied while mean P concentrations were deficient (<4.5 mg %) for all farms. Plasma Ca, P and Mg and forage Ca, P, Mg, K, Na, Fe, Cu, Zn, Mn, Co, oxalate and crude protein levels were determined on 5 dairy farms with and 4 without *Setaria sphacelata* as the major pasture species. No difference (P >.05) in plasma mineral concentrations due to pasture species was found. Plasma P was deficient (<4.5 mg %) in all farms and in all animals. Mean plasma Ca and Mg were in the normal range for the two types of pastures and in all farms. *Setaria* pastures were higher in Na (P <.01), Zn, Mn and oxalate (P <.10).

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ESTADO MINERAL DEL GANADO EN GUANACASTE, COSTA RICA

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Universidad de Florida. Estados Unidos; Universidad de Costa Rica. Costa Rica

El estado mineral del ganado de carne en pastoreo fue evaluado en la región de Guanacaste, Costa Rica, mediante la determinación de los niveles de P en el plasma sanguíneo y las concentraciones de Cu, Fe, Mn, Zn y Se en el hígado. Se escogieron 15 fincas distribuidas en 5 cantones (3 fincas por cantón). De cada finca se colectaron 10 muestras de hígado y 5 muestras de sangre procedentes de novillos de 3 a 4 años de edad. Las muestras fueron colectadas en un matadero central. Los promedios de Cu, Fe, Mn, Zn, Se y P fueron deficientes o cercanos a la deficiencia en 4, 4, 10, 4, 2 y 10 fincas, respectivamente. De las 150 muestras de hígado que se analizaron, aproximadamente 61, 40, 31, 63, 33 y 24% se encontraron deficientes o cercanas a la deficiencia en P, Cu, Fe, Mn, Se y Zn, respectivamente. A excepción del Se, no se encontraron diferencias ($P \geq .05$) debidas a la localización del cantón. Las concentraciones promedio de Cu, Fe y Zn fueron normales en los 5 cantones, mientras que los niveles de Mn, Se y P fueron deficientes o cercanos a la deficiencia en 5,2 y 3 cantones, respectivamente. Se encontraron diferencias ($P \leq .01$) para todos los minerales entre las fincas de cada cantón. Catorce de las 15 fincas informaron que suplementaban NaCl, mientras que 8 suplementaban P (harina de hueso) y 9 suplementaban elementos trazas en forma descontinuada. En base a las concentraciones de minerales en los tejidos, se considera que los actuales programas de suplementación mineral son inadecuados para el ganado de la región de Guanacaste, Costa Rica.

ALPA. 1975. 5a Reunión Latino Americana de Producción Animal. p. R2. Maracay, Venezuela Nov. 30 Dic. 4.

CURRENT STATUS OF MINERAL RESEARCH IN LATIN AMERICA

by

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Nutritional inadequacies can occur in almost any area of the world and result in inefficient animal production. In Latin America, the cattle industry is often restricted by mineral deficiencies, imbalances and toxicities. This is particularly true of the minerals in which severe or borderline deficiencies sometimes occur in widely scattered areas.

Cattle in Latin America depend almost exclusively on forages to obtain mineral elements. A low intake or imbalance of the mineral elements from forages can adversely affect fertility, weight gain, milk production and in general, the health of the animals. Only rarely can Latin American forages completely provide all mineral requirements of grazing cattle. Therefore, the determination of the chemical composition of forages and mineral supplementation are important to supply cattle with adequate levels of the minerals they need.

The purpose of this paper is to compile available literature on mineral research in Latin American and Caribbean countries. Emphasis was placed on mineral studies related to grazing ruminants. The authors are aware that many worthwhile research publications are not included because these are not readily accessible to libraries and abstracting journals.

Mineral Deficiencies and Toxicities in Cattle

Mineral deficiencies or excesses are found and reported to some extent from almost all countries in Latin America and the Caribbean. Due to lack of information, it is not generally appreciated how extensive the areas affected are. Mineral problems are closely associated with geographical areas. Allman and Hamilton (1949) gathered information from various parts of the world on locations of livestock nutritional deficiencies. Information on mineral deficiencies and toxicities for livestock in Latin America has been updated by Phillips (1956) and De Alba (1971). Recently, McDowell (1976) compiled a list of mineral deficiencies and toxicities in cattle in the developing countries of the world. Table 1 compiles our present knowledge on the occurrence of cattle mineral deficiencies and toxicities in Latin American and Caribbean countries. It includes both confirmed as well as highly suspected geographical areas of mineral deficiencies and toxicities in cattle. Obviously, this constitutes a very generalized approach with important geographical omissions inevitable but it does indicate the scope of the problem. The term "deficient or toxic area" is used to denote a region in which deficiencies or toxicities can be readily found, but it does not imply that all plants or animals in that area are, in fact, in deficient or toxic states. It does not even imply

that certain elements are in short or abundant supply, because, imbalances can occur due to natural conditions or induced by unsuitable agricultural practices.

Calcium and Phosphorus

A deficiency of calcium or phosphorus or both will cause a decrease in efficiency of production and eventually may result in the fracture of skeletal bones. Either one or both elements may be deficient under grazing conditions in certain geographical areas although phosphorus is the element most likely to be deficient. Forages tend to be higher in calcium and lower in phosphorus while grains are generally lower in calcium and higher in phosphorus.

McDowell et al. (1975) summarized the mineral concentrations of 2615 Latin American forages (tables 2 and 3), reported in the 1974 edition of the Latin American Tables of Feed Composition (McDowell et al., 1974). Average calcium values were reported for 1123 (42.9%) forage entries and average phosphorus values for 1129 (43.2%) forage entries (table 2). For these forages, 31.1% of the calcium values and 72.8% of the phosphorus values were 0.3% or less (table 3) which may be borderline to deficient in these elements for most classes of cattle. Phosphorus deficiency has been reported in parts of most Latin American countries (table 1). Low forage phosphorus has been found in Argentina (Kraemer and Mufarrege, 1964; Bingley et al., 1965a, b; Díaz, 1965a; Culot et al., 1967; Vonesch and De Riveros, 1967-1968; Villalba Palacios, 1973), Chile (Ares Rojas, 1947; Rogers, 1952), Colombia (Villamil, 1942; Vergara, 1967; Blasco Lamenca and Bohórques Ampudia, 1967, 1968; Salazar de Buckle and Medina Ramírez, 1970), Costa Rica (Arrea Baixench and Muñoz Sandoval, 1954; Velasco, 1961; Tergas, 1968; Blue and Tergas, 1969; Wills, 1971; Lang, 1974), Cuba (González, 1942; Alba Gómez et al., 1967; Figueroa and Sutherland, 1969), Guatemala (Fernandez et al., 1971), Guyana (Duthie, 1939; Mayers, 1969; Holder, 1972), Mexico (De Alba, 1950; González, 1966; Zavala and Galván, 1973), Panama (Rosas et al., 1969; Ríos Araúz, 1972; Chicco, 1972), Paraguay (Ramirez, 1954), Peru (Gómez et al., 1967; Mantari, 1968; Gómez et al., 1969; Echevarría et al., 1970b; Kalinowski et al., 1970b; Talavera, 1970), Uruguay (Fynn, 1940; Nores, 1944; Spangenberg, 1944; Spangenberg and Sanchez González, 1952) and Venezuela (Grünwald et al., 1947; Chicco and French, 1959; French and Chaparro, 1960; French and Chicco, 1961b). Blood serum (plasma) phosphorus is reasonably sensitive to variations in dietary phosphorus levels and thus has value as a diagnostic tool in determining phosphorus adequacy. Reduced serum (plasma) phosphorus concentrations in cattle have been noted in Argentina (Kraemer and Mufarrege, 1964; Bingley et al., 1965a), Chile (Ares Rojas, 1947), Colombia (Villamil, 1942), Costa Rica (Lang, 1974), Cuba (Figueroa and Sutherland, 1969), Mexico (Zavala and Galván, 1973), Panama (Rosas et al., 1969; Chicco, 1972; Ríos Araúz, 1972) and Venezuela (Chicco and French, 1959; French and Chicco, 1961b). Compared to phosphorus inadequacies, calcium is rarely a problem in grazing cattle with the exception of cows lactating large quantities of milk or those on acid, sandy or organic soils in humid areas where the herbage consists mainly of quick-growing grasses and is devoid of legume species (Underwood, 1966). On the basis of low calcium levels in forages, deficiencies of this mineral have been reported in areas of Colombia (Vergara, 1967; Salazar de Buckle and Medina Ramírez, 1970; De Alba, 1971),

Costa Rica (Arrea Baixench and Muñoz Sandoval, 1954), Guatemala (Fernandez et al., 1971), Guyana (Underwood, 1966; Holder, 1972), Mexico (Buller et al., 1960-1961), Panama (Williamson and Payne, 1965), Peru (Gómez et al., 1967; Echevarría et al., 1970b; Kalinowski et al., 1970b) and Venezuela (De Alba and Davis, 1957 and French and Chaparro, 1960). Blood serum (plasma) is practically insensitive to dietary calcium and thus has limited value in evaluating the calcium status of the animal. However, assuming that serum (plasma) values of 8 mg % calcium or less are borderline to deficient, areas in Argentina (Ovejero, 1964) and Venezuela (Chicco and French, 1959) are considered deficient in this mineral.

A widespread occurrence of massive cardiovascular calcification, "enteque seco," has been found in cattle and sheep in the Buenos Aires Province in Argentina (Carrillo and Worker, 1967). The principal clinical change in cattle and sheep has been a rapid elevation of calcium and phosphorus in the blood followed by metastatic ossification of the elastic fibers of the cardiovascular system. The symptoms are loss of weight and general condition and if animals are left in problem areas, they continue to lose condition and eventually die. An estimated 1,600,000 cattle manifest the condition annually (Paoli, 1971a, 1971b). Bingley (1964), Bingley et al. (1965a, 1965b), Landó et al. (1967, 1968) studied the calcium and phosphorus blood levels in affected animals. Although a phosphorus deficiency was noted in animals in affected areas, it was independent of the disease itself. Controlled studies with cattle, sheep and laboratory animals by Camberos and Davis (1969), Reinoso Castro (1970), Camberos and Davis (1970), Camberos (1971) and Carrillo (1973) have demonstrated that relatively small amounts of the leaves of Solanum malacoxylon, "duraznillo blanco," either fresh or dried, will result in a deranged calcium and phosphorus metabolism.

Probably the most important economic loss in the cattle industry in Latin America due to mineral deficiencies is the decreased reproductive efficiency resulting from a phosphorus deficiency. Improved growth and reproductive performance in cattle with phosphorus supplementation and pasture fertilization has been reported in Panama (Ríos Araúz, 1972), Uruguay (Schiersmann, 1965; De León Lora, 1963) and Peru (Echevarría et al., 1974). Novoa Barreto and Trujillo Ortiz (1968-1969) and Molina et al. (1969) reported adequate phosphorus levels in serum in cows that presented reproductive problems.

Buller et al. (1960-1961), in Mexico, supplemented grazing steers with salt, salt plus cottonseed meal and salt plus cottonseed meal and bone meal. Weight gains were increased with the cottonseed meal treatment but no further improvement in weight gains were observed with bone meal supplementation. Echevarría et al. (1973) obtained weight gains of 0.59 kg in steers supplemented with dicalcium phosphate and 0.27 kg for controls. Esteves Cancino (1960) reported increased milk production (up to 24%) with bone meal supplementation in farms that had phosphorus deficient soils and when cows grazed Hyparrhenia rufa.

Information on phosphorus and calcium availability in tropical forages is limited. In some tropical forages average true digestibilities of 71.1% and 32.9% for calcium and phosphorus have been determined with sheep, respectively (Perdomo, 1975). Butterworth (1966) reported that the true mean

absorption of phosphorus contained, various Venezuelan forages was 53% and the excretion of fecal endogenous phosphorus was 26.7 mg per kg liveweight.

Cobalt

Cobalt deficiencies under grazing conditions have been observed in many regions of Latin America (table 1). Marginal or deficient concentrations of cobalt in forages have been found in Argentina (Morandi, 1954, 1955), Colombia (Vergara, 1967), Guyana (Holder, 1972), Haiti (King and Price, 1966), Surinam (Dirven, 1963), Peru (Gómez et al., 1967; Echevarría et al., 1970b), Uruguay (Spangenberg and Sanchez González, 1952). McDowell (1975) reported that of 2615 Latin American forages analyzed for minerals, only 5.4% presented cobalt values (table 2) and 43.1% had concentrations of .10 ppm cobalt or less (table 3).

Insúa et al. (1964) reported values of 30 and 35 µg % cobalt in serum of normal cattle and sheep, respectively. The concentration of cobalt in the liver has received special attention because of its possible value in diagnosing cobalt deficiency in the field. Corrêa (1957) in the state of São Paulo, Brazil found .058 and .201 ppm cobalt in liver samples of animals from deficient and adequate cobalt areas, respectively. Probably the best way of verifying the deficiency is by feeding cobalt and observing a positive response. In Colombia, cobalt supplementation significantly increased forage consumption and milk production (Estevez Cancino, 1960) Vargas (1964) in Mexico, supplemented cobalt to cattle and observed a non-significant increase in weight gain. In Costa Rica, the low intake of some tropical forages was not related to cobalt deficiency (De Alba, 1951).

Cattle and sheep grazing Phalaris tuberosa in areas of Argentina presented the symptoms of the disease known as "Phalaris staggers" on "Tembleque del falaris" (Gaggino et al., 1963a; Gaggino and Carrillo, 1964; Gaggino and Carrillo, 1965). Cobalt supplementation has been shown to alleviate the condition (Gaggino et al., 1963b and Carrillo et al., 1963).

Copper and Molybdenum

Lack of copper is probably the most severe mineral limitation to grazing cattle in Latin America, with the exception of phosphorus and possibly cobalt (table 1). Copper deficiency is induced by low concentration of copper in forages. However, "conditioned" copper deficiency also occurs where normal copper concentrations in forages are inadequate due to interrelationships with molybdenum, sulfate and other factors (Russell and Duncan, 1956). Nine and 5.1% of the total Latin American forages were analyzed for copper and molybdenum, respectively (table 2). Copper averages were deficient or borderline to deficient in 46.6% of the forages, and 13.6% of 133 forage analyses had molybdenum concentrations over 3 ppm (table 3).

Low copper levels in forages have been reported in Cuba (Figueroa and Sutherland, 1968, 1970), Guyana (Holder, 1972), Haiti (King and Price, 1966), Panama (Chicco, 1972), Peru (Culot et al., 1967; Gómez et al., 1969; Echevarría et al., 1970a, b; Kalinowski et al., 1970b; Talavera, 1970), Surinam (Dirven, 1963) and Uruguay (Nores, 1944; Spangenberg and Sanchez

González, 1952). Areas in Peru (Goyzueta et al., 1972) and Argentina (Culot et al., 1967; Pizzi et al., 1964; Camberos et al., 1965, 1967; Nuñez, 1969) have been observed to contain normal copper levels but high molybdenum concentrations in forages. Camberos et al. (1965, 1967) in Argentina, reported high levels of sulfate in the water and Pizzi et al. (1964) high sulfate levels in forages. Regions in Peru, also have high levels of sulfate in forages (Goyzueta et al., 1972). Perdomo (1975) noted that maximum intake of copper in forages by sheep (.89 mg/day/kg body weight) approached levels reported to be toxic. The overall mean true digestibility of copper in several tropical grasses was 82.6%.

A copper deficiency in the animal can be reasonably well verified by taking a liver biopsy and determining the copper content of that tissue (Carrillo and Bingley, 1964a, b). Plasma copper levels of 50 µg % or less are indicative of low liver copper levels (Claypool et al. 1975). Ancasi et al. (1973) reported low serum copper in cattle in Peru. On the basis of copper concentration in the liver areas in Argentina (Epstein et al., 1971), Costa Rica (Lang, 1974), Panama (Ammerman et al., 1974) and Peru (Narvaez and Terri, 1964) are deficient in this mineral. Deficient concentrations of copper in both blood and liver have been observed in Argentina (Bingley et al., 1964a, b; Camberos et al., 1965; Carrillo et al., 1964a, b; Bingley and Carrillo, 1966) and Cuba (Figueroa and Sutherland, 1968, 1970).

Copper deficiency and molybdenum toxicity are corrected by providing additional copper to the animal. Good results have been obtained using copper injections in Argentina (Bingley et al., 1964a, b), Cuba (Figueroa and Sutherland, 1968) and Peru (Narvaez and Terri, 1964). Improved animal condition by adding copper to the diet has been observed in Cuba (Alba Gómez et al., 1967) and Argentina (Camberos and Figueiras, 1969).

Tabusso (1941a, b, c; 1942 a, b, c) in Peru, observed the symptoms of "Renguera Peruana" which is a copper deficiency. The symptoms described are similar to those recognized in Australia by Bennetts and Chapman (1937) as "Enzootic ataxia" or "Lamkruis" in South Africa by Schulz et al. (1951). In Argentina, "Enzootic ataxia" in ovines has been described by Epstein et al. (1971). Barúa (1966) indicated that "Renguera Peruana" was prevented with copper supplementation.

The condition of cattle known as "Muerte Subita" occurs in Cuba with appreciable frequency. It is characterized by collapse and death of apparently healthy animals when exposed to stress. Incidence is seasonal and restricted to specific areas. The condition simulates "Falling disease" associated with copper deficiency in Australia (Bennetts et al., 1941) and in Florida (Becker et al., 1965). Cases of sudden death (Muerte subita) in cattle in a pasture in the northeast area of Camaguey (Cuba) have been studied in relation to the metabolism of copper (Figueroa and Sutherland, 1968) and of sodium, potassium, calcium, magnesium and phosphorus (Figueroa and Sutherland, 1969). No deficiency or changes in the blood and tissue levels of these minerals were found that could explain the etiology of "Muerte subita." Valdivia et al. (1974) reported that in the region of Pucallpa, Peru, animals suddenly die when exposed to stress. Incidence is highest at the beginning of the rainy season. During the rainy season, 37.4% of the cattle had low levels of magnesium (>1.8 mg%)

while during the dry season only 13.9% presented low serum levels of this element. The authors feel that the low serum magnesium values alone may not cause "Muerte subita" and are studying the mineral status of plants and animals as well as other factors, such as toxic substances that may cause this condition.

Sodium and Chlorine

In most circumstances, all cattle whether grazing or in dry lot require supplemental dietary sodium. This requirement is generally met by supplying sodium chloride or "common salt" as 0.5 percent of the total ration for full-fed cattle or as a free-choice supplement for cattle on pasture on range. Sodium appears to be the essential nutrient in salt and evidence of a naturally-occurring dietary deficiency of chlorine, as distinct from sodium has not been established (Underwood, 1966).

The National Research Council (1970) recommends 0.1% sodium for cattle. About 60% of 146 forage averages in the 1974 Latin American Tables of Feed Composition (McDowell et al., 1975) contained mean sodium values of 0.1% or less (table 3). Natural forages low in sodium have been reported in Colombia (McCormick, 1966), Panama (Chicco, 1972), Surinam (Dirven, 1963) and Venezuela (French and Chaparro, 1960; Perdomo, 1975). Dirven (1963) and Underwood (1966) suggest that under tropical or hot semi-arid conditions where large losses of water and sodium occur in sweat, the sodium requirement may be higher.

Salt has been incorporated in self-feeding protein and/or energy supplements to regulate intake and has been demonstrated to be practical for grazing steers (Chicco et al., 1971).

Iodine

Iodine deficiency is one of the most prevalent deficiency diseases that has been shown to occur in almost every country of Latin America. A list of iodine deficiency reports in man and farm animals as endemic goiter is presented in table 1. Follis (1966) and Kelly and Snedden (1960) have illustrated in a map the most prevalent areas of endemic goiter in Latin America.

Iodine deficiency in domestic animals has been observed in regions of Antigua (Hutson, 1952), Argentina (Mazzocco and Arias Aranda, 1929; Piazza, 1937), Chile (Gruebler, 1951), Colombia (Vergara, 1967; De Alba, 1971), Ecuador (Kelly and Snedden, 1960), French Guyana (Hidiroglou and Prevost, 1958) and Peru (Zuñiga, 1960; Kelly and Snedden, 1960; Barúa, 1966; Valdivia et al., 1974). Nores and Rossi Stajano (1948) reported a possible iodine deficiency in forages in areas of Uruguay. Probably, the most complete and detailed studies of iodine deficiency as goiter in domestic animals observed in Latin America have been reported in Brazil (Martins, 1946; Megale, 1947, 1949 and Cardim, 1948).

The widespread use of iodized salt and iodine additions to mineral mixtures has reduced significantly the incidence of iodine deficiency in Latin America.

Magnesium

It appears that simple, uncomplicated magnesium deficiency in cattle rarely occurs under normal feeding programs. Countries where forages low in magnesium have been reported include Colombia (McCormick, 1966) and Costa Rica (De Alba and Davis, 1957; Arrea Baixench and Muñoz Sandoval, 1954). Slightly over one-third of 290 Latin American forages contained 0.2% magnesium or less (table 3).

A condition in cattle referred to as "Grass tetany," "Grass staggers" and perhaps other terms has been related to abnormal magnesium metabolism. It is a seasonal problem; and typical cases involve cattle grazing a small grain, winter pasture. Latin American countries where magnesium tetany is encountered are listed in table 1. Grass tetany or hypomagnesemia tetany has been studied extensively in Argentina where a considerable number of animals die annually due to this condition (Ovejero, 1964; Culot and Fernández Tuñón, 1967; Ruksan et al., 1967; De La Fuente, 1968; Barberis and Mizuno, 1969; Mizuno and Barberis, 1969). Hypomagnesemia tetany responds favorably to magnesium therapy. In Peru, magnesium deficient cattle are treated successfully with intravenous or oral administrations of magnesium sulfate (Barúa, 1966; Alvarado et al., 1970).

Selenium

Most of the information available from Latin America on selenium is related with toxicity. Selenium poisoning is often associated with consumption of selenium accumulator plants (i.e., Astragalus spp.) which may contain up to several thousands ppm selenium. Table 1 presents Latin American countries where selenosis is encountered and includes Argentina (Lemley, 1943), Chile (Lemley, 1943), Colombia (Ancizar Sordo, 1947; Benavides and Silva Mojica, 1965), Mexico (Byers, 1937; Figueroa, 1938; Figueroa, 1942a, b), Peru (Lemley, 1943; Barúa, 1966). Benavides and Silva Mojica (1965) described the regions and economic importance of selenium toxicity in Colombia. Based on the analyses of feeds over 3 ppm selenium, there are reported seleniferous zones in Venezuela and Puerto Rico (Jaffé et al., 1967, 1969; Bermudez de Cruces, 1967; De Mondragón and Jaffé, 1971).

The concept of selenium as an essential element is relatively recent and just a few countries in Latin America have been reported to have deficient areas. Latin American countries with confirmed or suspected selenium deficiencies are listed in table 1. Lang (1974) reported borderline to deficient selenium concentrations in 33% of the livers analyzed from beef cattle slaughtered in Guanacaste, Costa Rica. Low selenium concentrations have been reported in forages in areas of Chihuahua, Mexico (Gutierrez et al., 1974) and Guyana (Holder, 1972). In Peru, Terry (1964) reported a condition in ruminants resembling selenium vitamin E deficiency. When the animals were treated with selenium vitamin E injections, about 70% recovered from the condition.

According to Underwood (1971), the total areas of the world affected by selenium deficiency are far greater than those afflicted with selenium excess.

Fluorine

Reported incidences of fluorosis in Latin American countries are listed in table 1. Culot et al. (1967) reported fluorosis in grazing cattle in the districts of Tapalgue, Azul and Tandil, Argentina. Animals presented development of exostoses of the long bones with thickening of joints. Teeth were modified in shape and color, becoming mottled and pitted often with the pulp cavities being exposed. The cases of fluorosis were related to the high content of fluorine in the water (2 to 6 ppm). De Alba (1971) indicated that persons from Aguascalientes and Altos de Jalisco, Mexico have mottled teeth, but this condition has not been observed in cattle.

Manganese, Zinc, Iron, Potassium and Sulfur

Concentrations of manganese, zinc, iron, potassium and sulfur available from forages are generally adequate to meet cattle requirements under grazing conditions. However, decreased levels in forages and cattle deficiencies have been reported for some of these minerals in restricted areas of Latin America.

Of 2615 Latin American forages analyzed for minerals, only 11.2, 6.8, 9.8 and 7.6% reported analysis of manganese, zinc, iron and potassium, respectively (table 2). Borderline or deficient concentrations of manganese, zinc, iron and potassium were found in 21.0, 74.6, 24.1 and 15.1% of the total Latin American forages analyzed for these elements, respectively (table 3). Manganese, zinc, iron, potassium and sulfur deficiencies confirmed or suspected in Latin American countries are listed in table 1. Average true digestibility for potassium and iron in *Digitaria decumbens*, *Panicum maximum*, *Cynodon plectostachyum* and *Brachiaria decumbens* were 87.3 and 57.8%, respectively (Perdomo, 1975).

Lang (1974) reported that approximately 21, 63, and 24% of the total cattle livers examined in western Costa Rica were borderline to deficient in iron, manganese and zinc, respectively.

Forages containing low levels of manganese have been reported in Panama (Chicco, 1972). In a region of Costa Rica, characterized by volcanic soils, high manganese in forages have been observed which resulted in low reproductive rates of cattle (Fonseca and Davies, 1968; Amadeo Macia, 1971; Lang, 1971). In Peru, high manganese levels in forages have been reported by Gómez et al. (1967, 1969).

Legg and Sears (1960) found parakeratosis skin disorder in cattle of Guyana which were consuming forage containing 18 to 42 ppm zinc. Low levels of serum zinc were noted in cattle from Andahuaylas, Huancayo, Arequípa and Oxapampa, Peru (Ancasi et al., 1973). Latin American countries where forages contain low levels of zinc include Guyana (Legg and Sears, 1960; Holder, 1972), Panama (Chicco, 1972) and Venezuela (Perdomo, 1975).

Iron deficiency is of practical concern in grazing cattle in circumstances involving blood loss or parasitic infestation. Forage analyses from Panama indicate adequate iron concentrations to meet grazing cattle needs (Blue et al., 1969). Another report from Panama suggests that *Hyparrhenia rufa* in certain locations is marginal in iron in relation to cattle

requirements (Chicco, 1972). The author points out, however, that animals may supplement their intake with iron from soil.

French and Chicco (1961a) in Venezuela, found that 14.5, 5.7 and 15.2% of the cows, bulls and calves examined had hemoglobin levels of less than 8 g per 100 ml of blood, respectively. Highest deficiencies were found in the states of Tachira and Merida. Newborn calves receiving iron injections had increased hemoglobin concentrations and slightly higher gains (Acosta and Waugh, 1967; Botero and Franco, 1972).

Forages containing low level of potassium have been reported in Panama (Chicco, 1972), Venezuela (French and Chaparro, 1960) and Brazil (Gomide et al., 1969).

Sulfur may be lacking to Ecuador livestock as has been indicated by improvement observed following its administration in sulfurized salt blocks (Phillips, 1956).

Mineral Supplementation

Direct administration of minerals to cattle is the most economical method of supplementation. Cunha (1971) noted that self feeding trace mineralized salt is low cost insurance against deficiencies.

Table 4 presents a survey of mineral supplements supplied in cattle ranches of the north coast of Colombia (Rivas Rios, 1974). Sixty-six percent of the farms surveyed provided mineralized salt to cattle, 30% supplemented only salt and the remaining 4% did not provide any type of mineral supplement. Eighty-one percent of the farms in the coast of Bolivar supplemented mineralized salt while the regions of savannahs of Bolivar (south), Lower Sinu and Cesar River Valley had the lowest percentage (57) of farms that supplemented mineralized salt. Common salt was widely used as a mineral supplement in these areas.

In Colombia, Salazar and Waugh (1967) reported that a control group without any mineral supplement obtained better daily gains than heifers on pasture supplemented with salt. Gains were highest, however, on animals receiving a supplemental mineral mixture. In the native savannahs of Colombia, large growth responses were obtained by complete mineral supplementation but only in the rainy season. In the dry season, there was no difference between the supplemented and non-supplemented herds. The most dramatic improvement was obtained in breeding performance. Average conception in four months for the herds receiving complete mineral supplementation was 70% whereas it was 24% for the herds not receiving minerals (Anonymous, 1973). Improved weight gains and reproductive performance with mineral supplementation have been reported in Paraguay by Romero et al. (1973), Cattebeke et al. (1973) and Boggino et al. (1973). Improved weight gains with mineral supplementation have also been reported in Peru by Echevarría et al. (1973).

Rios (1974) measured mineral consumption by heifers, yearling bulls and pregnant and open cows under grazing conditions. Average consumptions were 27, 35, 36 and 44 g per animal per day, respectively. It was noted that maximum mineral intake was obtained during the rainy season. Holder (1972) reported average mineral consumption of 81 and 74 g per head per day

for bulls and heifers grazing pangola grass, respectively.

Agency for International Development-University of Florida Mineral Project

The department of Animal Science is engaged in a contract with the Agency for International Development entitled "Determination of Mineral Deficiencies and Toxicities for Cattle in Latin America." The research proposal has four principal objectives: 1) To experimentally determine the locations of mineral deficiencies, adequacies and toxicities in selected areas of Latin America where grazing livestock predominate, 2) To establish, by experimentation, the biological response and economic benefit of mineral supplementation to grazing animals, 3) To experimentally evaluate methods of mineral feeding and supplementation for grazing cattle, and 4) To publish and distribute information in order to stimulate the widespread use of mineral supplements. Previous research on mineral concentrations of soils, forages and animal tissues in addition to reports of clinical signs of plant and animal mineral deficiencies are evaluated to determine the areas where mineral deficiencies or toxicities are likely.

The research proposal can conveniently be divided into a (1) Tissue Collection and Analysis Phase and (2) Mineral Supplementation Phase. Animal and plant tissues obtained from specific cattle ranches will be analyzed for mineral concentrations. On the basis of the tissue concentration of each mineral, specific mineral deficiencies and toxicities will be established for selected cattle producing regions. Information from a number of ranches in many areas will be compiled and, by use of a mapping technique, research data will provide evidence of mineral deficiencies and toxicities in large cattle grazing areas. During the mineral supplementation phase, the production and economic benefits of mineral supplementation to grazing cattle will be clearly established. The combined mineral studies utilizing a tissue collection and analysis phase and a mineral supplementation phase will make it possible to obtain a comprehensive impression about the occurrence of mineral deficiencies, toxicities and imbalances in grazing livestock and they will also provide the methodology for improving cattle production through improved mineral nutrition.

At the present, research is being initiated in several Latin American countries which include Brazil, Colombia, Costa Rica, Guatemala, Ecuador and Venezuela.

Summary

An attempt is made to review mineral research data from Latin America. The most widespread mineral deficiency for grazing livestock is that of phosphorus. Calcium deficiencies are rare under grazing conditions. This fact is especially important since many old texts used in Latin America have given a greater importance to calcium than experimental evidence indicates.

Copper and cobalt deficient areas are likely to extend over wide areas of Latin America, but their limits are hard to define at present. Inadequacies of magnesium, sodium, iodine, selenium and zinc and toxicities of molybdenum, selenium, and fluorine are also encountered in areas of Latin America.

Forages rarely provide all the mineral requirements of grazing cattle, therefore, it is a good general practice to provide adequate mineral mixtures to assure the necessary intake of the elements needed.

The University of Florida, with assistance of a grant from the United States Agency for International Development, is cooperating with Latin American Institutions to initiate and establish mineral research.

TABLE 1 GEOGRAPHICAL LOCATIONS OF MINERAL DEFICIENCIES OR TOXICITIES IN CATTLE OF LATIN AMERICAN AND CARIBBEAN COUNTRIES.

Required elements	
Calcium	Argentina (6, 194, 198); Brazil (176); Colombia (6, 86, 198, 217, 258); Costa Rica (20); Guatemala (105); Guyana (6, 97, 141, 198, 252); Mexico (45); Panama (198, 264); Peru (99, 100, 128, 149); Surinam (93); Venezuela (66, 85, 114, 198).
Magnesium	Argentina (21, 77, 87, 94, 179, 194, 198, 215); Brazil (229); Chile (198); Colombia (170); Costa Rica (20, 85, 86, 260); Guatemala (220); Guyana (141); Haiti (198); Honduras (198); Jamaica (198); Peru (7, 22, 255); Surinam (229); Trinidad (202); Uruguay (205).
Phosphorus	Antigua (198); Argentina (6, 18, 36, 48, 77, 90, 91, 131, 156, 165, 198, 203, 259, 263, 264); Brazil (6, 8, 16, 80, 81, 82, 95, 123, 125, 126, 147, 148, 176, 177, 178, 198, 211, 229, 239, 245, 249, 262, 269), Chile (19, 75, 86, 210); Colombia (6, 38, 39, 198, 217, 258, 261); Costa Rica (20, 41, 161, 240, 241, 257, 265); Cuba (5, 110, 133); Ecuador (198); Guatemala (105, 220); Guyana (6, 97, 141, 168, 198); Haiti (198); Honduras (198); Jamaica (198, 264); Mexico (45, 83, 85, 135, 267); Nicaragua (198); Panama (65, 207, 213, 251); Paraguay (198, 201); Peru (1, 11, 23, 25, 86, 99, 100, 101, 129, 130, 149, 150, 166, 198, 225, 236, 237, 238, 254, 255); Surinam (86, 93); Uruguay (4, 6, 86, 117, 189, 198, 227, 228); Venezuela (66, 85, 114, 116, 138, 198).
Potassium	Brazil (132, 229); Haiti (198); Panama (65); Venezuela (114).
Sodium	Brazil (14, 211, 229); Colombia (170); Guatemala (220); Panama (65); Surinam (93); Venezuela (114, 197).
Sulfur	Brazil (211); Ecuador (198).
Cobalt	Argentina (60, 62, 77, 119, 120, 121, 182, 183, 198); Brazil (8, 15, 49, 71, 72, 73, 74, 79, 85, 122, 144, 157, 164, 198, 211, 219, 239, 244, 246, 248); Colombia (104, 258); Costa Rica (85, 198); Cuba (5); El Salvador (198); Guyana (141, 198); Haiti (154, 198); Mexico (6, 198); Nicaragua (198); Peru (98, 100, 128, 149, 225, 255); Surinam (93); Uruguay (228).
Copper or molybdenum toxicity	Argentina (32, 33, 34, 35, 53, 54, 55, 58, 59, 60, 61, 77, 103, 192, 200); Brazil (122, 164, 178, 198, 211, 219, 239, 243, 244, 247, 248, 250); Colombia (209); Costa Rica (161); Cuba (5, 109, 111); Guyana (141); Haiti (154); Mexico (127); Panama (65); Peru (6, 11, 22, 25, 98, 99, 100, 128, 129, 136, 149, 150, 186, 198, 225, 235, 236, 237, 238, 255); Surinam (93, 198); Uruguay (189, 228).

TABLE 1 (cont'd.)

Iodine	Antigua (142, 198); Argentina (169, 199); Bolivia (6, 198); Brazil (6, 56, 167, 174, 175, 198); Chile (137); Colombia (86, 258); Costa Rica (198); Ecuador (152, 198); Guatemala (198); Haiti (198); Nicaragua (198); Paraguay (198); Peru (6, 22, 152, 198, 255, 268); Uruguay (190); Worldwide (69, 70, 112, 152, 223, 224).
Iron	Brazil (124); Costa Rica (161); Panama (65).
Manganese	Argentina (198); Brazil (229); Costa Rica (161); Panama (65).
Selenium	Bahamas (96); Brazil (184); Costa Rica (161); Ecuador (44, 226); Guyana (141); Honduras (185); Mexico (139); Paraguay (42); Peru (242, 266); Uruguay (155).
Zinc	Argentina (192); Brazil (13, 132, 211); Guyana (141, 162); Costa Rica (161); Panama (65); Peru (11); Puerto Rico (151); Venezuela (197).
Toxic elements	
Fluorine	Argentina (6, 77, 198); Guyana (198); Mexico (6, 198).
Manganese	Brazil (211); Costa Rica (9, 113, 160); Peru (129, 130); Surinam (198).
Selenium	Argentina (6, 163); Brazil (153); Chile (6, 163, 198); Colombia (12, 26, 27, 214); Ecuador (198); Honduras (92); Mexico (6, 47, 106, 107, 108, 134, 146, 198, 216); Peru (6, 22, 163, 198); Puerto Rico (146); Venezuela (30, 89, 145, 146, 153, 193).

TABLE 2 PERCENTAGE OF LATIN AMERICAN FORAGES (2615) ANALYZED FOR VARIOUS MINERALS[a]

Mineral	Percentage
Calcium	42.9
Cobalt	5.4
Copper	9.0
Iron	9.8
Magnesium	11.1
Manganese	11.2
Molybdenum	5.1
Phosphorus	43.2
Potassium	7.6
Sodium	5.6
Zinc	6.8
Other minerals	<1.0

[a]McDowell *et al.*, 1975.

TABLE 3. AVERAGE MINERAL CONCENTRATIONS OF LATIN AMERICAN FORAGES[a,b,c]

Calcium	Concentrations, %	0 - 0.30	Over 0.30
(1123 averages)	% of total	31.1	68.9
Cobalt	Concentrations, ppm	0 - 0.10	Over 0.10
(140 averages)	% of total	43.1	56.9
Copper	Concentrations, ppm	0 - 10	Over 10
(236 averages)	% of total	46.6	53.4
Iron	Concentrations, ppm	0 - 100	Over 100
(256 averages)	% of total	24.1	75.9
Magnesium	Concentrations, %	0 - 0.20	Over 0.20
(290 averages)	% of total	35.2	64.8
Manganese	Concentrations, ppm	0 - 40	Over 40
(293 averages)	% of total	21.0	79.0
Molybdenum	Concentrations, ppm	0 - 3	Over 3
(133 averages)	% of total	86.4	13.6
Phosphorus	Concentrations, ppm	0 - 0.30	Over 0.30
(1129 averages)	% of total	72.8	27.2
Potassium	Concentrations, %	0 - 0.80	Over 0.80
(198 averages)	% of total	15.1	84.9
Sodium	Concentrations, %	0 - 0.10	Over 0.10
(146 averages)	% of total	59.5	40.5
Zinc	Concentrations, ppm	0 - 50	Over 50
(177 averages)	% of total	74.6	22.4

[a]Mineral concentrations expressed as dry matter basis.

[b]The approximate requirement (National Research Council, 1970, 1971 and Agriculture Research Council, 1965) of specific minerals for cattle is as follows: Calcium (0.18 - 0.60%), Cobalt (0.05 - 0.10 ppm), Copper (4 - 10 ppm), Iron (10-100 ppm), Magnesium (0.04 - 0.18%), Manganese (20 - 40 ppm), Molybdenum (0.01 ppm or less), Phosphorus (0.18 - 0.43%), Potassium (0.60 - 0.80%), Sodium (0.1%) and Zinc (10 - 50 ppm).

[c]McDowell *et al.*, 1975

TABLE 4 MINERAL SUPPLEMENTS SUPPLIED BY GEOGRAPHICAL AREA ON CATTLE RANCHES IN THE NORTH COAST OF COLOMBIA[a]

Geographical areas	Common salt		Mineralized salt		No supplement		Total	
	No. of ranches	%	No. of ranches	%	No. of ranches	%	No. of ranches	%
Middle Sinú	13	42	18	58	0	0	31	100
Savannahs of Bolívar (south)	18	43	25	57	0	0	43	100
Lower Sinú	13	37	20	57	2	6	35	100
Mompós-Magdalena River Depression	13	37	22	60	0	0	35	100
Savannahs of Bolívar (north and central)	13	21	49	78	1	1	63	100
Coast of Bolívar	5	11	39	81	4	8	48	100
Coast of Atlántico	6	17	21	60	8	23	35	100
Lower Magdalena	26	31	56	66	3	3	85	100
Cesar River Valley	35	42	48	57	0	0	83	100
Gulf of Morrosquillo	5	17	23	79	1	4	29	100
Total	147	30	321	66	19	4	487	100

[a]Rivas Rios, 1974.

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PRESENTATION PAPER

SYMPOSIUM ON FEED COMPOSITION, ANIMAL NUTRIENT REQUIREMENTS, AND COMPUTARIZATION OF DIETS

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MEETING MINERAL REQUIREMENTS FOR GRAZING LIVESTOCK IN THE TROPICS

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Summary

Nutritional disorders including numerous mineral deficiencies, imbalances and toxicities are a major limitation to ruminant livestock production in tropical countries. Oft grazing livestock do not receive mineral supplementation and must depend largely upon forages to supply their requirements. Only rarely, however, can forages completely satisfy all of the mineral requirements. Borderline or deficient levels of certain elements were noted for many forages in the 1974 Latin American Tables of Feed Composition: Co, 43%; Cu, 47%; Mg, 35%; P, 73%; Na, 60%; and Zn, 75%. Calcium deficiency has been reported in developing tropical countries, Mg in 17, P in 38, Na in 14, Co in 21, and Cu in 20 countr A systematic mapping technique, based on animal tissues and forage concentrations can be ployed to predict where mineral deficiencies or toxicities will occur. Attempts to raise livestock productivity in tropical countries will be unsuccessful unless the nutritional e vironment, including adequate mineral nutrition, is likewise elevated. Mineral supplementation is a least cost input to improvement of livestock production.

(Key Words: Minerals, Requirements, Supplementation, Deficiencies, Toxicities).

Introduction

At least 19 mineral elements, including calcium (Ca), chlorine (Cl), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), sulfur (S), cobalt (Co), copper (Cu), iodine (iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se) and zinc (Zn) are nutritionally essential for ruminants. In specific areas, toxic concentrations of Cu, fluorine (F), Mn, Mo or Se limit grazing livestock production. Additional toxic elements (arsenic, lead, cad mium, mercury and aluminum) for ruminants as well as the possible significance of newly di covered essential elements (chromium, vanadium, nickel, tin and silicon) have been reviewed (McDowell et al., 1976b).

Undernutrition is commonly accepted to be the most important limitation to ruminant livestock production in tropical countries. Wasting diseases, loss of hair, depigmented

hair, non-infectious abortion, diarrhea, anemia, loss of appetite, tetany, low fertility and pica are clinical signs often suggestive of nutrient or more specifically mineral deficiencies throughout the world. Numerous investigators have observed that cattle sometimes deteriorate in spite of an apparent adequate feed supply (Russell and Duncan, 1956). This report will emphasize the incidence and significance of mineral deficiencies and toxicities for grazing livestock in the tropics and the methods most appropriate for meeting these requirements.

Factors Influencing Mineral Requirements. Approximate mineral requirements and toxicities for selected ruminants are presented in table 1. Many factors affect mineral requirements including nature and level of production, age, level and chemical form of elements, interrelationship with other nutrients, mineral intake, breed and cattle adaptation. Factors which greatly reduce forage intake, such as low protein (<7.0%) content and increased maturity, lignification, and stem to leaf ratios, likewise reduce the total minerals consumed.

Since tropical forages contain less minerals during the dry season, one might expect more deficiencies during this time, but numerous reports including those from Kenya, Brazil, Colombia and the Union of South Africa noted specific mineral deficiencies more prevalent during the wet season (McDowell, 1976; CIAT, 1973). Grazing cattle were more prone to develop Co or P deficiencies, and the clinical signs were severest, after the rains when pastures were green and plentiful. From Africa, Van Niekerk (1974) noted that the beneficial effect of P was primarily during the wet season, although the P content in the grass was at its highest. Increased incidence of mineral deficiencies during the wet season is less related to forage mineral concentration than to the greatly increased requirements for these elements by the grazing animal. During the wet season, livestock gain weight rapidly since energy and protein supplies are adequate, and thus the mineral requirements are high, while during the dry season, inadequate protein and energy result in animals losing weight, which lowers mineral requirements.

Sources of Minerals to Grazing Livestock. With the possible exception of salt, many producers in tropical countries do not supplement livestock with minerals. Thus livestock

TABLE 1. SUGGESTED MINERAL REQUIREMENTS AND TOXICITIES FOR RUMINANTS (DRY BASIS)

	Growing and Finishing Steers and Heifers[a]	Lactating Dairy Cows[b]	Sheep[c]
Required Elements			
Calcium, %	0.18-0.6	0.43-.53	0.21-0.52
Magnesium, %	0.04-0.1	0.1	0.04-0.08
Phosphorus, %	0.18-0.73	0.33-.039	0.16-0.37
Potassium, %	0.6-0.8	0.70	0.50
Sodium, %	0.1	0.18	0.04-0.1
Sulfur, %	0.1	0.2	0.14-0.26
Cobalt, ppm	0.05-0.1	0.1	0.1
Copper, ppm	4	10	5
Iodine, ppm	0.05-0.1	0.6	0.10-0.8
Iron, ppm	10	100	30-50
Manganese, ppm	1-10	20	20-40
Molybdenum, ppm	---	---	>0.5
Selenium, ppm	0.05-0.1	0.1	0.1
Zinc, ppm	10-30	40	35-50
Toxic Elements			
Copper, ppm	---	100	8-25
Fluorine, ppm	30-100	40	60-200
Molybdenum, ppm	---	6	5-20
Selenium, ppm	5[d]	5	>2

[a]N.R.C. (1970), [b]N.R.C. (1971), [c]N.R.C. (1975), [d]N.A.S. (1971).

depend largely upon forages to supply their mineral requirements. However, only rarely can forages completely satisfy each of the mineral requirements for grazing animals. Table 2 summarizes the mineral concentrations of 2615 Latin American forages (McDowell et al., 1974) Borderline or deficient levels of certain elements were noted for many entries: Co, 43%; Cu, 47%; Mg, 35%; P, 73%; Na, 60%; and Zn, 75%.

Livestock obtain some minerals from water and soil. Although highly variable, all mineral elements essential as dietary nutrients occur to some extent in water. Table 3 present mean and maximum concentrations of specific minerals that could be supplied in drinking wate to lactating dairy cows (N.A.S., 1974) in the U.S.A. Animals sometimes consume appreciable amounts of soil, but this is also highly variable. High soil ingestion is favored by soils with a weak structure and poor drainage, high stocking rates, high earthworm populations and during the winter months when pasture growth is poor (Healy, 1973). From New Zealand, annua ingestion of soil reached 75 kg for sheep and 600 kg for dairy animals (Healy, 1974). Table 4 illustrates element intake by sheep consuming clean and soil contaminated pasture.

Factors Affecting Forage Mineral Content. Forage mineral concentrations are greatly affected by soil types, plant species, stage of maturity, yield, pasture management and climate. Most naturally occurring mineral deficiencies in cattle are associated with specific regions and are directly related to soil characteristics. The content of an element in soil would seem the most important. However, availability factors including soil pH, texture, moisture content and organic matter are often more limiting than soil content. As soil pH increases, the availability and uptake of Fe, Mn, Zn, Cu and Co decreases, whereas, Mo and Se concentrations increase (Williams, 1963; Miller et al., 1972).

Large variations in mineral content of different plant species growing on the same soil have been reported. It is a generally accepted view that herbs and legumes are richer in a number of mineral elements than are grasses (Fleming, 1973). For most minerals, "accumulato plants exist which contain extremely high levels of a specific mineral (Schütte, 1964). As plants mature, mineral contents decline due to a natural dilution process (Fleming, 1973) and translocation of nutrients to the root system (Tergas and Blue, 1971). In most circumstances, P, K, Mg, Na, Cl, Cu, Co, Fe, Zn, and Mo decline as the plant matures (Underwood,

TABLE 2. MINERAL BREAKDOWN AND CONCENTRATIONS OF 2615 LATIN AMERICAN FORAGES (DRY BASIS)[a]

Element	Percentage of forages with entries[b]	No. of entries	Requirement[c]			
Calcium	42.9	1123	0.18-0.60%	Concentrations, %	0-0.30	over 0.30
				% of total	31.1	68.9
Cobalt	5.4	140	0.05-0.10 ppm	Concentrations, ppm	0-0.10	over 0.10
				% of total	43.1	56.9
Copper	9.0	236	4-10 ppm	Concentrations, ppm	0-10	over 10
				% of total	46.6	53.4
Iron	9.8	256	10-100 ppm	Concentrations, ppm	0-100	over 100
				% of total	24.1	75.9
Magnesium	11.1	290	0.04-0.18%	Concentrations, %	0-0.20	over 0.20
				% of total	35.2	64.8
Manganese	11.2	293	20-40 ppm	Concentrations, ppm	0-40	over 40
				% of total	21.0	79.0
Molybdenum	5.1	133	0.01 ppm or less	Concentrations, ppm	0-3	over 3
				% of total	86.4	13.6
Phosphorus	43.2	1129	0.18-0.43%	Concentrations, %	0-0.30	over 0.30
				% of total	72.8	27.2
Potassium	7.6	198	0.60-0.80%	Concentrations, %	0-0.80	over 0.80
				% of total	15.1	84.9
Sodium	5.6	146	0.10%	Concentrations, %	0-0.10	over 0.10
				% of total	59.5	40.5
Zinc	6.8	177	10-50 ppm	Concentrations, ppm	0-50	over 50
				% of total	74.6	22.4

[a]Latin American Tables of Feed Composition (McDowell *et al.*, 1974; McDowell *et al.*, 1976a).
[b]Less than 1% of the other minerals were included.
[c]N.R.C. 1970, 1971 and A.R.C. 1965.

TABLE 3. MEAN AND MAXIMUM PERCENTAGES OF DAILY REQUIREMENTS OF NUTRIENT ELEMENTS IN THE DRINKING WATER OF LACTATING DAIRY COWS[a, b]

Mineral	Lactating Dairy Cow[b] (450 kg) Req. Daily[c]	Mean %	Max. %
Salt, NaCl (g)	66	19	2,600
Calcium (g)	76	7	21
Magnesium (g)	14	9	88
Phosphorus (g)	58	<1	1
Potassium (g)	99	<1	34
Sulfur (g)	20	20	507
Cobalt (mg)	1.4	6	32
Copper (mg)	160	1	16
Iodine (mg)	5.1	81	593
Iron (mg)	2	<1	21
Manganese (mg)	100	3	290
Selenium (mg)	2	1	5
Zinc (mg)	0.86	1	12

[a]N.A.S. (1974), [b]Daily water intake 90 liters. [c]N.R.C. (1971).

TABLE 4. COMPARISON OF ELEMENT INTAKE BY SHEEP PER DAY FROM CLEAN AND CONTAMINATED PASTURE[a]

Element	Element intake per day: Clean Pasture[c]	Element intake per day: Contaminated Pasture[c]
Calcium	4.2 g	5.7 g
Magnesium	1.8 g	2.6 g
Potassium	18 g	19 g
Sodium	1.2 g	2.7 g
Phosphorus	3.0 g	3.7 g
Iron	150 mg	4.15 g
Manganese	60 mg	160 mg
Zinc	18 mg	24 mg
Copper	4.2 mg	6.2 mg
Molybdenum	0.6 mg	0.7 mg
Cobalt	0.18 mg	0.68 mg
Selenium	0.06 mg	0.21 mg
Iodine	0.3 mg	0.8 mg

[a]Healy (1973).
[b]Pasture and soil compositions are an assumed "average."
[c]A DM intake of 600 g of clean pasture is assumed. In the case of contaminated pasture, the same DM intake is assumed plus 100 g of soil - approx. 14% soil contamination on a DM basis or less than 2% on a fresh weight basis.

1966; Gomide et al., 1969).

Climate, forage management and yield influence plant mineral composition. Cattle grazing pressures will influence the species of forage predominating and also change the leaf/stem ratio radically, thereby having a direct bearing on the mineral content of the sward. Increasing crop yields remove minerals from the soil at a faster rate so deficiencies are frequently found on the most progressive farms (Schütte, 1964). Overuse of N and K fertilizers increases the incidence of grass tetany (Kemp et al., 1961) with K also dramatically reducing forage Na content in plants (Underwood, 1966).

Incidence of Mineral Deficiencies and Toxicities in Tropical Regions. Mineral imbalance in ruminants are reported from almost all tropical regions of the world. Table 5 lists reports of mineral deficiencies or toxicities in the developing tropical countries of the world (McDowell, 1976) and specifically Latin America (Fick et al., 1976). These reports include both confirmed and highly suspected geographical areas of mineral deficiencies and toxicities in cattle.

Calcium and Phosphorus. Calcium and P are considered together because they are closely interrelated, along with vitamin D, in bone metabolism and the requirements of these nutrients are dependent on the concentrations of each other. A Ca/P ratio of 1:1 to 2:1 is usually recommended, with a close ratio most critical if P intake is inadequate. Compared to P inadequacies, Ca deficiency is rare in grazing ruminants with the exception of cows lactating large quantities of milk or those on acid, sandy or organic soils in humid areas where the herbage consists mainly of quick-growing grasses devoid of legume species (Underwood, 1966). On the basis of decreased Ca levels in blood and forages, certain tropical countries have reported Ca deficient areas (Table 5).

In cattle, the most prevalent mineral element deficiency throughout the world is lack of P (Table 5). In most livestock grazing areas of tropical countries, soils and plants have low P contents. In many tropical countries, high amounts of soil Fe, Ca and Al accentuate a P deficiency by forming insoluble phosphate complexes. Soils in the humid tropics are characteristically acid with high percentages of exchangeable Al, which complexes with P making it unavailable to plants (Woodruff and Kamprath, 1965).

TABLE 5. GEOGRAPHICAL LOCATIONS OF MINERAL DEFICIENCIES OR TOXICITIES OF RUMINANTS IN DEVELOPING TROPICAL COUNTRIES[a]

Required Elements	
Calcium	Argentina, Brazil, Colombia, Costa Rica, Guatemala, Guyana, India, Mexico, Panama, Peru, Philippines, Senegal, Surinam, Uganda, Venezuela.
Magnesium	Argentina, Brazil, Chile, Colombia, Costa Rica, Guatemala, Guyana, Haiti, Honduras, Jamaica, Kenya, Peru, Surinam, Trinidad, Uganda, Union of S. Africa, Uruguay.
Phosphorus	Antigua, Argentina, Botswana, Brazil, Ceylon, Chile, Colombia, Costa Rica, Cuba, Ecuador, Egypt, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Jamaica, Kenya, Malagasy Republic, Malaysia, Mexico, Nicaragua, Nigeria, Panama, Paraguay, Peru, Puerto Rico, Senegal, Somalia, Southern Rhodesia, Surinam, Tanzania, Uganda, Union of S. Africa, Uruguay, Venezuela, Zaire.
Potassium	Brazil, Haiti, Panama, Uganda, Venezuela.
Sodium	Brazil, Chad, Colombia, Guatemala, Kenya, New Guinea, Nigeria, Northern Rhodesia, Panama, Senegal, Surinam, Uganda, Union of S. Africa, Venezuela.
Sulfur	Brazil, Ecuador, Uganda.
Cobalt	Argentina, Brazil, Colombia, Costa Rica, Cuba, Egypt, El Salvador, Guyana, Haiti, India, Katanga, Kenya, Mexico, Nicaragua, N. Africa, Peru, Surinam, Uganda, Union of S. Africa, Uruguay, Zaire.
Copper (or Molybdenum toxicity)	Argentina, Brazil, Colombia, Costa Rica, Cuba, Guyana, Haiti, India, Kenya, Malaysia, Mexico, Panama, Peru, Rhodesia, Senegal, Sudan, Surinam, Tanzania, Union of S. Africa, Uruguay.
Iodine	Worldwide
Iron	Brazil, Costa Rica, India, Panama.
Manganese	Argentina, Brazil, Costa Rica, Panama, Uganda, Union of S. Africa, Burma.
Selenium	Bahamas, Brazil, Costa Rica, Ecuador, Guyana, Honduras, Mexico, Paraguay, Peru, Uganda, Union of S. Africa, Uruguay.
Zinc	Argentina, Brazil, Costa Rica, Guyana, India, Panama, Peru, Puerto Rico, Uganda, Venezuela.
Toxic Elements	
Fluorine	Algeria, Argentina, Guyana, India, Mexico, Morocco, Saudi Arabia, Tanzania, Tunesia, Union of S. Africa.
Manganese	Brazil, Costa Rica, Peru, Surinam.
Selenium	Argentina, Brazil, Central African Republic, Chad, Chile, Colombia, Ecuador, Honduras, India, Iran, Kenya, Madagascar, Mexico, Nigeria, N. Africa, Peru, Puerto Rico, Sudan, Union of S. Africa, Venezuela, Upper Volta.

[a]McDowell (1976); Fick et al., 1976; Arroyo-Aguilú and Coward-Lord (1974, P deficiency-Puerto Rico); Tartour (1975, Cu deficiency - Sudan).

The most devastating economic result of P deficiency is reproductive failure, with P supplementation dramatically increasing fertility levels in grazing cattle from many parts of the world (McDowell, 1976). In Rhodesia (Ward, 1968) and northern Australia (Lamond, 1970), the effects of undernutrition on fertility were apparent with few exceptions, lactating cows calving about once in two years. In P deficient areas, if a calf is produced, cows may not come into regular estrus again until body P levels are restored, either by feeding supplementary P or by cessation of lactation (Phillips, 1956). Deficiency of P indirectly results in death when P deficient livestock develop Botulism due to pica. In areas of Piauí (Brazil), an estimated 2 to 3% of approximately 100,000 cattle die annually of Botulism (Tokarnia et al., 1970).

Cobalt. Cobalt deficiency occurs in large areas of many countries (Table 5) and mostly but not exclusively, is restricted to grazing ruminants which have little or no access to concentrates. Incidence of Co deficiency can vary greatly from year to year from an undetectable mild deficiency to an acute stage. Cobalt deficiency signs are not specific and often difficult to differentiate from energy-protein malnutrition. Cobalt deficient cattle respond quickly to Co treatment, recovering appetite, vigor and weight. Cobalt sub-deficiencies or borderline conditions are extremely common and are characterized by low production rates unaccompanied by clinical signs (Latteur, 1962).

Cobalt deficiency in ruminants can be corrected by administration of Co in salt mixtures or as a drench, treatment of soil with Co-containing fertilizers, injections of vitamin B_{12} and use of Co bullets, which yield a relatively steady supply of Co to the rumen fluid.

Copper and Molybdenum. With the exception of P, and possibly Co, deficiency of Cu is the most severe mineral limitation to grazing livestock throughout extensive regions of the tropics (Table 5). Copper deficiencies in cattle, as with Co, occur mainly under grazing conditions with gross signs of the deficiency rare when concentrates are fed (Ammerman, 1970). The majority of world reports are concerned with a "conditioned" Cu deficiency where normal amounts of Cu (6-16 ppm) are inadequate due to other forage constituents such as Mo, sulfate and other factors which block utilization of Cu (Russell and Duncan, 1956). Copper deficiencies usually occur when forage Mo exceeds 3 ppm and the Cu level is below 5 ppm (Cunha, 1973).

Chronic Cu toxicity occurs under grazing conditions as a result of high Cu intake or very low Mo and SO_4 intakes. Todd (1969) concluded that chronic Cu toxicity in ruminants is almost entirely confined to sheep and young calves. Clinical signs of Mo toxicity are similar to Cu deficiency with both Mo toxicity and Cu deficiency generally corrected by Cu supplementation. In severe Mo toxic areas, injections of Cu compounds are often the preferred method of administration since the primary site for Cu x Mo interaction is the gut (Suttle and Field, 1974).

Iodine. Iodine deficiency in man and farm animals as endemic goiter is one of the most prevalent deficiency diseases and it occurs in almost every country in the world. The incidence of deficiency has declined in many countries as a result of the widespread use of iodized salt. However, in many tropical countries of the world, endemic goiter remains an exceedingly serious human and livestock problem.

Deficiency of I results in a lack of thyroxin and is manifested by general weakness, stunted growth or stillborn animals with goiter. Iodine deficiency in breeding animals results in suppression of estrus periods in the female and lack of libido in the male (Church, 1971). Although I deficiency results primarily from low dietary intake of I, its incidence is greatly enhanced by intake of goitrogens that interfere with I utilization (Underwood, 1971). The net effect of goitrogens in most instances is to increase the I requirement. The most effective method of goiter prevention is to provide I in the mineral mixture. Unstabilized potassium iodide is readily volatilized or leached and therefore less effective under wet tropical conditions. Calcium or potassium iodate, stabilized potassium iodide, or pentacalcium orthoperiodate are much more stable forms of I.

Sodium and Chlorine. Sodium is the essential nutrient in salt and evidence of a naturally occurring dietary deficiency of Cl, has not been established (French, 1957; Underwood, 1966). Tropical forages low in Na have been reported in many tropical countries (Table 5). Inadequacy of Na is easily overcome by the practice of providing common salt *ad libitum*. Nevertheless, grazing livestock in tropical countries often receive insufficient salt or have only very limited access to salt during certain times of the year. Cattle deprived of salt may be so voracious that they often injure each other in attempting to reach salt. According

to Underwood (1966), Na deficiency is most likely to occur (1) during lactation, due to secretion of Na in the milk; (2) in rapidly growing animals; (3) under tropical or hot semi-arid conditions where large losses of water and Na occur in the sweat and where pastures are low in Na; (4) in animals grazing pastures heavily fertilized with K, which depresses herbage Na levels. Even after prolonged severe deficiency NaCl levels secreted in milk remain high. Thus, lactating animals suffer most from lack of salt in the diet (Loosli, 1976).

Magnesium. Signs of hypomagnesemia tetany are encountered in both grazing ruminants and calves reared too long on milk, without access to other feeds. Susceptibility to grass tetany is increased in older ruminants because of the decreased ability to mobilize skeletal Mg with increasing age (Chicco et al., 1973). Grass tetany generally occurs during early spring, or a particularly wet autumn, among older cattle grazing grass or small grain forages in cool weather. Clinical tetany is endemic in some countries affecting only a small proportion of cattle (1 to 2%). However, individual herds may report tetany as high as 20% (Underwood, 1966). Although not characterized by death, incidence of non-clinical hypomagnesemia is far greater than clinical tetany and economic consequences of lowered production are substantial (N.C.M.N., 1973).

Grass tetany may be prevented by Mg fertilization, adding Mg to feed or salt blocks, and avoiding high K fertilizers. The majority of the commercial Mg-containing mineral supplements are often of little value becuase (1) they contain inadequate quantities of Mg to protect against tetany during susceptible periods, and (2) provision of such supplements to normal animals during non-susceptible periods is useless as a prophylatic measure since additional Mg will not provide a depot of readily available Mg for emergency use. In southeastern U.S., a complete mineral mixture with 25% MgO (14% Mg) has been effective in preventing grass tetany in beef cattle (Cunha, 1973).

Fluorine. Although apparently essential for most species, only toxic effects of F are likely of importance to grazing livestock. Chronic fluorosis is generally observed under three conditions: (1) drinking water high in F (3 to 15 ppm or more), (2) continuous consumption of high F mineral supplements, and (3) grazing F contaminated forages adjacent to industrial plants which emit F fumes or dust (Underwood, 1966). With notable exceptions, the

F content of plants is seldom more than 1 to 2 ppm since most plants have a limited capacity to absorb this element. The more common incidence of fluorosis results from consumption of high F mineral supplements or contaminated forages near industrial plants. Toxicity of F is a reflection of amount and duration of ingestion, solubility of fluorides ingested, age of animal, nutrition, stress factors, and individual animal differences. Suttie et al. (1957) observed that lactating cows could tolerate 30 ppm with no apparent difficulty, and that 50 ppm would result in fluorosis within 3 to 5 years.

Cattle are less tolerant to F toxicity than other grazing livestock (Phillips et al., 1960). Suttie and Faltin (1973) have indicated that general undernutrition enhances the deleterious effects of F toxicosis. For the prevention of fluorosis, F content of water and supplemental phosphates should be determined. Only defluorinated phosphates (<0.01% F) should be fed to cattle and feeding fertilizer rock phosphates avoided.

Selenium. Consumption of feedstuffs containing both toxic (>5 ppm) and deficient (<0.1 ppm) concentrations of Se presents a world-wide problem to grazing livestock. At present, practical measures for controlling Se poisoning for grazing cattle rely on pasture rotation and the use of supplemental feeds from nonseleniferous areas. Locating seleniferous soil and mapping them in sufficient detail is essential.

Since 1957, an interrelationship between Se and vitamin E has been recognized. Both nutrients are essential and in some instances, vitamin E will substitute for Se and vice versa. In grazing animals, three distinct Se-deficiency syndromes have been described: "white muscle disease" (WMD) in newborn or young lambs and calves; unthriftiness, with poor growth rates; and infertility. During some years, incidence of WMD in certain regions is sporadic with less than 1% of the herds affected. In other areas such as Turkey and New Zealand, a 20 to 30% incidence of WMD may occur (Wolf et al., 1963). The principal methods of increasing Se intake by livestock include providing (1) a free choice Se mineral supplement, (2) Se fertilization, (3) injections of Se and (4) Se-ruminal pellets. The use of Se-fortified salt mixtures appears to be the most promising procedure for prevention of ruminant WMD (Ammerman et al., 1976).

Iron, Manganese, and Zinc. Research from tropical regions often indicates that trace mineral supplements should contain Co, Cu, I, and Se, with the need for supplementing rumi-

1 nant diets with Fe, Mn and Zn less certain (McDowell et al., 1976c). Iron supplementation
2 is most warranted for grazing livestock when forages contain less than 100 ppm Fe and/or
3 if insects or parasites are causing substantial blood loss. Manganese deficiency in rumi-
4 nants results in delayed estrus, low conception rates and neonatal skeletal abnormalities
5 (Rojas et al., 1965). In a region of Costa Rica characterized by volcanic soils, dairy cat
6 that consumed high Mn forages (>100 ppm) had lower calving percentages and required more se
7 vices per pregnancy than controls (Fonseca and Davis, 1968; Lang, 1971). Zinc deficiencies
8 as evidenced largely by skin disorders and reduced performance have been reported under nat
9 ural conditions in Guyana, Finland, Norway, Venezuela and the United States (McDowell et al
10 1976c). Mineral supplementation with Mn or Zn is advised if tissue levels are low, when
11 clinical signs are suggestive of deficiencies or if forage concentrations are less than 40
12 Potassium. There are unlikely to be K deficiencies in most conventional ruminant diet
13 (ARC, 1965). Nevertheless, livestock suffering from a K deficiency have been reported in
14 Haiti, with additional tropical countries reporting low forage K concentrations (Table 5).
15 tropical regions, it is possible that K deficiencies could arise in view of the decreasing
16 content of this mineral with increasing forage maturity during the extended dry season (Go-
17 mide et al., 1969).
18 Sulfur. Sulfur supplementation will most likely be needed to meet the requirements of
19 ruminants when poor quality roughages grown on S-deficient soils or roughages combined with
20 non-protein nitrogen (NPN) are fed (Whanger, 1972). Indications of S deficiency have been
21 reported from Ecuador and Uganda as evidenced by improved animal response following S suppl
22 mentation (McDowell, 1976).
23 A Mapping Technique for Determining Mineral Deficiencies and Toxicities. Mineral defi
24 iencies or toxicities in grazing livestock can be predicted by use of a systematic mapping
25 survey technique or regional reconnaissance. Kubota et al. (1967) and Kubota (1968) analyze
26 Se and Co levels of U.S. forages and related concentrations of these elements to Se and Co
27 responsive diseases. Similar mapping techniques based on forage analysis have been under-
28 taken for Ca and P in Brazil (Gavillon and Quadros, 1970) and Se in Venezuela (Jaffé et al.,
29 1969). Egan (1975) reported that the sampling and analysis of stream bed sediments have re-

vealed areas of hitherto unsuspected Mo-induced Cu deficiency in sheep and cattle, Mn deficiency in cattle and Co deficiency in sheep.

Cobalt and/or Cu deficiencies of grazing ruminants have been established in specific Brazilian regions as a result of low liver concentrations of these elements (Tokarnia and Döbereiner, 1973). Deficiencies of P, likewise, were established in Venezuela (Chicco and French, 1959) and in Panama (Chicco, 1972) on the basis of low serum P levels.

The University of Florida, with support from the Agency for International Development, is presently engaged in cooperative mineral research with institutions in 7 Latin American countries. The purpose of this research is to locate mineral deficiencies or excesses for ruminants by use of a systematic mapping technique which analyzes plant and animal tissues and by observing the biological response from mineral supplements.

Detection of Mineral Deficiencies or Toxicities. The most reliable method of confirming mineral deficiencies is response derived from specific mineral supplementation. However, such studies are costly in time and resources if conducted with adequate control and assessment. The majority of mineral imbalances, particularly borderline conditions, do not result in clinical signs specific to a single mineral. Therefore, in order to determine mineral insufficiencies, chemical analyses are often required. Soil mineral analyses can sometimes provide clues to livestock mineral deficiencies but more often they are unreliable and difficult to interpret. Disadvantages of forage element analyses to assess mineral adequacy for grazing livestock include: (1) uncertainty of samples representing what livestock consume, (2) difficulty of estimating forage intake, (3) variation in the availability of forage elements and (4) the possibility of soil contaminated forage samples. Nevertheless, forage mineral analyses are preferable to soil analyses, while animal tissue analyses most accurately portray the contribution of the total environment (forage, soil, water, etc.) in meeting livestock mineral requirements.

Recently, excellent reviews (N.C.M.N., 1973; Miller and Stake, 1974; Egan, 1975; Conrad, 1976) have discussed methods of chemically diagnosing mineral deficiencies. Since mineral analyses are complicated and expensive, it is important to select and analyze the minimum number of plant and animal tissues which are most indicative of the mineral status. Table 6 il-

TABLE 6. DETECTION OF SPECIFIC MINERAL DEFICIENCIES OR TOXICITIES IN CATTLE[a]

Element	Dietary level	Tissue	Critical level indicating deficiency
Calcium	0.18-0.60%	Plasma	8 mg/100 ml
Magnesium		Serum	1-2 mg/100 ml
		Urine	2-10 mg/100 ml
Phosphorus	0.18-0.43%	Plasma	4.5 mg/100 ml
Potassium	0.60-0.80%		
Sodium	0.10%	Saliva	100-200 mg/100 ml
Sulfur	0.10%		
Cobalt	0.05-0.1 mg/kg	Liver	0.05 mg/kg
Copper		Liver	25 mg/kg
Iodine		Milk	300 μg/day
Iron		Hemoglobin	10 g/100 ml
		Transferrin	13-15% saturation
Manganese	20-40 mg/kg	Liver	6-10 mg/kg
Selenium	0.05-0.10 mg/kg	Liver	0.25-0.5 mg/kg
Zinc	10-50 mg/kg	Plasma	0.04 mg/100 ml
			Critical level indicating toxicity
Copper		Liver	700 mg/kg
Fluorine		Bone	4,500-5,500 mg/kg
Manganese	1000-2000 mg/kg	Hair	70 mg/kg
Molybdenum	6-20 mg/kg		
Selenium	5 mg/kg	Liver	5-15 mg/kg

[a]References for critical levels: McDowell (1976).

lustrates analyses of considerable value in assessing specific mineral deficiencies and to: cities (McDowell, 1976).

Alleviating Mineral Deficiencies and Excesses. Indirect methods of providing minerals to grazing cattle include use of mineral-containing fertilizers, altering soil pH, and encouraging growth of specific pasture species. Direct administration of minerals to cattle water, mineral licks, mixtures and drenches, heavy pellets and injections are generally th most economical methods of supplementation.

Problems concerned with mineral supplementation programs in tropical regions include: (1) insufficient chemical analysis and biological data to determine which minerals are required and in what quantities, (2) lack of mineral consumption data needed for formulating supplements, (3) inaccurate and/or unreliable information on mineral ingredient labels, (4) supplements that contain inadequate amounts or imbalances, (5) standardized mineral mixtures that are inflexible for diverse ecological regions (i.e., supplements containing Se distributed in a Se toxic region), (6) farmers not supplying mixtures as recommended by the manufacturer (i.e., mineral mixtures diluted 10:1 to 100:1 with additional salt) and (7) difficulties involved with transportation, storage and cost of mineral supplements. Despite the dramatic effects of P on weight gains and pregnancy rates, Bauer (1968) indicated that the high cost of transportation eliminated the profitability of P supplementation in the llanos of Bolivia.

In order to evaluate a mineral supplement for ruminants, it is necessary to have an approximation of: (1) requirement for each element, (2) biological availability of the elemen in the compounds supplied, (3) daily intake per head per day of both mineral mixture and total dry matter and (4) concentration of elements in the mineral mixture (Houser et al., 1976) Factors affecting mineral consumption have been summarized by Cunha et al. (1964). Comparisons of the biological availability of chemical forms for both macro and micro elements have been reported (Ammerman and Miller, 1972; Peeler, 1972). Table 7 presents an example of mineral allowances and proportions supplied by a typical mineral mixture offered free choice on range or pasture. An acceptable mineral supplement should provide a "significant portion" of the requirement for each mineral and it is generally believed that this figure should be at

TABLE 7. MINERAL ALLOWANCES AND PROPORTIONS SUPPLIED BY A MINERAL MIXTURE OFFERED FREE-CHOICE ON RANGE OR PASTURE

Element	Dietary Allowance[a]	Mineral Mixture (%)[b,c]	Amount from Mineral Mix (%)	% of Allowance From Mineral Mix
Sodium Chloride	0.50%	50.0	.25%	50.0
Calcium	0.30%	12.0	.06%	20.0
Phosphorus	0.25%	12.0	.06	24.0
Magnesium[d]	2000 ppm	---	---	---
Cobalt	0.1 ppm	.005	0.25 ppm	250.0
Copper	10 ppm	.025	1.25 ppm	12.5
Iodine	0.80 ppm	.010	0.50 ppm	62.5
Iron	100 ppm	.250	12.5 ppm	12.5
Manganese	25 ppm	.050	2.5 ppm	10.0
Selenium	0.1 ppm	.0005	0.03 ppm	30.0
Zinc	50 ppm	.050	2.5 ppm	5.0

[a] N.C.R., 1970, 1971 and A.R.C. 1965 recommendations.

[b] Composition similar to certain mineral mixtures available in tropical countries.

[c] It is assumed that mineral consumption will average approximately .5% of the total dietary intake. This is based on an estimated intake of 50 g of mineral mixture for cattle and 10 kg of total dry feed per head daily. The calculation is made as follows:

$$\frac{\text{\% element in mineral mixture X daily intake of mineral mix (g)}}{\text{Total daily dry matter intake (g)}} = \text{\% element in total diet}$$

If, for example:

Copper in mineral mixture (%) = .12
Daily intake of mineral mixture (g) = 50
Total daily intake of dry matter (g) = 10,000

Then: $\frac{.12 \times 50}{10{,}000} = .0006\%$ or 6 ppm

[d] Magnesium is generally not added except for special mixtures for lush winter or spring grazing of tetany-prone pasture.

least 25 to 50%. In known trace mineral deficient regions, it may be desirable to provide 100% of specific elements required especially in areas where they are known to be low in forages (Ammerman, 1976).

As a low cost insurance to provide adequate mineral nutrition, "complete" mineral supplements should be available "free choice" to cattle (Cunha _et al._, 1964). A "complete" mineral mixture usually includes salt, a low fluoride P source, Ca, Co, Cu, I, Mn and Zn. Selenium, Mg, K, S, Fe or additional elements can be incorporated into a mineral supplement as new information suggests a need. In the case of Mg, an oral supplement would only be of value during the seasonal occurrences of grass tetany (Allcroft, 1961). Copper or Se, when in excess, can be more detrimental to ruminant production than any benefit derived by providing a mineral supplement. In regions where high forage Mo predominates, 3 to 5 times the Cu content in mineral mixtures is needed to counteract Mo toxicity (Cunha _et al._, 1964). Thus, the exact level of Cu to use in counteracting Mo toxicity is a complex problem and should be worked out for each area. Data from Florida (Becker _et al._, 1965) and Montelonia, Colombia (A. Gil, personal communication) note that salt content of water supplies is important in formulating mineral supplements since cattle consume less minerals when water is high in salt. In Florida, mineral mixtures can include 86% salt for sandy soils and 43% in brackish areas.

Mineral toxicities are more difficult to control than deficiencies, especially under grazing conditions, Molybdenosis is controlled by additional doses of Cu, fluorosis by periodic removal of cattle from fluoridated feed or water and selenosis by rotational grazing to avoid continuous access to high Se forages or by diluting the ration with low Se feeds.

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PHOSPHORUS SUPPLEMENTATION FOR INCREASING REPRODUCTION IN CATTLE*

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Feed phosphate consumption in the United States increased from 340,000 tons in 1951 to 1.3 million tons in 1970. The requirements for feed phosphate supplements have been estimated at 1.8 million tons by 1985. This is an indication of the need and importance of feed phosphates in livestock production systems.

In ruminants, symptoms of phosphorus deficiency include loss of appetite, lowered performance and lowered reproductive rates. Severely affected animals may chew various objects and eat soil. Such symptoms may be confused with those of other nutrient deficiencies or management problems. A prolonged phosphorus deficiency reduces blood inorganic phosphorus. Normal plasma values are 4-6 mg/100 ml for adult animals and 6-8 mg/100 ml for young animals.

During the 1973-74 shortage of phosphorus supplements a report on Levels and Sources of Phosphorus Recommended for Livestock and Poultry was prepared by a Task Force on Phosphorus Requirements of Livestock and Poultry and published by the NRC-National Academy of Science. An abbreviated table of dietary phosphorus requirements of beef cattle is presented in Table 1. The phosphorus requirement depends on the age of animal and the biological function which it is performing. The lowest NRC recommendation is 0.18% phosphorus in the diet of non-lactating pregnant cows. Recommended dietary levels during periods of phosphorus shortage for this same animal are minimal levels of 0.16% and emergency levels of 0.15%. Most recommended phosphorus levels are from 0.21% up to 0.38%. In the Latin American Tables of Feed Composition the phosphorus levels of 1129 forage entries were studied. Fourteen percent of the forages contained less than 0.10% phosphorus, 48% of the forages contained less than 0.20% phosphorus and nearly 75% of the forages contained less than 0.30% phosphorus. These data support the conclusion, that for grazing cattle, the most prevalent mineral element deficiency throughout the world is lack of phosphorus. Furthermore, nineteen Latin American countries have reported a deficiency.

*Presented at the Ruminant Livestock Production System Seminar, Georgetown, Guyana, March 1, 1976.

Table 1. Abbreviated Table of Dietary Phosphorus Requirements for Beef Cattle

Weight		Daily Gain[a]		Present NRC Recommendation[b]		Recommended during Phosphorus Shortage: Minimal Level		Recommended during Phosphorus Shortage: Emergency Level	
Kg.	lb.	Kg.	lb.	(g/day)	(% in ration)	(g/day)	(% in ration)	(g/day)	(% in ration)
Growing Finishing Steer Calves and Yearlings									
250	550	0.7-1.3	1.5-2.9	16-23	0.28-0.38	14-21	0.25-0.34	14-20	0.24-0.33
400	880	1.0-1.4	2.2-3.1	20-23	0.21-0.26	18-21	0.19-0.23	17-20	0.18-0.22
Pregnant Yearling Heifers - Last 3-4 Months of Pregnancy									
375	825	0.4-0.8	0.9-1.8	15-22	0.21-0.19	14-20	0.19-0.17	13-19	0.18-0.17
Dry Pregnant Cows - Middle Third of Pregnancy									
454	1000	---	---	12	0.18	11	0.16	10	0.15
Dry Pregnant Cows - Last 2-3 Months of Pregnancy									
454	1000	0.4	0.9	15	0.18	14	0.16	13	0.15
Cows Nursing Calves - Average Milking Ability									
400	880	---	---	25	0.28	23	0.25	21	0.24
Cows Nursing Calves - Superior Milking Ability									
400	880	---	---	41	0.38	37	0.34	35	0.33
Bulls, Growth and Maintenance									
400	880	0.9	2.0	23	0.21	21	0.19	20	0.18
800	1760	---	---	19	0.18	17	0.16	16	0.15

a/ Ranges in recommendations correspond to ranges in daily gain.

b/ Based on Nutrient Requirements of Beef Cattle, 5th Revised Edition (In Press).

Effect of Phosphorus Deficiency on Reproduction

Early research in the United States and South Africa showed the dramatic effect of phosphorus supplementation on reproductive performance. More recent studies have substantiated these early results.

Black et al. (1943) conducted an investigation from 1937 to 1941 inclusive to determine what mineral elements were deficient in the vegetation of southern Texas and the methods of correcting such deficiencies. Comparatively few samples of vegetation contained more than 0.13 percent of phosphorus, but most of them contained more than 0.23 percent of calcium (Table 2). The indication, therefore, is that cattle grazing such forage would not get sufficient phosphorus to meet their requirements, but that the calcium would be ample. A low protein content of the forage was usually found to be associated with a low phosphorus content. One hundred Brahman x Shorthorn and Brahman x Hereford heifers about 18 months of age were used. The control groups received no mineral supplement. The three remaining groups were hand-dosed, six times a week, with the following mineral supplements: Group 2, bonemeal; Group 3, disodium phosphate; and Group 4, bonemeal with small quantities of iron, manganese, copper, cobalt, zinc, and boron. Groups 2 and 3, bonemeal and disodium phosphate were fed in such quantities as to supply 6.5 grams to lactating cows, per head daily. Group 4 cows, whether dry or in lactation, were kept at the 6.5 gram level. Except for several months at the beginning and end of the experiment, the average weights of the cows in each of the mineral-fed groups were significantly higher than those of the control group cows. Differences between the supplement-fed groups were not significant at any time during the experiment.

The primary advantage in feeding a phosphorus supplement to cows under the conditions of this experiment is the increased percentage of the calf crops and greater weights attained by the offsprings (Table 3). Based on a 2-year average, only 64 percent of the control cows produced calves as compared with 85 percent for those supplement-fed. This difference was highly significant. For the 2-year period, also, the control cows weaned only a 58 percent calf crop, whereas the supplement-fed cows weaned 81 percent. Only slightly more than 30 percent of the control cows calved in 2 consecutive years, whereas the supplement-fed cows averaged about 73 percent. The difference was highly significant. The feeding of phosphorus supplements to cows had no influence on the birth weights of calves. However, on the average for 2 years, the weaning weight per calf in the supplement-fed groups was 69 pounds more than in the control group, which was a considerable advantage.

Differences in weaning weights of the calves in the supplement-fed groups were not statistically significant.

At 12 months of age, the difference in average weight between the heifers in the supplement-fed and control groups was essentially the same as at weaning time, but, at 18 months of age, the former heifers averaged 126 pounds heavier than the latter.

Table 2. Average protein, calcium, and phosphorus content, on an air-dry basis, of some of the more important forage plants in southern Texas.

Year and Month	Paspalum plicatulum			Andropogon litoralis			Elyonurus tripsacoides			Aristida purpurea			Rainfall
	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	Protein	Calcium	Phosphorus	
1939	%	%	%	%	%	%	%	%	%	%	%	%	Inches
January	5.70	.43	.06	4.03	.27	.05	4.15	.26	.04	5.51	.29	.06	1.75
February	7.73	.44	.09	5.75	.28	.06	4.26	.25	.05	7.03	.24	.07	.56
March	9.53	.54	.08	7.26	.36	.10	6.85	.29	.08	7.64	.25	.08	.31
April	8.32	.51	.08	6.20	.34	.07	6.07	.30	.07	6.37	.23	.06	1.84
May	9.26	.50	.10	7.14	.31	.10	6.70	.26	.09	7.92	.24	.10	5.62
June	6.48	.46	.07	6.22	.29	.08	5.74	.24	.08	—	—	—	1.74
July	4.35	.51	.06	4.53	.34	.06	3.62	.22	.05	5.70	.29	.05	.40
August	3.97	.49	.05	3.45	.30	.04	3.43	.32	.04	4.41	.24	.07	.56
September	7.92	.51	.07	7.01	.41	.09	5.85	.29	.07	7.17	.26	.07	4.02
October	7.02	.44	.08	7.19	.30	.09	—	—	—	8.06	.26	.10	.51
November	4.62	.36	.04	2.88	.26	.05	4.60	.23	.05	5.63	.22	.06	.00
December	3.30	.41	.03	4.69	.24	.03	2.91	.23	.03	3.23	.19	.03	.14
1940													
January	3.20	.34	.03	3.44	.24	.03	3.18	.24	.04	3.09	.21	.02	.40
February	3.85	.38	.03	3.38	.27	.03	3.24	.21	.03	3.67	.21	.02	.31
March	4.15	.36	.03	3.90	.29	.04	3.48	.20	.03	3.96	.22	.03	2.25
April	9.85	.54	.11	7.69	.39	.10	9.22	.36	.11	11.29	.23	.11	.00
May	5.82	.47	.05	4.06	.26	.04	4.75	.31	.04	—	—	—	.15
June	8.72	.58	.09	6.94	.34	.08	7.13	.33	.10	7.46	.31	.08	1.52
July	9.84	.49	.10	6.87	.29	.08	6.76	.29	.07	—	—	—	3.75
August	5.73	.20	.08	7.41	.54	.08	—	—	—	—	—	—	2.38
September	9.63	.41	.11	—	—	—	5.27	.27	.06	7.79	.31	.10	2.92
October	3.83	.30	.05	3.94	.24	.05	3.38	.26	.04	—	—	—	1.01
November	2.39	.49	.03	3.40	.25	.03	3.66	.33	.04	3.38	.23	.03	1.10
December	4.76	.33	.04	3.67	.25	.03	4.32	.26	.04	—	—	—	2.46

Table 3. Effect of Phosphorus Supplements on Cattle Production data for the 2 calf crops, 1939 and 1940.

Item	Group 1. Control fed no supplement		Group 2 fed bonemeal		Group 3 fed disodium phosphate		Group 4 fed bonemeal and trace minerals	
	1939	1940	1939	1940	1939	1940	1939	1940
No. cows	25	23	25	24	24	23	25	22
Calves born	22	9	25	16	22	18	23	18
Calves weaned	19	9	23	14	21	18	22	18
% calf crop	88	39.1	100	66.7	91.7	78.3	92	81.8
% calf crop weaned	76	39.1	92	58.3	87.5	78.3	88	81.8
Avg. weaning wt. calves	421	429	486	503	513	501	460	503
Avg. wt. cows at weaning	701	832	878	885	864	889	859	884
% cows calving 2 consecutive, %	30.4		58.3		78.3		81.8	
Cost of supplement per weaned calf	0		3.81		4.36		3.80	
Net increased return per calf due to supplement	0		5.91		6.55		4.89	

Source: Black et al., 1943, Calves were valued at $8.00 per hundred weight.

Reynolds et al. (1953) report the results of P supplementation experiment on range cattle breeding performance. This experiment was carried out in southern Texas over a five-year period, during a prolonged drought. The purpose of it was to find the effect of three different methods of providing P to breeding cattle.

Group 1 received no supplement, Group 2 was fed bonemeal in self-feeders, Group 3 received disodium phosphate in drinking water, and Group 4 cattle grazed on a range which was fertilized with triple superphosphate.

Table 4. Effect of Phosphorus on Calf Production in Texas.

Item	Group 1 Control	Group 2 Bonemeal	Group 3 Disodium Phosphate	Group 4 Fertilizer
Weight of calves at weaning, lb.	489	535	542	551
No. of days between calvings	459	365	367	364
Weaned calf weight per acre, lb.	21	31	33	47
Calf crop weaned, %	64	88	92	96

Source: Reynolds et al., 1953.

Conrad and Mendes (1965) reported the results of an experiment which was conducted on a private ranch near Aquidanauna, Mato Grosso, Brazil. This ranch had about 10,000 Brahman crossbred cattle on 70,000 acres and had an average annual calf crop of about 55%.

A total of 381 cows which had weaned at least three calves were divided into four experimental groups. Each group was kept in separate pastures of similar conditions and were fed trace mineralized salt ad libitum. The duration of the experiment was from August 10, 1963, to February 28, 1965.

Treatments were as follows:

Group A - Molasses - urea, 9:1, 2 kg. head daily
Group B - Disodium phosphate, ad libitum
Group C - Bonemeal, ad libitum
Group D - Control

Results are outlined in Table 5.

They show that the control group had an average calf crop of 55% as compared to 77% for those fed bonemeal, an increase of 22% from the feeding of bonemeal. Cows receiving any of the three supplements also calved earlier than those receiving only trace mineralized salt.

Table 5. Effect of Phosphorus on Calf Production in Brazil.

	No. of cows	No. births by 10/22/64	No. births by 02/28/65	Total calf crop	% births
Group A Urea - Molasses	98	48	20	68	69
Group B Disodium Phosphate	94	62	4	66	70
Group C Bone Meal	90	59	10	69	77
Group D Control	99	22	32	54	55

Source: Conrad and Mendes, 1965.

Proof that large numbers of grazing cattle are not receiving adequate phosphorus supplementation and that mineral supplementation will produce an economical return of two to one on mineral investment is shown in two reports from research conducted by ICA-CIAT in the eastern Llanos of Colombia.

The Preliminary Implications of the ICA-CIAT Herd from Stonaker et al., 1974.

The early and currently operating strategy in the ICA-CIAT Herd Systems Project has been to introduce, under the challenge of an inhospitable environment, a series of existing inputs to increase beef production economically. The opportunity to study a wide range of interactions of inputs has been provided.

With grade Zebu heifers purchased in the Carimagua area by ICA, effects of several variables on reproductive rate, growth, mortality and disease, and total beef produced are being investigated. These variables are complete mineral supplement, improved molasses grass pasture and urea-molasses supplementation. On a hierarchical basis, it will be possible to study the effects of early weaning and crossbreeding within the groups. Thus several variables in the project are concurrently being examined at two levels: the prevailing or existing level versus an estimated or improved level.

Salt and mineral supplementation. Complete mineral supplementation has been proven to affect reproductive capacity markedly, increasing reproductive rates across a wide range of soil and climatic conditions. The prevailing question is why this mineral supplementation is not widely used in the Llanos. Current indications are that pregnancy rates in first-calf heifers may be greatly increased by mineral supplementation (CIAT Annual Report 1973). The effect on nursing cows is almost certain to be less; ICA data indicated that except for the North Coast station at Montería, wet cows are not bred, even though they receive minerals.

The increased reproduction of first-calf heifers alone will more than pay for mineral supplementation of the entire cow herd (Tables 7 7 and 8). The mineral response in cows at Carimagua is not yet known, but it will probably be less than in others because of other more limiting stress factors for the nursing cow.

An additional advantage is that these heifers reach a breeding weight at least four months sooner than those that do not receive mineral supplementation.

Table 6. Preliminary results from ICA-CIAT Herd Systems Project (1972-1974).

	Herd	Heifer Dec. 73	Weight (kg) Feb. 74	Percentage Oct. 73		Pregnant Feb. 74	
Native	1	307	316	63		66	
Savanna-salt	2	289	289	31	24	57	50
Savanna-salt	3	270	275	17		43	
Savanna-minerals	4	334	343	68	70	88	84
Savanna-minerals	5	332	335	71		79	
Savanna-molasses grass-minerals	6	325	338	58	60	89	86
Savanna-molasses grass-minerals	7	326	347	63		83	
Molasses grass-minerals	8	328	333	78	80	86	88
Molasses grass-minerals	9	335	333	81		89	

Table 7. Summary of salt and mineral consumption per cow at Carimagua (1973).

	Salt only			Salt - mineral mix*					
Herds	1	2	3	4	5	6	7	8	9
	8.9	6.6	13.4	17.0	18.2	28.8	25.2	27.0	27.0
Avg consumption, kg.	9.6			17.6		27.0		27.2	
Cost/year (Col$)	9.65			70.48		108.00		108.80	

*Salt 47%, dicalcium phosphate 47%, trace minerals 6%; approximate cost Col$ 4 per kg, salt only Col$ 1 per kg (1$US = 25$ Col)

Table 8. Projected returns from mineral supplementation in herd of 80 cows and 20 heifers.

Herds'	2	3	4	5	6	7	8	9
	%	Nb*	%	Nb*	%	Nb*	%	Nb*
Calf crop from heifers	50	10	84	17	86	17	88	18
Assumed calf crop from cows	50	40	50	40	50	40	50	40
Total calves		50		57		57		58
Value of calves at Col$1,600		$ 80,000		$ 91,200		$ 91,200		$ 92,800
Increase in calf value from minerals		—		$ 11,200		$ 11,200		$ 12,800
Salt or mineral cost		$ 965		7,048		10,800		10,800
Increased value of minerals		—		6,083		9,835		9,835
Net increase from minerals				$ 5,117 (84%)		$ 1,365 (14%)		$ 2,965 (30%)

*Nb=number of births.

Minerals from Annual Report, 1974, CIAT. Up to February, 1974, about 18 months after the experiment began and before the first calving, mineral-supplemented heifers weighed 1.20 times more than heifers receiving only salt. On a gain basis, mineral-supplemented heifers gained 1.63 times more than the heifers on salt only. In contrast to African results, mineral-supplemented heifers actually responded more to minerals in the dry season than during the wet season. It might be inferred from this that the lowland pasture used in the dry season was of somewhat higher nutritive value than the upland pasture grazed in the rainy season. The mineral comparison was limited to native pasture.

First-year calving and pregnancy rates were greatly different for the mineral-supplemented group. This amounted to 34 more calves born or predicted to be born per 100 cows; that is, 1.49 times more for the mineral-supplemented herd.

These early results reinforced the recommendations for feeding complete minerals, advocated for so long by all agricultural advisory agencies, public and private. It is difficult to understand why there has been so little adoption of mineral feeding. Perhaps an explanation such as that of Bauer (1968)* pertains. He found in the Beni region of Bolivia that the economics of mineral supplementation in cow herds was not favorable. However, in the present study with heifers, return on mineral investment is at least two to one. Comparative results with cows will become available in future years.

Consumption was about 10 kg/year/heifer for salt-only herds, 20 kg of complete mineral mix on native pasture, 30 kg of complete mineral mix on molasses grass pasture year round, and 25 kg of complete mineral mix per cow per year for herds on molasses grass only during the rainy season. The mineral formula was: 47% salt, 47% dicalcium phosphate, 6% trace mineral mix. The trace mineral mix was copper sulfate 1.95%, ferrous sulfate 5.0%, zinc oxide 1.24%, manganese sulfate 3.09%, cobalt sulfate .2%, potassium iodide .07%, wheat middlings 88.45%.

Summary

One of the major advantages from phosphorus supplementation under range conditions is the increase in percent calf crop and the resulting increase in the percent of calves weaned. Phosphorus supplementation as bonemeal in a two year study in Texas resulted in a weaned calf crop of 81% as compared to 58% for the controls. In a later study, the weaned calf crop was 88% for those fed bonemeal compared to 64% for the controls. A study conducted in Brazil resulted in a 77% calf crop when bonemeal was fed compared to 55% for the controls. Recent trials in Colombian llanos demonstrated that the pregnancy rate was increased from 50% for the controls up to 84% when complete minerals were fed. Economical returns on mineral investment has been at least two to one in some studies.

In view of the current information on low phosphorus levels in Rupununi and intermediate savannah soils and forages and the results of the survey in the Rupununi cattle producing area (only 2 of 42 producers feeding minerals), mineral supplementation, especially phosphorus, appears to be an economically sound practice which has tremendous potential for increasing the precent calf crop in the major cattle producing areas of Guyana.

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