MICHIGAN STATE UNIVERSITY LIBRARIES
3 1293 10663 8731

THESIS

This is to certify that the

thesis entitled

Interrelationships Among the Mineral Content of Soils, Forages and Cattle in the Central and Northern Regions of Veracruz, Mexico

presented by

Hipolito V. Barradas

has been accepted towards fulfillment of the requirements for

M.S. degree in Dairy Science

Robert N. Cook

Major professor

Date November 3, 1960

O-7639

LIBRARY
Michigan State
University

OVERDUE FINES:
25¢ per day per item

RETURNING LIBRARY MATERIALS:
Place in book return to remove
charge from circulation records

HF 135
MAY 6 '88
000 H317
NOV 27 '87
FEB 2 '88
65 K033
65 K047
R
1 '88
48 K057

INTERRELATIONSHIPS AMONG THE MINERAL CONTENT OF SOILS, FORAGES AND CATTLE IN THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO

BY

HIPOLITO VICTOR BARRADAS

A THESIS

submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Dairy Science

1980

ABSTRACT

INTERRELATIONSHIPS AMONG THE MINERAL CONTENT OF SOILS, FORAGES AND CATTLE IN THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO

By

Hipolito Victor Barradas

The mineral status and mineral interrelationships of soils, grasses and cattle were studied in two regions of the State of Veracruz, Mexico, to develop appropriate sampling methodology and laboratory techniques for local conditions, and to set basic guidelines for mineral supplementation. The minerals studied were calcium, phosphorus, potassium, magnesium, copper, iron, selenium and zinc.

Three farms with Pangolagrass (Digitaria decumbens) and three with Guineagrass (Panicum maximum) were sampled per region during the wet season of 1979. Farms were selected where no mineral supplementation, with the exception of common salt, was offered to the animals, and where no pasture fertilization practices were observed. Animals sampled were lactating cows, heifers, and calves.

Deficiencies of calcium, phosphorus and selenium in grasses were found, especially for the Central Region and for Pangolagrass. These elements were also deficient in serum of cattle from both regions. Protein was deficient for both grasses in the Northern Region.

To my parents,

Victor Barradas Sosa
Refugio Lagunes de B.

To my sister and brothers,

M^{a} del Refugio,
Fernando,
Victor, and
Fco. Javier

To my aunt,

Manuela Lagunes Grajales

For their continuous encouragement, support
and understanding throughout the years.

ACKNOWLEDGMENTS

I wish to express my deepest gratitude to my academic advisor, Dr. Robert M. Cook, for his continuous counseling and guidance, and for his support for this research. I also extend my appreciation to Dr. J.L. Gill, Dr. J.T. Huber and Dr. H.D. Stowe for graciously consenting to serve on my committee, and for being of insuperable help during my thesis work.

I thank faculty members and graduate students from the Dairy Science Department for the valuable ideas and suggestions offered. I particularly appreciate the help of Dr. M. Villareal during the computer processing of the final data, as well as his friendship and understanding. I am also in debt to the nutrition laboratory personnel, especially to Ms. Anne Goatley, for their assistance and encouragement. I am grateful to Ms. Elaine Kibbey, Departmental secretary, for her constant willingness to be helpful.

I sincerely thank Dr. D.E. Ullrey for his advice and for the use of the laboratory facilities in the Animal Husbandry Department. I am very grateful to Ms. Phyllis Whetter for her invaluable experience on mineral analyses, and for her kindness in teaching me the many important details of laboratory procedures. I also thank Dr. D.D. Warncke, from the Department of Crop and Soil Sciences, for his advice on soil analysis.

I am in debt to staff and personnel of the Instituto Nacional de Investigaciones Pecuarias in Mexico City for their help and support,

especially to Dr. A. Shimada and M.S. I. Tejada de H. I also express sincere thanks to staff and personnel of the Centro Experimental Pecuario "La Posta" in Veracruz, particularly to Dr. H. Roman P. and Dr. H. Castillo R., for their invaluable assistance and support during the sampling period. I greatly appreciate the marvelous help of staff and personnel at the Centro Regional de Salud Animal in Tuxpam, especially from Dr. B. Alarcon.

The assistance and enthusiasm of the Cattlemens' Associations and individual farmers from the two regions studied are also greatly acknowledged.

Finally, but not least, I express my deepest gratitude to the Mexican Government for the economic support granted to me through its Consejo Nacional de Ciencia y Tecnologia (C.O.N.A.C.Y T.).

TABLE OF CONTENTS

LIST OF TABLES

Table

Table

LIST OF FIGURES

LIST OF ABBREVIATIONS

Ca	Calves
CF	Crude Fiber
Co	Cows
CP	Crude Protein
DM	Dry Matter
Gra	Grass
HB	Hemoglobin
He	Heifers
Ht	Hematocrit
Reg	Region
So	Soil

The different elements studied and measurement units used throughout the text, tables, and figures were abbreviated according to the official chemical symbols and standard nomenclature.

Compound abbreviations should be read as follows:

CaSe = Calves selenium

CoP = Cows phosphorus

GraSe = Grass selenium

SoCa = Soil calcium

INTRODUCTION

The importance of ruminant animals to mankind was established many centuries ago, based upon their peculiar and unique characteristic of being able to transform feed of low biological quality for humans into high quality products, such as beef and milk. The ruminants themselves, however, like other animals, did not have the required enzymes for degradation and utilization of the most abundant polysaccharide in the plant world, cellulose. Hence, their digestive system was modified to include billions of cellulolytic microorganisms, mainly bacteria and protozoa. These microorganisms and the ruminant animal live in a symbiotic relationship, being dependent upon one another.

Rumen microbes, as with other living systems, need basic sources of nutrients in order to meet biological requirements. Protein and carbohydrates are supplied and converted into forms useful to the microbiota; and subsequently to the ruminant itself as microbial protein or fermentation products. The rumen is the most important organ of the digestive tract of ruminants, and is a continuous anaerobic culture system in which the established microbial population ferments carbohydrates. In addition to the major nutrients, vitamins (mostly the water solubles) and minerals are also needed for microbial growth.

In Latin America, grazing cattle depend almost exclusively on forages to meet their nutrient requirements. Most of these forages are

native grasses which are a relatively good source of nutrients only during the rainy season, and before they mature. After maturity and during the dry season protein, minerals, palatability and digestibility decrease, while fiber increases. At this point, animals are unable to eat and digest enough even to maintain their body weight. The common pattern of livestock growth is: daily gains are acceptable during the wet season, but loss of weight during the dry months may exceed that gained during the wet season. Figure 1 illustrates this trend.

The final result is a net gain of 50-100 kgs per year and poor reproductive performance with first calving at three or four years of age. Compounding the problem are the low calving rates (40 to 50%), a low percentage of animal slaughtered (less than 12% of the total population), and the high mortality levels (12 to 15%) (97, 98). All these factors lead to poor herd turnover rates, characteristic of developing tropical countries.

Little or no mineral supplementation is given to cattle in Latin America. As a result, grazing livestock have to depend largely upon forages to fulfill their mineral requirements. Forages can rarely satisfy completely the needs for each mineral (99). This is why numerous mineral deficiencies, imbalances and toxicities severaly affect the cattle industry in most of these countries. Table 1 shows the geographical distribution of some mineral deficiencies and toxicities for ruminants in Latin America. These reports include both confirmed and highly suspected areas.

Mineral requirements are primarily dependent upon the level of productivity, and this is related to some specific mineral deficiencies which are more prevalent during the wet season. Higher incidence of mineral deficiency during the rainy season is less related to forage

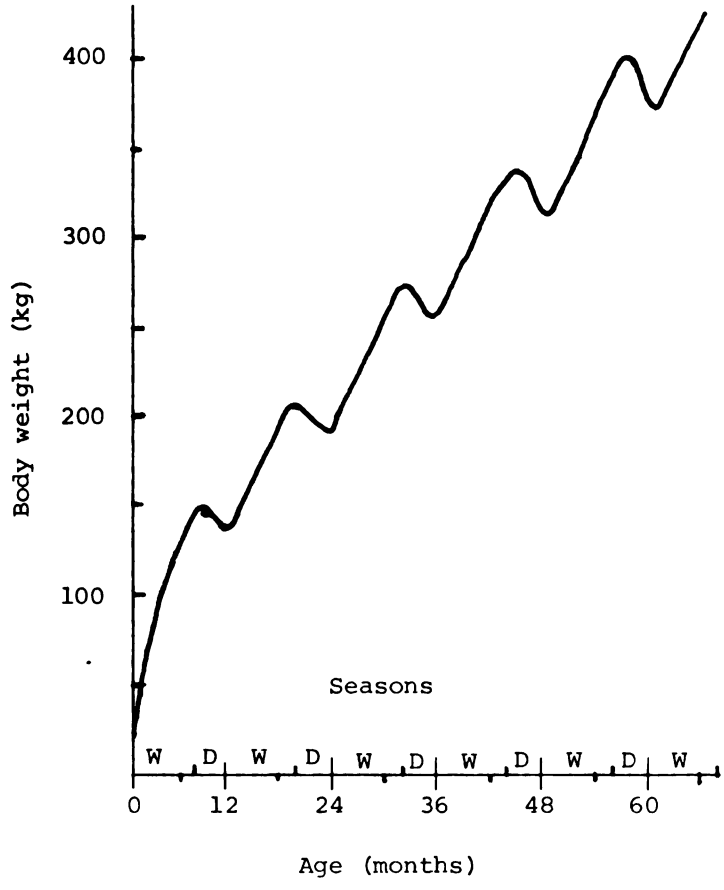


Figure 1. Typical growth curve for cattle on unimproved tropical grasslands in areas with 4-month dry season. (104)

mineral concentration than to the greatly increased requirements for the grazing animal. During the wet months, livestock gain weight rapidly because energy and protein supplies are adequate; thus, the mineral needs are high. During the dry season, inadequate protein and energy result in the animal losing weight, which lowers mineral requirements (48, 121). It is also true, however, that in most circumstances, phosphorus, magnesium, sodium, chlorine, cobalt, iron, zinc, and molybdenum decline as the plant matures (58, 99). It has been said that these losses of nutrients as plants mature are probably due to translocation to the root system (143).

Soil ingestion (geophagia) is also an important factor. It is usually considered that soils influence animal nutrition by the quantity or quality of the herbage they produce, so that the usual sequence is soil-plant-animal. It is suggested that a direct soil-animal effect also needs to be considered because of geophagia (65), which, by grazing cattle over the winter months, varies from 140 to 1,400 g/day (147). Cattle may thus ingest up to ten times as much copper, lead and arsenic from soil than is consumed from herbage. Soil may also be the main source of cobalt, which is present in relatively small amounts in herbages compared to soil concentrations.

On the other hand, soils in the tropics are highly leached, so that concentration of certain trace elements can be expected to be relatively low. Also, because of the usual acidity, the uptake of some elements like selenium and molybdenum may be inadequate.

Most of the above considerations apply to Mexico, as well as all other Latin American countries. Twenty-five percent of Mexico is tropical and 60% of the national cattle population is found in the tropics.

TABLE 1.-GEOGRAPHICAL LOCATIONS OF MINERAL DEFICIENCIES OR TOXICITIES OF RUMINANTS IN LATIN AMERICA

REQUIRED	
Ca	Argentina, Brazil, Colombia, Costa Rica, Guatemala, Guyana, Mexico, Panama, Peru, Surinam, Venezuela.
Mg	Argentina, Brazil, Chile, Colombia, Costa Rica, Guatemala, Guyana, Haiti, Honduras, Jamaica, Peru, Surinam, Trinidad, Uruguay.
P	Antigua, Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Surinam, Uruguay, Venezuela.
K	Brazil, Haiti, Panama, Venezuela.
Na	Brazil, Colombia, Guatemala, Panama, Surinam, Venezuela.
S	Brazil, Ecuador.
Co	Argentina, Brazil, Colombia, Costa Rica, Cuba, El Salvador, Guyana, Haiti, Mexico, Nicaragua, Peru, Surinam, Uruguay.
Cu (or MO toxicity)	Argentina, Brazil, Colombia, Costa Rica, Cuba, Guyana, Haiti, Mexico, Panama, Peru, Surinam, Uruguay.
I	Antigua, Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Haiti, Nicaragua, Paraguay, Peru, Uruguay.
Fe	Brazil, Costa Rica, Panama.
Mn	Argentina, Brazil, Costa Rica, Panama.
Se	Bahamas, Brazil, Costa Rica, Ecuador, Guyana, Honduras, Mexico, Paraguay, Peru, Uruguay.
Zn	Argentina, Brazil, Costa Rica, Guyana, Panama, Peru, Puerto Rico, Venezuela.
TOXIC	
F	Argentina, Guyana, Mexico.
Mn	Brazil, Costa Rica, Peru, Surinam.
Se	Argentina, Brazil, Chile, Colombia, Ecuador, Honduras, Mexico, Peru, Puerto Rico, Venezuela.

Sources: McDowell (98); Fick et al. (49).

Among the states located in the tropical areas of Mexico, Veracruz ranks first in beef production in the country with 689,880 steers slaughtered in 1976; seventy-five percent of them were exported to Mexico City (154). Milk production for the same year was about 663.4 million liters.

With a cattle population of more than 4.5 million head, a great variation in herd composition and an extraordinary diversity of climates, soils, and forages in the state of Veracruz, there are many possibilities for scientific investigations. Currently, animal research is being done throughout the state on such subjects as the use of agricultural and industrial by-products for nutrition; improvement of genetic characteristics through herd selection and artificial insemination; reproductive performance of dairy cattle breeds in the tropics and their crosses with zebu or "criollo" cattle.

The determination of mineral adequacies, deficiencies or toxicities for animals is a fruitful field for investigation. Also, certain mineral problems exist in specific geographical areas, due primarily to soil origin and climate characteristics.

As a part of a nation-wide mineral sampling project, this reasearch will contribute to identifying some of these mineral problems. It is expected to find a relationship between the mineral status of soil and plants and the livestock productivity.

Objectives

1. To establish interrelationships among the mineral content of soils, herbages and cattle for two particular regions of the State of Veracruz, Mexico.

2. To detect possible interactions between minerals that could be affecting their supply for plants and/or animals and thereby inhibiting good productivity.

3. To find the most appropriate methodology for sampling and analyzing samples for local conditions and to use this experience in future, broader projects.

4. To set basic guidelines for mineral supplementation in the two selected regions and for other similar areas.

LITERATURE REVIEW

Mineral nutrition became a very interesting area of research after the early discoveries that many clinical manifestations of diseases of man and animals could not be explained by current knowledge in medicine, but could be related to mineral imbalances, deficiencies of toxicities.

Minerals play very diverse roles in organisms. Some, like calcium, phosphorus and magnesium, are important as structural elements in bones and teeth. Others, such as sodium, potassium and chlorine, are primarily related to the acid-base mechanisms and regulation of osmotic pressure of body fluids. Some function as active parts of enzymatic systems or transport substances (zinc, copper, iron, among others).

By various means, all of these minerals have been shown to be essential for one or more organic function. There are several criteria for considering whether or not an element is essential. Arnon (cited by Bowen, 16) mentions three criteria which are both necessary and sufficient to establish the essentiality of element X for an organism:

1. The organism can neither grow nor complete its lifecycle in the absence of X.
2. X cannot be replaced completely by any other element.
3. X has a direct influence on the organism and is involved in its metabolism.

Pond (125) relates the essentiality of an element to the following postulates:

1. Present in the newborn and/or excreted in milk
2. Found in organs and tissues

3. Not normally accumulated in tissues to toxic levels
4. Supplied at physiological levels in a normal diet

Finally, Underwood (152) considers an element as essential if its deficiency consistently results in impairment of function from optimal to suboptimal.

As mineral research has progressed, new names have been added to the growing list of elements that fulfill the requirements cited above. Actually, twenty-two mineral elements are considered to be essential for at least some animal species (153). These required elements are divided into two main groups, based on the amounts needed in the diet:

a) Macroelements, usually required in milligrams or grams per day and expressed as percent of the daily ration. They are Calcium (Ca), Phosphorus (P), Magnesium (Mg), Sodium (Na), Potassium (K), Chlorine (Cl), and Sulfur (S).
b) Microelements, also called trace elements, are required in very low amounts, usually expressed in parts per million (ppm). These are, in the general order of discovery of essentiality (152): Iron (Fe), Iodine (I), Copper (Cu), Manganese (Mn), Zinc (Zn), Cobalt (Co), Molybdenum (Mo), Selenium (Se), Chromium (Cr), Tin (Sn), Fluorine (F), Silicon (Si), Nickel (Ni), and Vanadium (V), and the last one added, Arsenic (As), according to Nielsen et al (115) and Anke et al (6).

New discoveries are expected in the mineral nutrition field. Pond (125), from several sources, listed the minerals that were, at that time, definitely, probably, or possibly required by animals for normal metabolism (Table 2), and this compilation clarifies the subject.

Minerals found to be essential for one or another animal do not always function in a direct way. Many interact among themselves and with other nutrients. These interactions are usually complex with more

TABLE 2. MINERALS DEFINITELY, PROBABLY OR POSSIBLY REQUIRED BY ANIMALS

Definite	Probable	Possible
Calcium (Ca)	Chromium (Cr)	Bismuth (Bi)
Chlorine (Cl)	Molybdenum (Mo)	Gallium (Ga)
Cobalt (Co)	Nickel (Ni)	Hafnium (Hf)
Copper (Cu)	Silicon (Si)	Indium (In)
Fluorine (F)	Tin (Sn)	Iridium (Ir)
Iodine (I)	Vanadium (V)	Lanthanum (La)
Iron (Fe)		Niobium (Nb)
Magnesium (Mg)		Osmium (Os)
Manganese (Mn)		Palladium (Pd)
Phosphorus (P)		Platinum (Pt)
Potassium (K)		Rhenium (Re)
Selenium (Se)		Rhodium (Rh)
Sodium (Na)		Ruthenium (Ru)
Sulfur (S)		Scandium (Sc)
Zinc (Zn)		Tellurium (Te)
		Thallium (Tl)
		Yttrium (Y)
		Zirconium (Zr)

Source: Pond (125)

than two factors involved, and can lead to nutritional imbalances, deficiencies and toxicities.

Many interactions involving trace elements are known, and they can be conveniently grouped into six categories according to the type of mechanism involved (140):

1. Formation of insoluble complexes between dissimilar ions
2. Competition for metabolic pathways between similar ions
3. Induction of metal binding proteins
4. Changes in the metal component of metallo-enzymes
5. Facilitation of trace element transport
6. Enhancement of trace element excretion

Among minerals, the interactions are primarily manifested as a type of antogonism, and almost every element is affected, one way or another. Examples of nutritional mutual antagonisms within ion pairs and trios are shown in Table 3. To show how complex these interactions may be, a discussion follows about the copper-molybdenum-sulphate interrelationships in ruminants.

The metabolism of copper is complicated by its interactions with molybdenum and sulphate (and perhaps other factors). It is one of the few elements of which a deficiency or a toxic excess can occur under normal agricultural conditions (71, 131).

Copper deficiency is manifested by the same syndrome as chronic molybdenum poisoning (20). Sheep are more susceptible than cattle to excess copper and a deficiency of molybdenum in their diet (20, 131), which leads to positive copper balance and the accumulation of Cu in the tissues, particularly in the liver. Young calves are also susceptible, but as they mature, tolerance increases. Copper poisoning

TABLE 3. EXAMPLES OF ESTABLISHED NUTRITIONAL ANTAGONISMS WITHIN ION PAIRS AND TRIOS

Ag and Cu	Cd and Mn
Ag and Se	Cd and Se
As and Se	Cd and Zn
Ca and F	Cr and N
Ca and Pb	Cu, Fe and Zn
Ca, Pb and Zn	Cu, Mo and S
Ca and Zn	Cu and Fe
Ca and Cd	Cu and Zn
Cd, Cu and Zn	Hg and Se
Cd and Fe	Sn and Se
Cd, Fe and Zn	Te and Si

Source: Pond (125), with references from different authors.

is brought about by the sudden release into the blood of copper which has been stored in the liver.

Molybdenum accumulates in tissues and can be eliminated in milk when given in excessive amounts in the absence of copper or inorganic sulphate. That is why there exists a potential public health hazard of giving molybdenum as a mineral supplement. It is better to add molybdenum and copper to animal feed at a ratio of about one part molybdenum to six to ten parts copper. Cattle are apparently more susceptible than sheep to a diet excessive in molybdenum and deficient in copper. When the ratio of copper to molybdenum in feeds drops below 2:1, Mo poisoning can be expected in cattle (20).

It is also said that low copper status in grazing cattle is mainly caused by a poor availability of the mineral, rather than by a low intake (63). This observation comes from a field trial in which copper status of housed and grazing cattle was compared. The conclusion was that housing itself does not affect the copper status, but a favorable effect of hay compared to fresh herbage resulted, partly due to the haying process, and also to the difference in stage of growth between pasture grass and hay.

Huisingh et al (71) propose specific mechanisms to explain this complex interrelationship in the rumen.

Cu - Mo interactions. It has been proposed that the Cu:Mo antagonism is due to the formation of a Cu - Mo complex (41), which was shown by X-ray diffraction analysis to be similar to the mineral lengrenite [2 $CuMoO_4 \cdot Cu(OH)_2$], referred to as cupric molybdate. Both Cu and Mo are biologically unavailable after formation of this complex. When the complex is not formed before absorption, it is proposed that it may form at the tissue level, thereby hastening a copper deficiency.

Cu - $SO_4^=$ interactions. Results suggest that this interaction is primarily a copper-sulphide interaction (63, 139). It is proposed that this mechanism results from the formation of hydrogen sulphide in the rumen, either from inorganic sulphide reduction or desulphydration of sulfur amino acids by rumen microorganisms. Under conditions of high concentrations of sulphide in the rumen, copper becomes unavailable because soluble copper decreases due to formation of CuS which is not absorbed (17, 92, 139). Sulphite and thiosulphate are also reduced to sulphide. The pathways of the sulphide formation appear to be via ATP (adenosine triphosphate) to APS (adenosine-3-phosphosulfate), which either interacts with ATP to produce PAPS (5'-phospho-adenosine-3-phosphosulfate) or releases H_2S by the action of dissimilatory

sulfur-reducing bacteria (17).

Assimilatory reducing bacteria derive reduced sulfur from PAPS. These processes can be disrupted by competitive inhibition of APS formation by molybdate, selenate, tungstate or chromate. The suggestion is that microbial reduction is the major, if not sole, method of sulphate reduction in the rumen, and that most forms of ingested sulfur pass through the rumen sulphide pool.

There is some disagreement concerning metabolism of different sulfur sources in the rumen. Suttle (139) proposes that organic and inorganic sulfur have similar effects since both are readily degraded to yield sulphide, and that this is an important fact, since 60 to 70% of the sulfur in the herbage exists in the organic form (sulfur-containing amino acids of leaf proteins). Hume and Bird (73) found that sulfur as cystine resulted in higher rumen fluid sulphide levels than sulfur as inorganic sulphate, whereas sulphur was used in the synthesis of protein with the same efficiency from both sources.

According to Bray and Tell (17), the sulfur from cyst(e)ine and methionine may appear as free sulphide in the rumen, cyst(e)ine being broken down more rapidly than methionine.

Since a major portion of the insoluble copper in the rumen appears to be associated with the microflora, it is possible that sulfur partly reduces the availability of copper by increasing the formation of "microbial copper" which is poorly absorbed (139).

Mo - $SO_4^=$ interactions. In the rumen, this interaction may occur either as the first step of the sulphate reducing system, or at the bacterial membrane transport system. It is thought that a common carrier is involved, and the following assumptions are proposed:

a) sulphate can replace molybdate in the carrier

b) the absence of free carrier in the kidney results in the excretion of molybdate via the urine since it cannot be reabsorbed without a carrier.

Huisingh and Matrone (70) investigated sulphate reduction by rumen microorganisms. They showed that molybdate inhibition increases as the concentration of sulphate decreases. Also, molybdate has little effect on sulphide reduction. Finally, in the presence of copper, molybdate inhibition is markedly decreased.

Cu - Mo - $SO_4^=$ interactions. Dick et al (40) suggested that the mode of action whereby molybdate and sulphate in the diet limit the absorption and storage of copper in the liver of ruminant animal is, first, the reduction of sulphate to sulphide by the ruminal microorganisms. Secondly the reaction of this sulphide with molybdate to form the thiomolybdates (141) which in turn combine with copper to form the insoluble copper thiomolybdates, thereby limiting the absorption of dietary copper. Some remaining thiomolybdates are absorbed into the bloodstream and mobilize tissue copper, giving rise to the elevated blood-copper values. This increment, for any given copper intake, is related to the molybdenum intake.

Suttle (141) studied the effects of varying the dietary sulfur source (sodium sulphate, methionine or cysteine) on the sulfur-molybdenum interaction in three copper-repletion experiments with sheep which were hypocupremic. The effects of the three S sources on copper and molybdenum metabolism were similar. Both organic and inorganic sulfur potentiated the inhibitory effect of molybdenum on copper repletion rates while simultaneously decreasing molybdenum concentration in plasma.

Data from Huisingh et al. (72) showed that sheep fed sulfur exclusively in the form of sulphate develop a ruminal microflora (S cells) adapted to the production of H_2S primarily via sulphate reduction, and those fed methionine develop a microflora (M cells) adapted to the production of H_2S derived primarily from methionine. Dietary Mo decreases the capacity of the rumen microflora to produce H_2S from sulphate, whereas Mo increases H_2S produced from methionine. They also found that desulfovibrio species (anaerobic sulphate-reducing bacteria) isolated from the rumen of sheep fed a sulphate-containing diet, contain ATP-sulfurylase (the first enzyme in the sulphate-reducing pathway) that it is inhibited by molybdenum. The results are supportive that the dietary source of sulfur will to a great extent determine the effect of molybdenum on the sulphide production capacity of the rumen.

In summary, molybdate can either aggravate or alleviate the copper deficiency symptoms in ruminants, depending on both the copper status of the animal and the level of sulphate in the diet. A copper deficiency is aggravated by the formation of cupric molybdate, but prevented when dietary sulphate levels are high because of the competition between sulphate and molybdate by the common carrier system in the rumen microorganisms. This interaction decreases the amount of sulphate entering the bacterial cells and that reduced to sulphide. Molybdate would also alleviate the deficiency of copper by inhibition of the enzyme ATP-sulfurylase of the sulphate reducing system. Levels of sulphide formed in the rumen would again be decreased, and the available form of copper increased.

Sulphate, like molybdate, also enhances or relieves the copper deficiency, depending on the copper status and the level of dietary

molybdenum. When copper is deficient, sulphate aggravates the condition by decreasing available copper through the formation of copper sulphide. In cases of high dietary molybdate, but adequate copper, sulphate alleviates, and in some cases completely overcomes, the effects of molybdate. This could again be explained by the hypothesis of the common carrier.

There are many factors conducive to trace element deficiencies. The principal ones are intake, chemical form of the element or its compounds, organic matter content, pH, presence of other minerals, and plant species. Table 4 shows different factors contributing to specific mineral deficiencies in animals.

Antagonism or interactions can also lead to toxicity states. An element is said to be toxic if it injures the growth or metabolism of an organism when supplied above a certain concentration (16). Toxicities are also affected by many factors such as diet, form of compound, animal individualities and species. For instance, sheep are more susceptible than cattle to copper toxicosis (111).

The mineral nutrition problem is not only related to the uptake and metabolism of any particular element for the animal, however; it is also very much concerned with all soil characteristics that will determine the availability of that mineral to the plants and animals.

Soil is the product of climate and living organisms acting on rocks, and its nature is determined both by the parent rocks and by the forces acting on them (16). The presently available world soil surveys identify only about 20% of the land as of agricultural utility (23) and 22.5% of the world's land area (2.9 billion hectares) are limited in crop production because of mineral stress (42).

TABLE 4. FACTORS CONTRIBUTING TO TRACE ELEMENT DEFICIENCIES IN ANIMALS.

COPPER	MANGANESE
Low total Cu	High soil pH
Free $CaCO_3$	Neutral-alkaline peats
High organic matter content (e.g. peats)	Free $CaCO_3$
Low organic matter content (sands)	Unconsolidated soil
High N, P and Zn	Poor drainage
Moisture stress	High iron
High Mo and SO_4 = (livestock)	Liming
	Moisture stress
IRON	COBALT
High soil pH	Alkaline and calcareous soils
Free $CaCO_3$	High soil Fe and Mn
High HCO_3	Liming
High Mn	Moisture stress
Poor drainage	
Extreme moisture changes	MOLYBDENUM
Liming	Low soil pH
Plant species	High soil Fe and Al oxides
	High SO_4-S
ZINC	Leached soils
Low Zn	Low seed Mo content
Low organic matter content	
Free $CaCO_3$	SELENIUM
High pH	Low soil pH
High clay content	Waterlogging and high rainfall
High N, P	High soil Fe oxides
Liming	High SO_4-S
Low temperature	Pasture species
Land leveling	

Source: Reuter (132)

The trace element content of soils, and to a certain degree of pasture, is influenced by the nature of the bedrock from which the parent soil material is derived (130, 148). In general terms, acid igneous and coarse sedimentary rocks contains lower concentrations of the trace elements associated with nutrition than do more basic igneous rocks and fine grained sediments. For example, trace element deficiencies in livestock, crops and pastures, are known to occur in granites, rhyolites and sandstones, while metal toxicities have been reported on andesites and shales.

The amount of readily soluble trace elements is generally smaller in coarse-textured than fine-textured soils (130). For instance, the amount of cobalt extracted by 2.5% acetic acid from a granitic soil containing 8% clay was 0.14 ppm Co, compared with 0.39 ppm in a similar granitic soil containing 24% clay.

Association of Co-adequate areas with medium- and fine-textured soils results from the fact that the cobalt content of most soils increases with fineness of soil texture (88). The cobalt content of clay soils is generally large, and the amounts present do not differ among clays because of location or soil pH.

Soils play a major role in determining the level of availability of nutrients to plants, either present in the soil or added to it, through their mineral reserves, pH, organic matter content, cation exchange capacity, base saturation, sesquioxide content, permeability, and moisture retention capacity (42).

Korte et al (86) suggest that soil texture, surface area, the content of hydrous oxides, and the content of free lime provide the most useful information for predicting a soil effectiveness for trace element retention. The value of cation exchange capacity for predictive

purposes with natural soils is limited. The percent of clay in the soils stands out as the most useful predictor of whether a soil will retain a particular element. Surface area and the percentage of free iron oxides provide the next best correlations after the clay fraction.

Soils that account for the major land surface dedicated to forage and pasture production in the tropics are (11): Oxisols (Ferrasols), characterized by extreme weathering of parent material; Ultisols (Acrisols), highly leached; Alfisols; Inceptisols, of more recent origin, very variable; and Entisols.

Oxisols show a low base exchange and low retention capacities, as well as the presence of exchangeable Al, known to be toxic for many plants and highly active in the fixation of phosphates, and free Mn, also toxic (110). Ultisols of tropical and subtropical regions are also characterized for their low base saturation, low content in weatherable minerals, strong acidity and possible toxicities of aluminum (Al), manganese (Mn), and iron (Fe) (43). Al^{+3} is the primary source of soil acidity, since as the degree of weathering increases, there is a shift from the H-ion concentration to the Al^{+3}; a change in base saturation, especially Ca and Mg, also occurs, going from high to very low.

Calcium and Phosphorus

These two major elements are frequently considered together because of their close relationship, along with vitamin D, in bone metabolism. About 99% of total Ca (24) and 80 to 85% of body P (50) are in the skeleton as constituents of bones and teeth. Herodotus (484-425 B.C.) made the earliest recorded observation that bones differ greatly in quality (cited by McCollum, 95); he inspected the skulls of

Persians and Egyptian soldiers killed during a battle; he noted that the Persian skulls were very fragile, whereas the Egyptians' were strong. It was said by the Egyptians that this was because they went bareheaded since childhood, exposing their heads to sunlight; the Persians, on the other hand, used to cover their heads with turbans. It took many centuries to discover the complex processes involved in bone metabolism. Now, several clinical manifestations affecting primarily the skeleton can clearly be related to Ca or P dietary inadequacies or imbalances, or to the failure of the homeostatic mechanisms that regulate their metabolism.

As essential part of plant cell wall structure, calcium provides for normal transport and retention of other elements as well as strength in the plant (156). It is absorbed by plants as the ion Ca^{+2}, which comes from the soil solution and by contact exchange (149).

In general, with the exception of very acid soils (pH below 5.0), calcium content is adequate for most field crops and pastures. Even acid soils needing lime generally contain sufficient Ca for plant growth (159); it is said that poor growth of plants on acid soils is usually caused by excess soluble manganese, iron and/or aluminum rather than to the Ca levels (160).

Liming of soils is usually done to raise the pH between 6.5 and 7.5, the optimum acidity conditions for most crops; this can be accomplished with reasonable volumes of lime in soils of temperate regions where the pH rarely goes below 6.0. In tropical soils, however, pH values are generally much lower, and the amount of lime needed for these soils is often too expensive for farmers. So, the primary objective for adding lime to soils in the tropics is to partially neutralize the acidity caused by high concentration of aluminum ions.

Care should be taken since liming can reduce the Cu, Zn, Mn, and Fe content of herbage while increasing Mo, Se, and P levels (57, 126).

Phosphorus occurs in soils in both inorganic and organic forms; the concentration of the inorganic forms ($H_2PO^-_4$, $HPO_4^=$) in the soil solution is considered as the most important single factor governing the availability of this element to plants (149); this is because plants absorb phosphorus from solutions in proportion to the concentration of the phosphate ions.

It is general knowledge that P is required in considerable amounts for crop production, and that very acidic or very basic soils are low in available phosphorus; so, deficiencies of this element are likely to occur in the highly weathered, acidic soils of the tropics where total and available P levels are very low (110). Deficiency is mainly caused by considerable fixation of phosphates by free sesquioxides of Fe and Al, and by clay components (43). On the other hand, above pH 7.0, the ions of calcium and magnesium, as well as the presence of the carbonates of these metals in the soil, cause precipitation of added phosphorus, and its availability again decreases (149).

Breland, cited by De Sousa (39) reports that, for Florida soils, calcium levels from 0 to 71 ppm are considered low; 72 to 140 ppm are medium, and 141 ppm or more are high. For phosphorus, soils with 0 to 5 ppm are considered very low, 6 to 12 ppm low, 14 to 25 ppm medium, and 26 to 50 ppm very high. In the case of Michigan soils, phosphorus levels of less than 10 ppm are very low, 20-30 ppm medium and above 50 ppm very high for field crops (159). In general, a soil is said to be rich in phosphorus when it contains above 30 ppm in the available form (57).

In many areas, phosphorus is the first limiting factor for growth of pasture plants (96). The principal form of phosphorus in most plant source ingredients is phytate phosphorus (8), which is said to account for two-thirds to three-fourths of the total. This phytate P is about 60% available for cattle, or even only 50% according to Peeler (123). Older animals have a greater ability to utilize the phytate form by having more of the enzyme phytase present in the gut. In any case, phytate phosphorus is substantially less available than most inorganic sources, as it has been determined in experiments with sheep. The availability of phosphorus from herbages is affected by different factors, like age of plants, because phosphorus levels decrease markedly with maturity (112); this is mainly due to the fact that phosphorus concentration is higher in meristematic regions of plants; thus, young leaves and seeds contain more of this element than older leaves and stems (19). All of this probably conditions the strong correlation found between phosphorus and protein contents, at least for pasture plants (96). It is also known that phosphorus remaining in mature and weathered forages usually is not well utilized because much of it is bound in the phytin form (145). In areas with well-defined wet and dry seasons, as much as 85% of the phosphorus content in many types of forages may be lost by mid-winter. This is why in most Latin American countries phosphorus deficiency is such an important nutritional problem, second only to protein inadequacy.

On the other hand, there has not been a clear demonstration of a calcium deficiency for grazing livestock; exceptions may be cows producing large quantities of milk or those grazing on acid, sandy, or organic soils in humid areas (35, 151). The adequacy level has been set at 0.30% of dry matter; it is said that for grazing beef cattle,

even 0.25% calcium should be enough to meet the animal's requirements (29). The same level of 0.30% for phosphorus has been established as adequate in grazing areas.

Normal serum or plasma calcium ranges between 9 and 12 mg/dl, most of the time being remarkably constant around 10 mg% (8, 126, 128, 135). Levels of 8 mg/100 ml are considered low, but some authors maintain that hypocalcemia becomes severe and paresis may develop when Ca in plasma falls below 5 mg%, even for a few hours (87, 94).

Normal plasma or serum inorganic phosphorus values vary from 4 to 6 mg/100 ml. for adult calle, and from 6 to 8 mg/100 ml. for young animals, mostly under one year of age (28, 29, 75, 113, 126, 145). Levels below these figures should be considered as indicative of a phosphorus deficiency.

McDowell et al (101) report that approximately 31% and 73% of the forage entries for calcium and phosphorus, respectively, in the Latin American Tables of Feed Composition (100) were 0.30% or less; these values may be borderline or deficient for most classes of cattle.

De Alba (34) remarks that observations of probable mineral deficiencies in some areas of Paraguay and Brazil have been reported in the literature since 1802, and that those references could be related to P or Co deficiencies.

Theiler et al (144) observed remarkable improvement in cattle grazing on arid, sparse, phosphorus-deficient pastures in South Africa when mineral supplements were offered.

From the savannah grasslands of British Guiana, serious phosphate deficiencies have been reported since 1939; cattle showed prevalence of bone chewing, and chemical analysis later confirmed the inadequacy of phosphorus levels (44).

In Mexico, calcium and phosphorus contents of native grasses from the northern region were determined; these pastures were growing in highly alkaline soils, with pH ranging from 7.5 to 10.0. In one study, severe phosphorus deficiencies were observed (33). From a second report, both calcium and phosphorus were below what the authors considered the minimum requirements, 0.25% and 0.18%, respectively, in most months of the year. Finally, phosphorus levels in 13 forages were found to be low, either in the growing or in the dry period; the conclusion was that it is necessary to supplement phosphorus to cattle in both periods (59).

French and Chaparro (51) analyzed several fodder species growing with and without irrigation in Venezuela; they found low levels of phosphorus in samples from certain districts. Chico and French (22) found deficiencies of phosphorus in most of the areas studied in the central and eastern regions of the same country, while calcium deficiencies were reported for only two regions. The authors considered that animals were affected by Ca or P deficiencies when the blood values were lower than 8.0 and 3.5 mg/100 ml., respectively. In another study conducted on cattle from farms in and near the Andean region, deficiencies of phosphorus were found in only 13% of the animals from one of the regions; also, no cases of low calcium levels were discovered (52).

Estevez (46) added phosphorus and cobalt to common rations for milking cows in the Cauca Valley, Colombia; cows increased milk production up to 24% while they grazed Jaraguagrass (Hyparrhenia rufa) on a mountain pasture; the general appearance of the cows also improved. In a later study, pastures from this same region showed a phosphorus deficient status with levels lower than 0.15% of dry matter (13).

In central and southern Brazil, most native forages were observed to be deficient or borderline in phosphorus content (78, 122); calcium levels were considered adequate or at least enough to meet the animal's requirements. It is clear, though, that lack of phosphorus is the most important mineral deficiency of cattle in Brazil (150).

Blue et al (15) analyzed soils, forages and cattle tissues from eastern areas of Panama; plant calcium and phosphorus content ranged among normal values; the exception was Jaraguagrass for which all major nutrients, except calcium, were extremely low and substantially less than cattle requirements.

In the Junin region of Peru, low levels of calcium and phosphorus were found for native forages (less than .20% and .16% respectively), while introduced species were adequate (45). Phosphorus is also reported critically deficient in the upper Amazon basin of Peru (11).

Kayongo-Male et al (82) found in grass samples from Puerto Rico that 62% of the phosphorus values were deficient for milking dairy cows, but 98% were adequate for beef cattle, except for young calves. The same grasses contained over 0.2% Ca, which should be adequate to maintain mature ruminants; however, 70% of the samples were considered Ca deficient for milking cows. In a recent study in the Guanacaste region of Costa Rica, 49% of the blood samples taken were found borderline to deficient in phosphorus (103).

In addition to the low levels of calcium and phosphorus in forages, it is also important to consider the ratio between these two elements; this is because during the dry season in the tropics the Ca/P ratio increases to ultimate values above 10, which are far in excess of those recommended, particularly with low phosphorus concentrations (14).

Potassium

Potassium is present in relatively large quantities in most soils, being absorbed by plants in greater amounts than any other mineral, except nitrogen. Tisdale and Nelson (149) remark that the total amount of potassium in soils is no criterion of the amount available to plants; also, that availability is governed by the equilibrium in the soil system among the forms of potassium arbitrarily designated as unavailable (90-98% of total), slowly available (1-10%), and readily available (0.1-2%). The unavailable forms are occuring in the primary potassium-bearing minerals (micas and feldspars); the slowly available forms are those resulting from the interaction of K^+ ions with certain clay minerals; the readily available forms are made up of exchangeable and water-soluble potassium.

This element is absorbed by plants as the ion K^+ from the soil solution, the requirements being quite high. The bulk of this needed potassium has to move to the roots by means of convection and diffusion, the latter being the most important mechanism (60). It is known that clay and organic soils are rich in potassium, while sandy soils are frequently deficient (57). Total potassium content in tropical soils may be low; the reason is the soil origin and the high rainfall and continued high temperatures, which have hastened the release and leaching of soil potassium over the years (43, 149).

In general, a soil is said to be rich in potassium when it contains more than 120 ppm available K (57). For Michigan soils, K tests of less than 30 ppm are very low for field crops; 80 to 105 ppm medium; and above 150 ppm very high (159). Bahia (cited by De Sousa, 39) for soils from Minas Gerais, Brazil, considers K levels from 0 to 60 ppm as low; 61 to 120 ppm as average, and more than 120 ppm as adequate.

Potassium concentration in plants changes during growth for physiological reasons and independently from the soil K level (60). This element is very mobile in the plant, meristematic tissue being richer; therefore, a deficiency will show first in the older (lower) leaves. The decrease in potassium content with maturity of plants is well documented; this could be a problem for grazing livestock, but the average K concentration in roughages of all kinds is nearly always in great excess of requirements (135). On the other hand, hand-fed cattle may be in need of K supplementation since feed grains and concentrates are relatively low in K compared to most roughages (25, 66).

Potassium levels in forages rarely go below 1.0% of dry matter, ranging between this figure and 2.5% or even higher values. Requirements recommended for livestock vary according to type, age and physiological stage of the animal. Thus, levels of 0.3 to 0.4% K are suggested for calves growing at a slow rate; 0.5 to 0.7% for gestating cows; and 0.62 to 0.72% for finishing steers, all these figures expressed as percent of the ration total dry matter (25). The N.R.C. (113) recommends 0.8% for lactating cows and 0.6 to 0.8% for finishing steers. There are some remarks that K content in the diet of 0.7% appears to be adequate for cows in mid to late lactation, but it may not be optimal for high producing cows in early lactation. The suggestion is that the potassium requirement in this case could be as high as 1.0% of the ration dry matter (37, 146).

Plasma potassium concentrations range from 4.2 to 6.0 mEq/liter (64, 146), approximately equal to 16.4 to 23.5 mg/100 ml. A value of 19.3 mg % is given for dairy cows (135).

Research on potassium as a significant part of the diet of domestic animals has not been conducted to any significant extent until recent

years; the main reason for this was the common argument that all roughages normally provide above the recommended requirements. Therefore, few articles can be found in the literature dealing with the possibility of potassium deficiencies for grazing livestock.

Latin American forages appear to fall into that criterion of adequacy. Only 15% of 198 forage entries reported by McDowell et al (101), were from 0 to 0.80% K (dry basis), while 53% ranged between 0.81 to 2.0%; the other 32% were above 2.0% K.

Magnesium

The striking importance of magnesium relates to its being the central part of the chlorophyll molecule in all green plants, and thus, in its essentiality for photosynthesis. The soil magnesium available to plants is in the exchangeable and/or water soluble forms, and it is absorbed as the ion Mg^{+2} by contact exchange.

Uptake by plants depends on the amount present, the degree of saturation, the nature of the other exchangeable ions, and the type of clay (149). Magnesium may also occur in soils in a somewhat slowly available form, keeping equilibrium with the exchangeable part.

Magnesium is considered adequate for Michigan soils when levels are above 40 ppm in mineral soils, and above 75 ppm for organic soils (159). For Florida soils, values from 0 to 9.1 ppm are considered low, 9.2 to 21.1 ppm medium and above 22.2 ppm high (Breland, cited by De Sousa, 39).

It is known that inadequate liming and excessive nitrogen, especially ammoniacal forms, and/or high rates of potassium applications, depress magnesium uptake by plants. The depressing effect of potassium has been attributed to leaching losses of Mg^{+2} as a result of its

displacement from exchange sites by the applied K^+ (129). This situation is of special concern since low levels of magnesium in forages may lead to the development of hypomagnesemia in cattle, especially in lactating animals, known as "grass tetany" or "grass staggers".

The coarse-textured soils of the humid regions are those on which a deficiency of magnesium is generally manifested; also, ultisols and oxisols of the tropics are commonly deficient (43). However, grass tetany occurs more in temperate regions than in tropical and subtropical areas; the reason may be that there are contributing factors for the disease to develop; thus, outbreaks of grass tetany have been observed most frequently when cattle are grazing cool-season forages growing on soils that are nearly water saturated (81). It is also more likely to occur during cool, cloudy, wet weather extended over a period of two to three days (32).

Another factor of importance is that high protein content of ingested forages or other feeds will depress the absorption of magnesium by the animal; this is especially true for diets that produce high levels of ammonia in the rumen. The explanation to this interference is the formation of an ammonium-magnesium-phosphate complex which precipitates and becomes insoluble at near neutral pH, reducing the availability of the three constituents (47). High intakes of sodium and potassium also affect the net absorption of magnesium; in this case, these two monovalent cations, ranking higher in solubility, will compete with magnesium for absorption from the rumen (127).

In general, the apparent availability of magnesium form pastures is about 20% for ruminants (113, 123, 135), and from 30 to 40% for grains and concentrates. The suggested essential minimum content for

magnesium in forages has been said to be 0.2% of dry matter, because hypomagnesemia rarely occurs at higher levels (1, 80, 151). Thus, the requirements for livestock will fluctuate around that figure: lactating beef cattle, 0.18%; young calves, 0.07%; lactating dairy cows fed common rations, 0.20%, or up to 0.25% if grazing lush, highly fertilized pastures in cool seasons (112, 113).

The normal levels of magnesium in blood plasma or serum of cattle vary from 1.8 to 3.2 mg/100 ml (29, 135, 151, 155). Clinical signs of hypomagnesemia may develop at concentrations of 1.0 to 1.7 mg % if predisposing factors are present, and especially at concentrations lower than 1.0 mg % (32).

In Latin America, about 35% of 290 forage entries reported by McDowell et al (101) contained 0.2% magnesium or less. De Alba (34), reports that magnesium is probably deficient in some areas of Uruguay and Argentina. In Puerto Rico, values for 30-day-old grasses tended to be high, with a mean concentration of 0.32% magnesium (82). De Alba and Davis (35) report low magnesium figures for forages from Costa Rica (0.04 to 0.14% Mg); Kiatoko et al (84) report a mean of 0.18% magnesium content for pastures from the same country. No evidence of magnesium deficiency has been found in Brazil (150). Values from 0.13% to 0.34% for Pangola grass, and from 0.11% up to 0.74% for Guineagrass have been reported from different Latin American countries (4, 13, 15, 51).

Copper

Copper in soils is primarily found as Cu^{+2} adsorbed by clay minerals, and tied up with organic matter. The cupric ion (Cu^{+2}) is the form usually absorbed by plants, but may also be absorbed as

a salt of an organic complex such as EDTA (149). The copper content in soils ranges between 2 and 100 ppm, with a mean value of 20 ppm (16).

Organic matter content and pH of soils are important factors affecting the availability of copper to plants. In general, as the pH increases, the amount of available copper decreases; also, as the organic matter increases, copper retention in the soil increases, which makes it less available to plants. Deficiencies of this element in plants are more likely to occur in crops growing on peat and muck soils, where the retention of copper is greatest (149).

Normal copper concentrations in plant tissues range from 8 to 20 ppm; deficiencies may occur at values below 6 ppm, while toxicities can develop when levels higher than 20 ppm are found in mature leaves (16, 79, 156).

The net absorption of copper by the animal is usually low, younger animals being more efficient than mature animals. Suttle (138) reports that mature sheep normally utilize less than 10% of the copper they ingest, while young lambs prior to weaning utilize four to seven times this proportion. Presence of other ions in the diet also influence the absorption of copper; the most evident interaction is the antagonistic effect of copper with zinc, with levels of one element increasing the requirements for the other (26, 108). High dietary levels of cadmium and iron may also depress copper absorption and subsequently reduce plasma copper concentrations (153). Probably the most important interrelationship of copper in ruminant nutrition is the one existing with molybdenum and sulphate, which has already been discussed.

Copper requirements for animals have not been clearly defined, mainly because there are many interactions with other nutrients. However, generally copper levels of 5 to 7 ppm of ration dry matter

are suggested for cattle (93); recommendations for beef cattle are 4 ppm copper when levels of molybdenum and sulphate are low, since requirements for copper may increase two- or three-fold if sulphate and molybdenum are high (112). For dairy cattle, a minimum of 10 ppm is suggested (26, 113, 135).

Plasma or serum normal copper values vary from 0.5 to 1.5 ug/ml (108, 135, 183); concentrations lower than 0.5 ug/ml are indicative of deficiency.

Lack of copper is a severe mineral limitation to grazing cattle in Latin America. Copper deficiency has been related as "Renquera Peruana", similar to the "Enzootic Ataxia" of South Africa; also, as "Muerte Subita" (sudden death) in Cuba, which resembles the "Falling Disease" reported in Australia. McDowell et al (101) remark that 47% of 236 forage entries from Latin America were deficient or borderline to deficient for copper. De Alba and Davis (35) relate copper deficiencies in Peru to high losses in sheep; copper is also reported critically deficient in the upper Amazon basin of Peru (11), and for native grasses from the Junin area (45) for which introduced forages were adequate in their copper levels, ranging between 5 and 8 ppm. Copper deficiency is reported as quite common in cattle in Brazil (150); native pastures from Rio Grande do Sul, sampled during the ten-year period of 1959 to 1969, had different values when related to season; the mean for spring sampling, was 7.1 ppm copper, while for summer the average value was 5.7 ppm (55). Mineral deficiencies that could probably be attributed to copper, have been observed since 1944 in Argentina, and are reported to be more severe at the end of spring and summer seasons (116); Camberos et al (21) demonstrated copper deficiency of cows in the same country, noting that the factors

involved were not only low copper, but high molybdenum and sulphate concentrations in grasses and drinking water as well. A similar situation is described by Nunez (117). In Puerto Rico, copper deficiency in grasses was not apparent, according to Kayongo-Male et al (82).

Iron

As a component of hemoglobin, iron's vital role is in oxygen transport mechanisms. It occurs in soils as oxides, hydroxides, and phosphates, as well as in the lattice structure of primary silicates and clays (149). Iron may be absorbed by the roots of plants in ionic form or as complex organic salts; it can also be absorbed by the leaves. Availability to plants is greatest in acid soils, being dependent on the oxidation state (Fe^{2+} or Fe^{3+}) (16). Soil iron content is very variable, going from a couple of hundred parts per million up to 10% in some soils (149). According to Bowen (16) the range goes from 7,000 to 55,000 ppm. In any case, it is said that total iron concentration in soils is of no value in diagnosing availability. It is also generally accepted that there is not a deficiency of this element per se in soils, but it is known that for each pH unit increase above pH 4.0, the solubility of Fe^{3+} decreases by a factor of about 1000 (18).

Iron uptake by plants can be affected by several other factors. Excess phosphate, bicarbonate, and calcium salts in the growth medium have been shown to interfere with the uptake of iron; high levels of copper, manganese, nickel and zinc also can induce iron deficiency or chlorosis in plants (18). In the particular case of zinc, it is said that excessive uptake of this element by a plant may disturb the

metabolic function of iron, and the plant may suffer from iron chlorosis even though iron is present at normal concentrations in the plant (118). On the other hand, it has been observed that zinc deficiency increases the iron uptake in some plant species (18).

The iron concentration in plants as in soils, varies widely, and can be greatly affected by contamination with soil and dust; because of this, it is generally accepted that iron analyses in plants are probably invalid unless the material has been washed in dilute acid or detergent. For crops, the sufficiency range for iron seems to be from 50 to 250 ppm. When iron values are 50 ppm or less in the dry matter, deficiency is likely to occur (79). Underwood (153) for pastures in New Zealand, reports values of 111-3850 ppm iron in the dry matter, while leguminous pastures range from 200 to 400 ppm; also, that concentration of 40 ppm or less have been found for some grasses grown on sandy soils.

It is known that iron is poorly absorbed from most diets, with better absorption from foods of animal than plant origin. Uptake by the animal is affected by other nutrients present in the diet. High zinc intakes reduce the iron absorption and retention (26). Also, high levels of phosphate, cobalt, cadmium, copper, and manganese, interfere with iron absorption through competition for absorption binding sites (153).

Serum iron concentration for normal sheep and cattle is reported to range from 1 to 2 ug/ml (126). Underwood (153) gives a value of 1.46 ug/ml for normal cows. Iron requirements have not been clearly defined for cattle. However, levels of 10 to 30 ppm of dietary dry matter for beef cattle, and 100 to 150 ppm for dairy cattle have been suggested by McDowell et al (102). The N.R.C. (113) recommends 100 ppm

in the dry diet of calves up to 3 months of age, and 50 ppm for other dairy cattle. The N.R.C. (112) publication states that mineral requirements for beef cattle have not been established.

It is generally accepted that iron deficiency in grazing cattle is rarely observed under natural conditions, the exception being a result of severe loss of blood caused by parasitic infestations or disease (68, 96, 102, 113, 153). In the case of calves on an exclusive milk diet or those reared for veal, anemia resulting from iron deficiency may occur (112, 153).

A few publications are available where iron status of forages and animals is discussed, and this is particularly true for Latin America, where main attention has been given to the elements already known to be deficient or toxic in different areas.

McDowell et al (101) report that for 256 forage analysis from Latin America, only 4% contained less than 30 ppm Fe in the dry matter; 21% were between 31 and 100 ppm; 54% range from 101 to 500 ppm; and 21% contained more than 500 ppm. A wide range of 74 to 880 ppm for iron levels in crops and native pastures has been found in Argentina, with the author's conclusion that there are not iron deficiencies; however, he points out the possibility of contamination of samples by soil (117). In Eastern Panama, iron values of 91-226 ppm for Guinea-grass, and 141-156 ppm for Pangola-grass have been reported by Blue et al (15). Gomide and co-workers (58) present figures of 403 ppm iron in Guinea-grass, and 259 ppm for Pangola-grass for samples taken in Central Brazil; they point out the significant decrease in iron content with plant maturity.

Selenium

The importance of selenium in animal nutrition is now well recognized. Several clinical manifestations of domestic animals have been corrected by addition of selenium supplements to their diets. Most common of these nutritional deficiencies are white muscle disease (WMD), mainly of lambs and calves, and named because of the white appearance of muscle tissue due to calcification, selenium responsive infertility (SRI), which is common in ewes (12) and exudative diathesis in chicks.

Most soils contain between 0.1 and 2.0 ppm total selenium, with a mean value of 0.2 ppm (16, 142). It is suggested that the total selenium content of a soil is rarely useful for the prediction of the selenicity of plants (12). However, most reports in the literature concerning soil selenium are given in total content.

Soils may derive their selenium content from the rocks that form the parent material, from fertilizers fortuituously containing Se, from industrial wastes such as dust from coal burning operations, from irrigation water and from contemporaneous volcanism (91). Many factors are interrelated with the selenium levels in soils; the principal ones are the Se content of host rocks, the redox potentials, pH, and nature of the drainage waters (31). For example, in neutral to alkaline, well aerated soils, selenium is oxidized to $SeO_4^{=}$, which forms readily soluble salts and is subjected to leaching; in arid regions these soluble salts may accumulate in the soils. Generally, this is why the toxic soils are neutral or alkaline and with moderate precipitation (12); in the same reference, soils are said to be seleniferous when the total selenium content is 2 ppm or above.

In slightly acid to neutral soils, Se may be largely held in organic substances; removal of vegetation as in harvesting would tend to deplete

it unless selenium is replaced (91). In acid ferruginous soils Se is bound as a basic ferric selenite or strongly adsorbed on ferric oxide, and it is only slightly available to plants.

Availability of selenium from soils is then affected for several factors; form of Se in soils, as well as the total amount, are considered among the most important (31). In relation to forms, selenate and organic selenium are reported as the most available to plants (12). For instance, selenite is normally taken up by plants, but can become associated with iron in acid soils to form a poorly available complex. On the other hand, there is a great variation among plants for Se uptake. Some species are well characterized as being Se-accumulators or indicator plants because they are commonly found on toxic soils and containing much more selenium than other species growing in the same soil.

A wide variation of Se levels in plants has been reported, and it is common to find those reports associated with areas where Se-responsive diseases have been diagnosed. Ganther (54), gives figures of 0.01 to 0.05 ppm (avg. of 0.02) for forages sampled in areas where WMD in sheep was found; he suggests that 0.1 to 0.5 ppm in the forage should be considered protective, but non-toxic levels for livestock. Bisberg (12) remarks that a selenium concentration on a dry basis below 0.02, 0.03, or even 0.05 ppm in the pastures, has caused nutritional muscle disease (NMD) or SRU, and that it is reasonable to consider 0.05 to 0.1 ppm selenium as the minimum desirable concentration in the food.

An excellent survey by Kubota et al (90) shows the regional distribution of Se concentrations in crops in the United States. They called selenium-adequate areas those regions where over 80%

of the plant samples collected contained more than 0.1 ppm Se; very low Se areas were those in which more than 80% of the forages sampled contained less than 0.05 ppm, with a median lower than 0.03 ppm.

Blood selenium levels of 0.05 ug/ml are considered satisfactory for grazing sheep (29, 62); deficient animals will have values below that level. Hupkens and Watkinson (74) consider this critical level to be somewhat lower, around 0.01 ug/ml of blood or less.

Although not well defined, it is generally considered that 0.1 ppm selenium in the dry diet will satisfy the requirement of the ruminant animal (2, 112, 113). Conrad and Moxon (3) suggest 0.1 to 0.2 ppm Se as sufficient to meet the dietary needs of cows.

Most of the available literature from Latin America about selenium is related to toxicity problems. Chronic selenium poisoning for cattle results when feeds containing 10-30 ppm Se in the dry matter are consumed over extended periods (112); the lowest toxic level is approximately 3 to 5 ppm (113). Acute selenium poisoning is most often associated with consumption of the Se-accumulator plants (i.e. Astragalus racemosus), which may contain from 100 to 9,000 ppm Se (99).

Ancizar-Sordo (3) found a high selenium content in soils and plants in a particular place in Colombia where men and cattle were losing their hair. Jaffe et al (76) analyzed sesame samples from most regions in Venezuela; results showed concentrations over 3 ppm Se for 52% of the 138 samples, and about 28% with more than 10 ppm; also, in 12 of 47 commercial foods and in 12 of 40 industrial animal feeds, the selenium levels were 3 ppm or more. The same authors (77) determined Se content in 136 samples of fat free sesame seeds from Venezuela and 19 other countries; this time, 32% of the samples contained over 3 ppm

Se; they point out that decortication or extraction processes did not reduce selenium levels. Ortiz and Carrasquero (121) measured Se content in plants from areas in Venezuela where selenium toxicity was probably occurring; 38% of the samples contained over 10 ppm, 39% were between 5 and 10 ppm, and 35 ranged below 5 ppm. De Mondragon and Jaffe (36) found that selenium contents in feeds from different zones in Venezuela and in urine samples of school children from across the country were very high when compared to values from similar samples from non seleniferous areas. Gutierrez et al (61) suggest from their data that borderline selenium deficiencies may be prevalent in certain areas of New Mexico, U.S.A., and Chihuaha, Mexico.

Zinc

Zinc is primarily absorbed by plant roots as the ion Zn^{2+}; it may also be absorbed as a molecular complex such as EDTA (Ethylenediamine-tetraacetic acid), or directly through the leaves when applied as foliar sprays (149). Zinc content in soils ranges from 10 to 300 ppm, with a mean concentration of 50 ppm (16).

Several factors affect zinc uptake by plants. It is known that an increase in soil pH by liming reduces the availability of zinc to plants; in consequence, soil types associated with zinc deficiency are usually neutral to alkaline in reaction (118, 156). Another important interrelationship is the zinc-phosphorus interaction, usually designated as phosphorus-induced zinc deficiency, which is observed frequently on high phosphate soils. At the soil level, high content of one of these elements may reduce plant uptake of the other; if the soil is borderline to deficient in either element, application of one may induce a deficiency of the other (160); generally, and because of the widespread use of phosphate fertilizers, the tendency of this two-way interaction

is in the direction of zinc inadequacy. At plant level, high levels of phosphorus have been shown to restrict zinc movement within the plant, resulting in accumulation in the roots and deficiency in the tops (156).

Normal ranges given in the literature for zinc content in plants are from 30-100 ppm in the dry matter, with other figures going from 20 up to 150 ppm (79, 109, 156). Plant tissues are said to be deficient in zinc when the concentration is lower than 20 ppm; toxicity may develop if zinc leaf levels exceed 400 ppm.

Utilization of dietary zinc by animals is affected by several factors. Among others, it has been observed that zinc needs are increased with high levels of calcium and/or phytate in the ration; in these cases, even Zn-adequate plants will often fall short of meeting animal requirements (32, 89). It is in these situations when zinc deficiency results from an ineffective digestion and use of dietary sources, instead of its absolute deficiency in the diet.

Zinc requirements for beef cattle appear to be between 20 and 30 ppm of diet dry matter (112). The estimate for dairy cattle is 40 ppm in the diet (113). Herrick (67) proposes that zinc needs of dairy cattle could be estimated by the following equation: Zn (ppm) = 159 x % calcium; thus, in the average diet containing 0.3% calcium, about 48 ppm of zinc are needed, and for every 0.1% increase in calcium, 16 ppm more zinc will be needed.

Normal levels of plasma or serum zinc for calves and lambs range from 0.8 to 1.2 ug/ml; for adult female sheep a mean value of about 0.7 ug/ml is reported (153). Plasma levels from 0.60 to 1.40 ug/ml are considered normal for cows; values lower than 0.40 ug/ml would be indicative of zinc deficiency (27). It is generally accepted that

deficiency of zinc in grazing ruminants rarely occurs under natural conditions (68, 96). However, it is recommended that zinc should be supplemented when the content in forages is less than 40 ppm (102).

Andreasi et al (5) determined the zinc content of pastures from the state of Sao Paulo, Brazil. Samples were collected from forages growing on four different soils and during the dry and rainy seasons. Mean values for Guinea-grass were significantly higher for the dry season (60 ppm) than for the wet season (37 ppm). In Eastern Panama, values reported are 38 to 48 ppm for Guinea-grass, and 50 to 63 ppm for Pangola-grass (15). Kayongo-Male et al (82) sampled a variety of 30-day-old tropical grasses in which zinc content ranged from 26-60 ppm; it is pointed out that 82% of the grass species studied did not meet zinc requirements for dairy cattle. Similar results are reported by McDowell et al (101) since almost 75% of 177 forages entries had 50 ppm Zn or less, and 49% had 30 ppm or less.

MATERIAL AND METHODS

The state of Veracruz is located on the east coast of Mexico between 17^{o} 08' and 22^{o} 28' north latitude. It has an area of 71,896 km^2 (approximately 7.2 million hectares) that accounts for 3.7% of the national territory. Veracruz is a very large state that stretches along the Gulf of Mexico's coastal line with a total extension of 684 kms (425.0 mi) of seashore. It is also in this state where the highest mountain peak in the country is found, just about a hundred miles from the coast (The Citlaltepetl or Pico de Orizaba, 5,700 m . or 18,700 ft. high).

These two main characteristics, coast and mountains, cause the great diversity of climates, soil types and vegetation found in Veracruz.

Official reports gave an estimate of 4.5 million bovine for the state in 1976 (154). Crossbreeds of native or "criollo" cattle with zebu or European breeds are predominant, around 75% of total population. About 20% remain as "criollo" animals, and only 5% are pure breeds (zebu or European types). It is considered that approximately 54% of the estimated 2.3 million hectares of grasslands are native pastures, the remaining being introduced forages. Among these, the most abundant are Guinea-, Para-, African star-, Jaragua-, Pan gola-, and Kikuyo-grasses.

Sampling Sites

Two regions with six farms each were selected. In each region, three farms with Pangola-grass (Digitaria decumbens), and three with Guinea-grass (Panicum maximum) were sampled.

A. Region I or Central - Farms from this region are found within a 25 mile radius in the vicinity of the city of Veracruz, placed at 19° 12' north latitude and 96° 11' west longitude. Predominant climactic characteristics include a well-defined 3 to 6 month dry period and heavy rains in the summer. The annual average temperature is 25°C, relative humidity is 80%, and annual rainfall is 1200 mm (105).

B. Region II or Northern - Samples for this region were taken in the proximities of the city of Tuxpam, which is located at 20° 57' north latitude and 97° 25' west longitude. All farms were within 10 miles of that city, with the exception of farm #10, which is about 25 miles to the southwest. The dry season is shorter forthis region than for region I, and the rains are better distributed throughout the year. The total annual rainfall volume is about 1,100 mm, though. Annual average temperatures and relative humidity are 23.6°C and 88% (106).

Collection and Preparation of Samples

Samples from the two regions were collected from July 23 through August 24, 1979. Farms 1 to 3, in region one, were sampled first; then, samples were taken from all six farms in region two, and, at the end, from the remaining three farms in the central region. In each farm, 30 hectares (74 acres) were sampled for soils and forages, and 30 blood samples were taken from cattle.

Soils - Areas of five hectares each were taken as the basic sampling units. Four samples were taken per hectare, and pooled

together for each unit to complete six composite samples per farm. A cut-away triple-plated stainless soil sampling tube was used to do the boring on one edge of a hole previously dug in the ground with a straight shovel; the depth of sampling was 20 cm. (8 inches). Samples were air-dried in a covered place, ground with mortar and pestle (wood or porcelain), passed through a 1-2 mm plastic sieve, mixed in a stainless-steel electric mixer, and stored in plastic bags. One hundred grams of each of those composite samples were brought to the United States in whirl-pack type plastic bags.

Forages - Three farms with Pangola-grass and three with Guinea-grass were selected in each region. The sampling density was the same as that for soils. Forage sub-samples of about 100g. each were taken with stainless-steel scissors from a circular area at the sites where the soil boring was being done. Pangola-grass samples were cut at a height of 2 to 4 inches, while Guinea samples were taken at a height of 2 to 3 feet. Composite samples weighing 2 kg were prepared in the field and taken to the experiment station. The grasses were then thoroughly rinsed in a sequence of tap water, distilled water, acidified water (0.1% HCL) and de-ionized water. After draining off the excess water, samples were trimmed with scissors to pieces 2 to 3 inches long. The drying process was accomplished in two parts; first, at the station, grasses were partially dried in forced-air ovens at 60^{o}C for 12 hours to reduce moisture to a minimum necessary to stop fermentation and decomposition of the forage. Samples were then brought to Mexico City and dried for another 24 hours at similar conditions. The dry weight was recorded for dry matter determination right after removing from the oven. A Wiley mill with a 2 mm stainless-steel sieve was used to grind the samples; ground material was mixed

thouroughly in stainless-steel mixers and stored in plastic bags. The final representative sample was taken and about 100 g. were transported to the U.S. for analysis.

Livestock - Animals sampled were representative of the predominant type of cattle in the state of Veracruz. An exception was farm 6 with F_1 heifers from Holstein-Zebu crosses and farms 7 and 9 which had animals with a high percent of Brown Swiss and Holstein, respectively. Types of cattle sampled were lactating cows in their second to fourth lactations, one- to three-year old heifers and two- to five-month-old calves. Ten animals of each type were randomly selected at each farm and duplicate blood samples were taken from each animal by jugular venipuncture. One of these samples, of about 10 mls, was mixed with heparin, kept under refrigeration, and used for hemoglobin and hematocrit determinations. The second one, 20 ml. sample, was collected in silicon-coated tubes with no anticoagulant added; these tubes were kept in an upright position for at least 3 hours before moving them. Transfer of serum to plastic vials was made about 24 hours after sampling, and serum samples were kept frozen. It was necessary to use dry ice to bring them to Michigan State.

Soil Analyses

Calcium, magnesium and potassium were extracted with 1N Ammonium Acetate solution, pH 7, while phosphorus was extracted with Bray P_1 solution (0.03 N NH_4F - 0.025 N HCL) on 1:8 soil:solutions ratios (158). Two and a half grams of soil were weighed into 50 ml. Erlenmeyer flasks and 20 ml of the extracting solutions were added; samples were shaken for 5 minutes at 180 excursions per minute, and filtered through a #42 Whatman filter paper. One ml of the ammonium acetate soil extract was diluted 1:14 with a 1500 ppm Lanthanum solution

for Ca, Mg and K determinations (Lanthanum was used to avoid interferences for Ca due to Si, Al, PO_4^- or $SO_4^=$). Copper extraction was made with a 1N HCL solution on a 1:10 soil:solution ratio. Two grams of soil were placed in 50 ml. Erlenmeyer flasks, shaken for 1 hr. with 20 ml. 1N HCL and filtered. One ml. of the filtrate was diluted ten fold with deionized water. The extraction for iron, zinc and cobalt was obtained with a 0.1 N HCL solution; the soil:solution ratio was also 1:10, but this time samples were shaken for only 10 minutes. Soils were prepared for selenium determinations by digestion with nitric and perchloric acids: 0.5 grams of air-dried soil were weighed in 50 ml Erlenmeyer flasks; 2.0 ml concentrated HNO_3 and 3.0 ml concentrated $HClO_4$ were added and the flasks were heated on hot plates to speed up the reactions. For pH, a 1:1 soil to water mixture was used. Ten grams of soil plus 10 ml distilled water were placed in 50 ml. beakers, stirred intermittently for 10-15 minutes and read in an Orion Research digital ionizer pH meter.

Determinations of Ca, K, Mg, Cu, Fe, Zn and Co were made by flame atomic absorption spectrophotometry with the 5000 model spectrophotometer of Perkin Elmer. Calibration procedures and instrument settings used were mostly those given by the manufacturers (7). Color development for phosphorus analysis was accomplished by the ammonium molybdate-ascorbic acid method (157). A Gilford stasar II spectrophotometer was utilized for phosphorus determinations. A modification of the fluorometric method described by Olson et al (120) was implemented for determination of total selenium in soil.

Forage Analyses

Grass samples were prepared for analysis by a wet digestion procedure. 0.5 gram samples were weighed into 50 ml Erlenmeyer flasks;

concentrated nitric and perchloric acids were added, 5 and 3 mls respectively, and heat was applied until the samples were dried down to about 1.0 or 2.0 mls. After cooling, the digested samples were diluted with 25 mls. of deionized water. Copper and zinc were determined directly from this dilution. Iron and calcium were obtained from a further ten-fold, and potassium and magnesium from a one hundred-fold dilution with a 3,000 ppm Lanthanum solution. Concentrations for all above elements were determined by flame atomic absorption spectophotometry. One hundred-fold dilution was also prepared for phosphorus determination, but in this case the ascorbic acid-molybdate preparation was utilized. One gram samples were also digested with nitric and perchloric acids for selenium analysis. Determinations were carried out by fluorometric procedures (120). Total nitrogen and crude fiber were determined using the methods given by the A.O.A.C. (10). Crude protein was calculated multiplying total nitrogen times 6.25.

Serum and Blood Analyses

Serum samples were thawed and centrifuged at 1650 g for 10 minutes. An aliquot of the supernatant was diluted 1:4 with 15% trichloroacetic acid (TCA) and centrifuged at 1650 g for 15 minutes to precipitate the proteins (9). Phosphorus was determined by diluting 0.5 ml of supernatant with 9.5 mls of ammonium molybdate-ascorbic acid solution. A Gilford stasar II spectrophotometer was used to measure the diluted color. A separate 1.5 mls of supernatant were diluted with 3.0 mls of a 3,000 ppm Lanthanum solution for calcium analysis. From this preparation, 1.0 ml was further diluted with 7.0 mls of the Lanthanum solution for determination of magnesium and potassium. The remaining supernatant was used to measure copper and zinc concentrations. A special preparation for iron analysis was needed. One ml serum and 2.0 mls 20% TCA were

mixed, heated at 90°C for 15 minutes and centrifuged at 1710 g for 20 minutes. The supernatant was taken for iron analysis (119). For selenium, 1.0 ml of serum was digested with 3 mls of nitric and 2 mls of perchloric acids. Selenium concentrations were determined by fluororimetry according to the procedure given by Olson et al (120).

Hemoglobin and erythrocyte volume (Hematocrit) was determined in heparinized blood samples. The cyanmethemoglobin method was used for hemoglobin determinations. The reagent utilized was 0.1 mM potassium cyanide. Readings were obtained in a Zeizz PM2A spectrophotometer at the 540 nm. Hematocrit values were obtained by the microhematocrit method. Blood samples in capillary tubes were centrifuged in a SolBat centrifuge, 7.5 cm radius, at 11,000 r.p.m. for 15 minutes. It should be pointed out that determination of the hematocrit was not done within the recommended time after taking the samples because the necessary equipment was not on hand. Thus, hemolysis to some degree occured in several samples causing lower values.

Statistical Analysis

Soil data were analyzed according to farm, region and the type of grass growing on each soil. Forage data were analyzed according to farm, region and grass type. The animal data were analyzed according to farm, region, type of grass, and type of livestock.

For the soil and forage data a 3-stage nested model was used. Regions, grasses and their combinations were considered as "treatments". The experimental design for the animal data was a split-plot because variation among farms constituted experimental error for differences between regions and grasses, but variation among animals of the same type and farm constituted experimental error for differences among livestock types. Bonferroni's t test was used to make specific

comparisons among means.

All possible correlations were established between minerals in soils and between soil minerals and soil pH; also, between the minerals in grasses and between grass minerals and grass dry matter, crude protein and crude fiber. Correlations between homogenous pairs (same variable in two materials) were obtained between minerals in soils and minerals in grasses, and between minerals in soils or grasses and minerals in serum. Many more correlations were determined for those mineral pairs known to have some kind of interaction. Serum to serum correlations were also obtained for individual elements between the livestock types. For any correlation in which animal data was a part, values used were the average figures per farm. This was because of the difference in number of samples for forages, soils and animals per farm (six, six and ten, respectively). Farm averages were also used when analyzing the animal data for mean effects and interactions, as well as for the regression analyses of the entire data.

The SPSS system (Statistical Package for the Social Sciences) was used for computer processing of the data (114).

RESULTS AND DISCUSSION

Means and standard errors for all samples per region, per grass, their combinations, as well as the overall figures are presented in Tables 5 to 14. Results for individual farms have been summarized in Tables 15 to 24 (see Appendix). Selected correlation coefficients and their confidence limits are given in Table 25 to 30, while significant regression equations are presented in Table 31 (Appendix).

Soil-Plant-Animal Calcium Relationships

Table 5 shows calcium content of soils, grasses and livestock. Calcium values of soils and grasses from Region I were significantly lower ($P<.00001$) than those from Region II. Calcium content was also lower for Pangola- than for Guinea-grass ($P<.0003$). No differences were found for serum calcium of cattle grazing in the two regions or on the two grasses. The overall serum calcium concentrations indicated some differences between livestock types ($P<.06$). Interactions among regions and grasses were not strongly significant. However, the calcium content of soils growing Pangola-grass was less in Region I than for soils growing Guinea-grass, the reverse being true for Region II ($P<.07$). This is shown in Figure 2. The livestock-type by region interaction showed a greater change among regions for serum calcium of cows than for heifers and calves ($P<.08$) (Figure 3).

Extractable calcium in soils ranged from 919 ppm for Farm 1 up to 7583 ppm for Farm 12, while grass calcium varied from 0.21% (dry basis) for Farm 5 to 0.85% for Farm 7 (Table 15). Values found for

TABLE 5. MEAN CALCIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	Soils[b]	Grasses[c]	Livestock Type		
			Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Overall	4061	0.51	9.9	9.5	9.8
	(308)	(.026)	(.12)	(.11)	(.12)
Region I (Central)	1604	0.32	9.5	9.5	9.7
	(116)	(.017)	(.14)	(.14)	(.17)
Region II (North)	6517	0.69	10.3	9.6	9.9
	(161)	(.020)	(.20)	(.16)	(.17)
Grass I (Pangola)	3810	0.42	10.0	9.6	9.7
	(494)	(.034)	(.19)	(.17)	(.18)
Grass II (Guinea)	4311	0.60	9.8	9.5	9.9
	(370)	(.032)	(.16)	(.13)	(.16)
Region I & Grass I	1042	0.22	9.7	9.8	9.8
	(43)	(.010)	(.20)	(.22)	(.22)
Region I & Grass II	2166	0.41	9.3	9.2	9.5
	(128)	(.006)	(.19)	(.16)	(.27)
Region II & Grass I	6579	0.61	10.2	9.5	9.5
	(316)	(.019)	(.33)	(.26)	(.29)
Region II & Grass II	6455	0.78	10.4	9.7	10.4
	(85)	(.018)	(.22)	(.19)	(.13)

[a]Numbers in parenthesis are standard errors.
[b]Region I lower than Region II ($P<.001$).
[c]Region I lower than Region II ($P<.001$); Pangola lower than Guinea ($P<.001$).

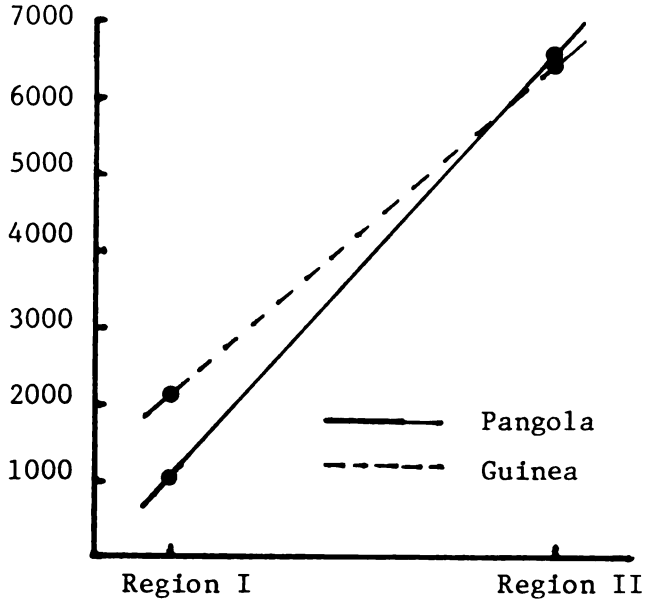


Figure 2. Soil calcium (ppm): Region by grass-cover interaction (P<.07).

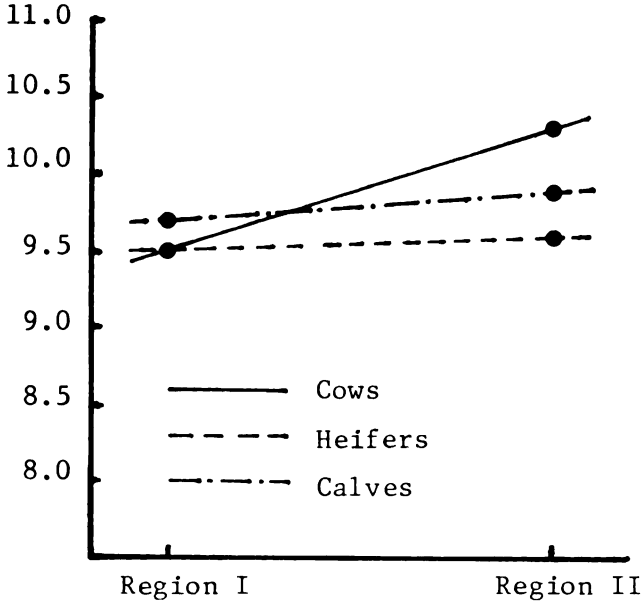


Figure 3. Serum calcium (mg/dl): Livestock-type by region interaction (P<.08).

soils were generally three to four times higher than those reported by De Sousa (39) for Brazilian soils sampled during the wet season and extracted with a double acid extracting solution. Blue et al (15) report values ranging from 2400 to 12,000 ppm ammonium acetate extractable calcium for soils from estern Panama. The calcium concentrations obtained for forages were within the values reported for the same grasses from other Latin American countries (56, 85, 100, 124). Calcium levels in serum ranged from 8.48 mg/dl for heifers in Farm 4 to 11.04 mg/dl for cows in Farm 10 (Table 15). Most of those values were within the normal range reported in the literature (8, 126, 128, 135). Similar figures have been given by De Oliveira (38) and Kiatoko et al (84) for grazing cattle from Brazil and Costa Rica, respectively.

Soil calcium correlations with other soil variables are shown in Table 25 in the Appendix. The relationships of soil calcium to soil iron, selenium, cobalt and soil pH were fairly consistent for regions and for soils growing a particular grass. The correlation coefficients for calcium to iron interrelation ranged from -.61 to -.87, with an overall figure of -.86. Coefficients for calcium to selenium correlations varied from .27 to .92, with an overall value of .87. The relationship of calcium to cobalt ranged from .13 to .58 with an overall figure of .56. Finally, the soil calcium to soil pH correlation coefficients were .66 to .95, and the overall value was .92. In all cases, correlation coefficients were higher for a particular grass than for a particular region (soil type). De Sousa (39) also reports a highly significant correlation ($r = 0.67$) between pH and soil exchangeable calcium for Brazilian soils. This strong relationship explains the negative correlations found between calcium and iron, since it is known that iron availability from soils is

greatest in acid soils (16). It also helps to explain the direct correlation between calcium and cobalt and calcium and selenium, since these two elements are more available in alkaline soils (12, 91).

Grass to grass correlations for calcium are presented in Table 26. The correlations that showed some consistency were grass calcium with grass magnesium, iron, selenium and grass dry matter. Calcium to magnesium correlation coefficients ranged from .13 to .91, with .53 as the overall. The relationship between calcium and iron in grasses was anywhere from 0 to -.70, with an overall value of -.55. Calcium to selenium correlations were positive and of relative significance only when taking the groups of farms within each particular grass. The coefficients were .52 and .49 for Grass I and II, respectively, and the overall correlation was .42. The relationship with dry matter was low, but consistent. The coefficients ranged from .06 to .47, with .34 as the overall. A high correlation ($r = 0.73$) between calcium and magnesium was also found by Kayongo-Male et al (82) for 101 30-day-old tropical grasses from Puerto Rico. The calcium to iron negative correlation can again be explained by the effect of soil pH on iron availability to plants. The relationship between calcium and selenium in grasses for the two main effects is not clear, and it suggests, as in soils, a stronger effect of grass type.

The soil to grass correlations for calcium are given in Table 27 (Appendix). Coefficients for the soil calcium to grass calcium correlation were high, ranging from .76 to .92, and with .86 for the overall data. The exception was Region II that had a correlation of -.12. Soil calcium to grass iron relationship was negative and consistent through the whole set of data. Correlation coefficients varied from -.05 to -.63, with an overall value of -.42. Soil calcium

to grass selenium correlations were positive and significant to a certain extent when soils growing a particular grass and that forage were paired. Values found were .59, .51 and .54 for Grass I, II and the overall. The soil pH to grass calcium interrelation was also high. Correlation coefficients ranged from .42 to .93, with .87 as the overall figure. De Sousa (39) reports a low correlation (r = 0.149) between soil and forage calcium for samples from the Mato Grasso area in Brazil. Soil calcium to grass iron and grass selenium correlations seem to follow the same trend as that in our study. Echevarria et al (45) found a significant correlation between soil pH and grass calcium in forages from Peru.

Soil to serum correlations are presented in Table 28 (Appendix). The soil calcium to serum calcium correlation was of relative significance only for cows, with a coefficient of .58. Soil calcium to serum copper relationship were consistently negative for the three types of livestock sampled. Correlation coefficients were -.44, -.55, and -.45 for cows, heifers and calves, respectively. The soil calcium to serum zinc relationship was also consistent, with a .40 correlation for cows, .36 for heifers and .46 for calves.

Grass to serum correlations are given in Table 29 (Appendix). Grass calcium to serum calcium correlations had coefficients of .49 for cows, .02 for heifers and .33 for calves. Grass calcium to serum copper correlation coefficients were -.54, -.34, and -.34 for cows, heifers and calves. Correlation coefficients for the grass calcium-serum zinc relationship were .61 for cows, .61 for heifers, and .54 for calves.

Serum to serum correlations are shown in Table 30 (Appendix). Cow's calcium to heifer's calcium correlation was .57, cows to calves was .34, and heifers to calves was .23.

The only significant regressions involving calcium variables were grass calcium with soil calcium, cow's calcium with soil calcium, and soil calcium with soil pH, which are presented in Table 31. Soil calcium helped to explain about 81% of the calcium content variation of grasses (R^2= .806) and 34% of the variation for serum calcium of cows (R^2= .339). Soil calcium showed a dependence of about 89% on soil pH (R^2= .893).

Soil-Plant-Animal Potassium Relationships

Means and standard errors for potassium are shown in Table 6. Concentrations in soils growing Pangola- were lower than for soils growing Guinea-grass ($P<.002$). There was also a significant difference for the potassium content of grasses, Pangola- being lower than Guinea-grass ($P<.002$). There were no differences for serum potassium among the two regions or grasses. Significant difference was found for the overall average concentration of potassium in serum between livestock types ($P<.00001$). Means differed significantly between cows and calves, and between heifers and calves, but not among cows and heifers (Bonferroni t test, $P<.01$). Interactions among regions and grasses were not significant. The livestock type by region interaction was highly significant ($P<.00001$), and mostly given by the large decrease in serum potassium of heifers from Region I to Region II (Figure 4). Livestock type by grass interaction was also significant ($P<.0002$), mainly reflecting the greater change of potassium levels in serum of calves among the two grasses (Figure 5). The three way interaction, livestock type by region by grass, was also significant ($P<.049$). Calves' serum potassium responses varied markedly from region to region when looking separately at each grass (Figure 6).

TABLE 6. MEAN POTASSIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	Soils[b]	Grasses[c]	Livestock Type		
			Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Overall	154.9 (10.0)	1.824 (.055)	21.48 (.36)	22.28 (.35)	24.27 (.43)
Region I (Central)	169.5 (16.2)	1.913 (.066)	21.01 (.50)	24.27 (.49)	24.08 (.74)
Region II (North)	140.3 (11.5)	1.735 (.086)	21.95 (.50)	20.28 (.33)	24.46 (.44)
Grass I (Pangola)	92.5 (6.4)	1.495 (.062)	20.95 (.51)	22.45 (.49)	22.78 (.55)
Grass II (Guinea)	217.3 (11.9)	2.154 (.047)	22.01 (.50)	22.11 (.48)	25.76 (.61)
Region I & Grass I	90.2 (11.8)	1.674 (.084)	20.06 (.72)	24.41 (.78)	21.58 (.80)
Region I & Grass II	248.8 (14.3)	2.152 (.066)	21.95 (.67)	24.13 (.60)	26.58 (1.08)
Region II & Grass I	94.7 (5.7)	1.315 (.071)	21.83 (.69)	20.48 (.36)	23.98 (.69)
Region II & Grass II	185.8 (16.3)	2.155 (.069)	22.07 (.74)	20.08 (.55)	24.93 (.55)

[a]Numbers in parenthesis are standard errors.
[b]Soils growing Grass I were lower than those growing Grass II ($P<.002$).
[c]Pangola lower than Guinea ($P<.002$).

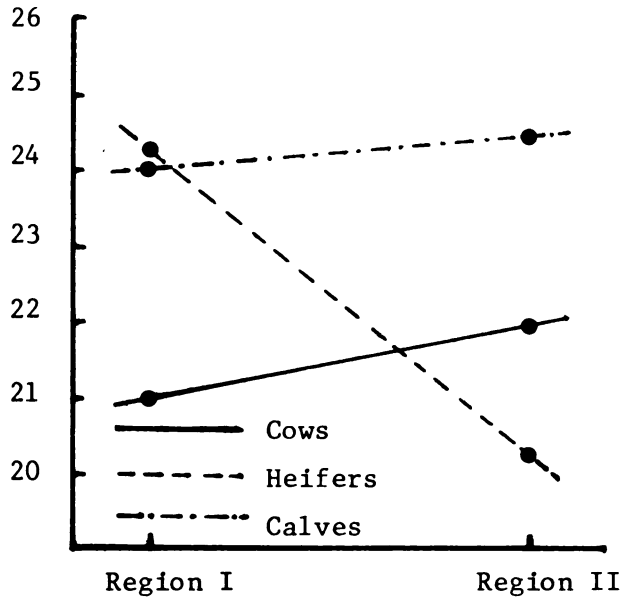


Figure 4. Serum potassium (mg/dl): Livestock-type by region interaction (P<.00001).

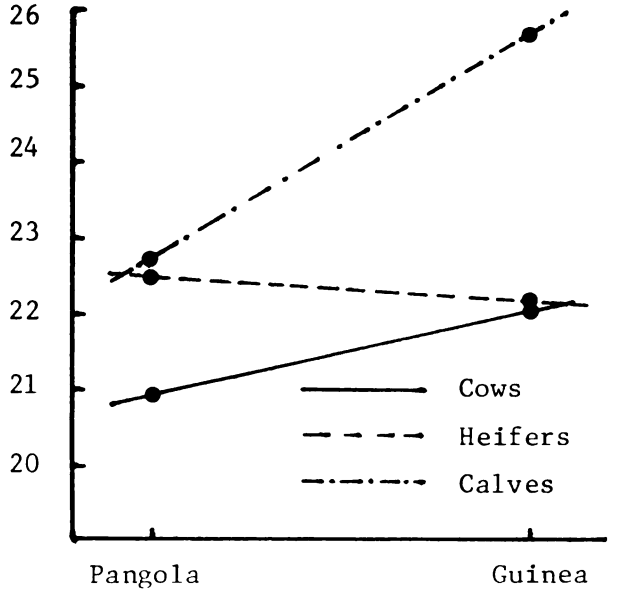


Figure 5. Serum potassium (mg/dl): Livestock-type by grass interaction (P<.0002).

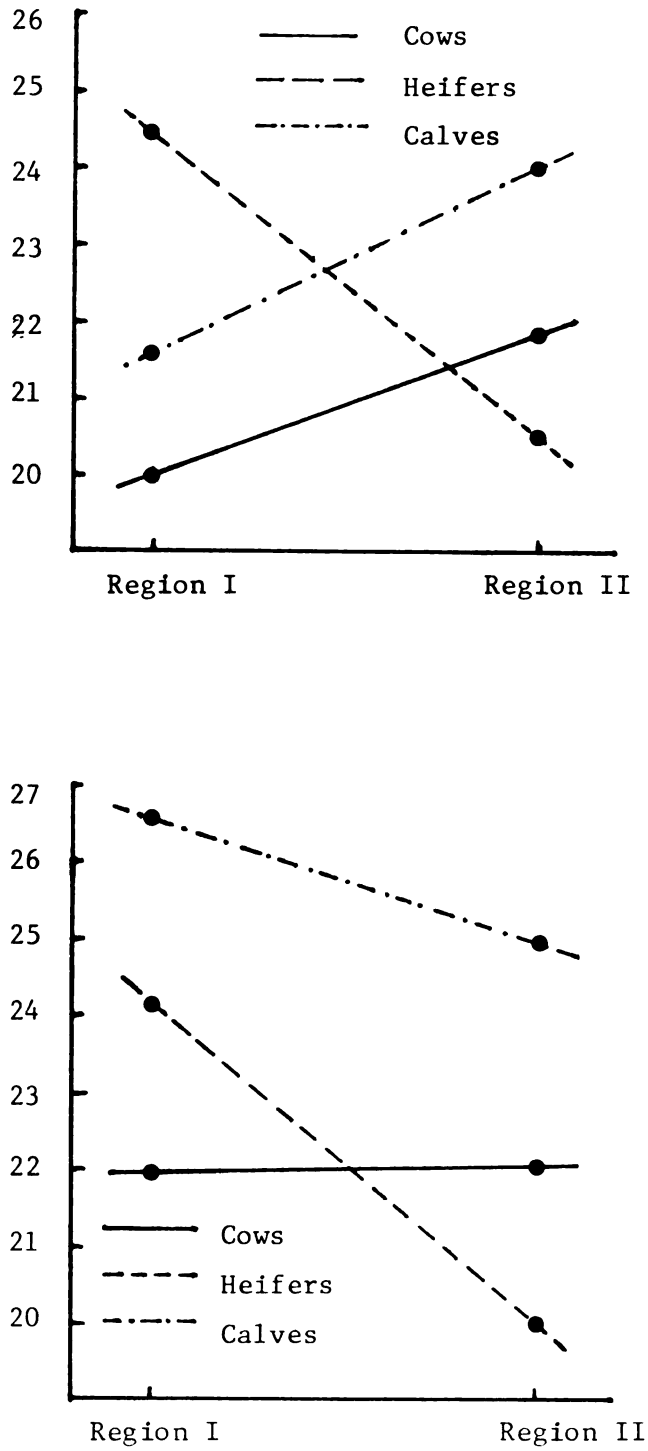


Figure 6. Serum potassium (mg/dl): Livestock-type by region by grass interactions (P<.049). Pangola (top) and Guinea (bottom).

Levels of extractable potassium in soils varied from 62.5 ppm for Farm 5 to 299.1 ppm for Farm 4 (Table 16). Most of these values are adequate or even high, according to the literature (57, 159). De Sousa (39) reports 87±61 ppm extractable K for soils from Brazil. Blue et al (15) gives a higher range of 194 to 754 ppm K for soils from eastern Panama. Potassium values found for grasses were generally high, ranging from 1.06% (d.b.) as the average for Farm 11, to 2.5% for Farm 10 (Table 16), which are the usual values for forages. Similar figures are given for the same types of grasses from Venezuela (51, 124), Colombia (13) and Panama (15), Guinea- being always higher than Pangola-grass. Serum potassium ranged from 17.6 to 32.6 mg/dl, adequate to very high when compared to the 16.4 to 23.5 mg% reported as the normal figures (64, 146).

Correlations of soil potassium with other soil variables are presented in Table 25 (Appendix). There was not a defined pattern among regions, grasses or their combinations for these relationships. Exceptions may be the soil potassium to soil copper correlation with coefficients of .40 for the overall, and .45 and .48 for Regions I and II. The potassium to iron correlation, having coefficients of -.64, and -.58 for Regions I and II, and -.20 for the overall. The soil potassium to soil pH correlation was also meaningful for regions, coefficients being .66 for Region I and .50 for Region II. Negative, positive or no interaction between potassium and calcium in soils has been reported (129), a case similar to the present study. Potassium to copper and potassium to iron correlations in soils are reported as not significant for Brazilian soils (39). A correlation coefficient of 0.415 between soil pH and soil potassium is given in

the same reference. The expected depressing effect of potassium on magnesium levels in soils was not found, or at least it was not negatively consistent.

Grass to grass correlations are presented in Table 26. Grass potassium to grass dry matter correlations were all negative for regions and grasses; values ranged from -.06 to -.78, with an overall figure of -.39. Grass potassium was also correlated with grass crude protein; correlations coefficients varied from .41 to .66, and the overall was .58. Kiatoko et al (84) also reported a positive relation of grass potassium to grass protein and digestibility estimates (r = 0 to 0.50).

Soil to grass relationships are shown in Table 27 (Appendix). Soil potassium to grass potassium were fairly correlated throughout main effects and combinations. Correlation coefficients ranged from .41 to .82 with .70 as the overall. There was also some correlation between soil potassium and grass magnesium, but only for the two regions and the overall data. A low level correlation (r = 0.190) is reported between potassium in soils and grasses from Brazil (39).

Soil to serum potassium correlation was low for the three livestock types, as can be seen in Table 28. The correlation of soil potassium with serum magnesium was not consistent, with a 0 value for cows, -.44 for heifers and .54 for calves.

No correlation was found for the grass to serum potassium relationship. Grass potassium was also not correlated to serum magnesium.

Correlations of serum potassium between livestock types are shown in Table 30. A high correlation coefficient between cows and calves was found (.81), while the relationship between cows and heifers was zero, and between heifers and calves was .23.

Only one prediction equation was significant for potassium variables (Table 31). This was for potassium in grasses, for which 65% of the variation could be explained by differences in potassium content in soils (R^2 = .649).

Soil-Plant-Animal Magnesium Relationships

Magnesium means and standard errors for soils, grasses and livestock are presented in Table 7. The magnesium content in soils from Region I was significantly higher than for soils from Region II ($P<.001$). There were no differences among soils growing the two different grasses. Magnesium levels in Pangola- were lower than for Guinea-grass ($P<.01$). No differences were found in serum magnesium concentrations of cattle grazing in the two regions or on the two grasses. On the other hand, there were highly significant differences ($P<.00001$) for serum magnesium among the livestock types. A Bonferroni t test showed that those differences were between cows and heifers and between cows and calves ($P<.01$). The interaction of region by grass was highly significant for magnesium in soils ($P<.001$). Figure 7 shows that the positive difference for soils growing Guinea-grass in Region I is reversed in Region II. No significant region by grass interaction was found for grass magnesium or serum magnesium. The livestock type by region interaction was also not significant ($P<.09$), while there was a strong interaction ($P<.00003$) between the livestock type and grass effects (Figure 8). The three way interaction between livestock type, region and grasses was significant ($P<.026$). It mainly reflected the difference in response of heifers grazing on each grass in the two regions, as well as the greater positive change for cows grazing on Guinea-grass (Figure 9).

TABLE 7. MEAN MAGNESIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	Soils[b]	Grasses[c]	Livestock Type		
			Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Overall	273.3	0.179	2.90	2.56	2.45
	(15.6)	(.007)	(.04)	(.04)	(.04)
Region I	349.2	0.168	2.82	2.53	2.45
(Central)	(22.0)	(.009)	(.04)	(.06)	(.05)
Region II	197.5	0.190	2.99	2.59	2.44
(North)	(13.0)	(.010)	(.07)	(.05)	(.05)
Grass I	255.9	0.139	2.78	2.64	2.39
(Pangola)	(10.5)	(.006)	(.06)	(.05)	(.05)
Grass II	290.8	0.219	3.02	2.48	2.50
(Guinea)	(29.2)	(.008)	(.05)	(.05)	(.05)
Region I &	262.2	0.120	2.78	2.75	2.42
Grass I	(10.6)	(.006)	(.05)	(.07)	(.08)
Region I &	436.2	0.216	2.85	2.31	2.48
Grass II	(31.5)	(.007)	(.06)	(.07)	(.07)
Region II &	249.6	0.157	2.79	2.52	2.36
Grass I	(18.3)	(.008)	(.11)	(.06)	(.08)
Region II &	145.4	0.222	3.19	2.65	2.52
Grass II	(5.9)	(.014)	(.06)	(.06)	(.05)

[a]Number in parenthesis are standard errors.
[b]Region I higher than Region II ($P<.001$); interactions are significant ($P<.001$).
[c]Pangola lower than Guinea ($P<.01$).

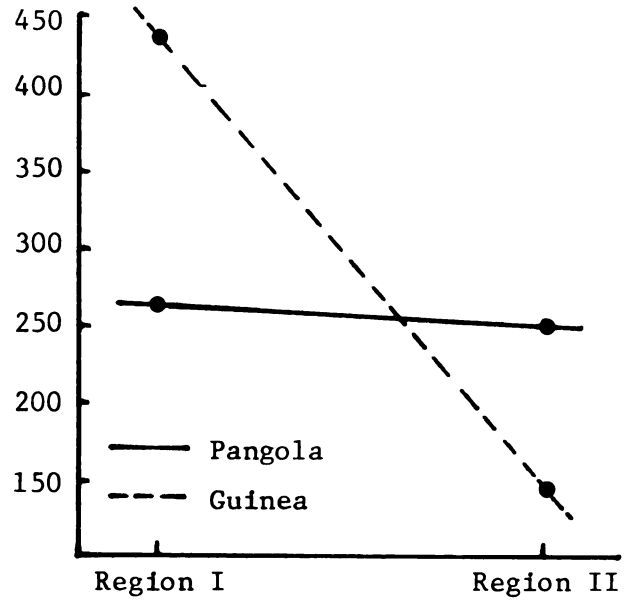


Figure 7. Soil magnesium (ppm): Region by grass-cover interaction (P<.001).

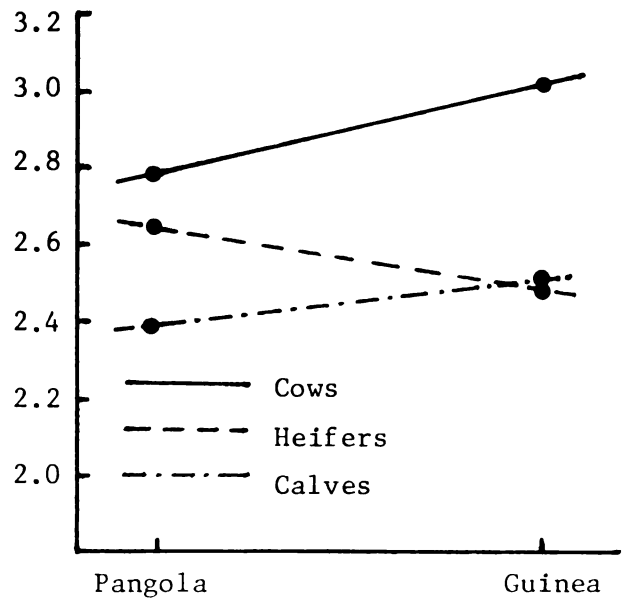


Figure 8. Serum magnesium (mg/dl): Livestock-type by grass interaction (P<.00003).

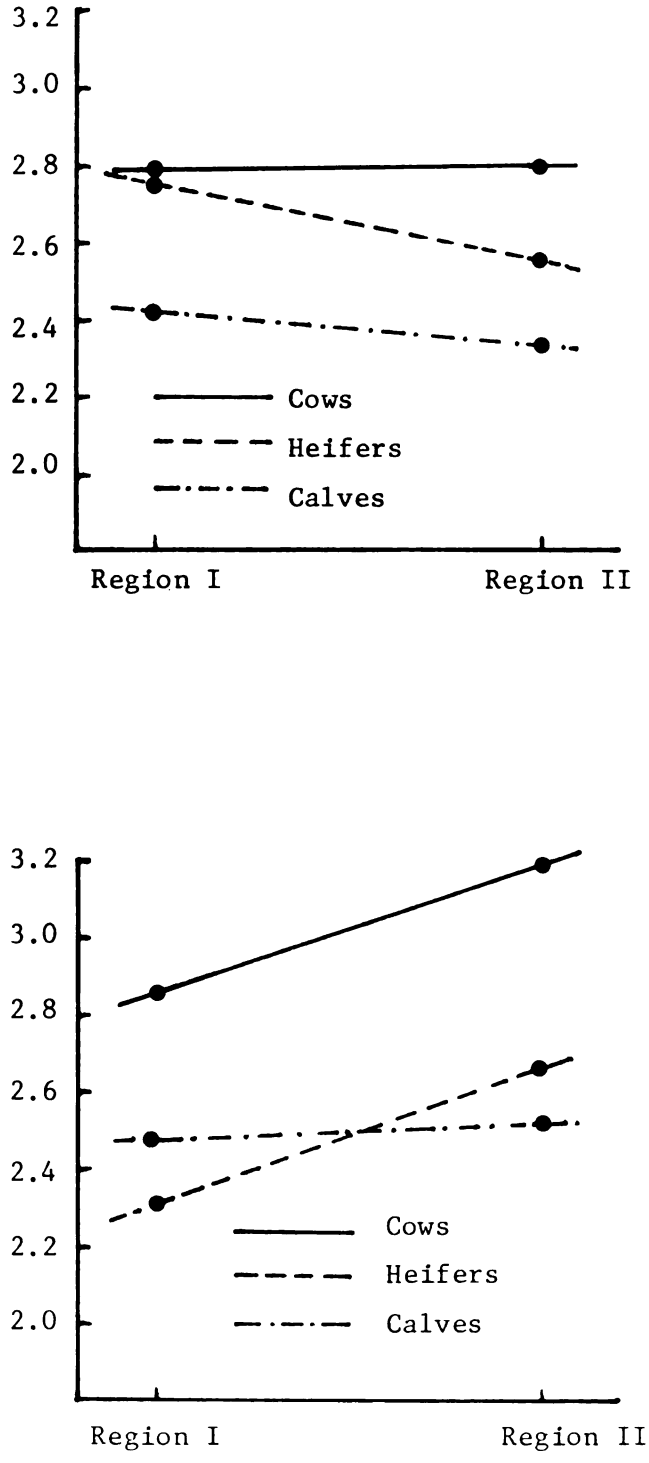


Figure 9. Serum magnesium (mg/dl): Livestock-type by region by grass interaction ($P<.026$). Pangola (top) and Guinea (bottom).

Extractable magnesium in soils ranged from 116 ppm in Farm 7 to 464 ppm for Farm 4 (Table 17), which can be considered high according to what has been reported (39, 159). A mean of 130±140 ppm Mg is given by De Sousa (39) for Brazilian soils, while very high values (700 to 1600 ppm Mg) have been given for soils from eastern Panama (15). Magnesium concentrations in grasses varied from 0.11% (d.b.) in Farm 5 to 0.30% for Farm 9. Similar values have been found for Guinea-grass in Brazil (4), Eastern Panama (15) and Venezuela (124), and for Pangola-grass in samples from Colombia (13) and Eastern Panama (15). McDowell et al (101) report that about 35% of 290 forage entries in the Latin American Tables of Feed Composition (100) contained 0.2% Mg or less, a level that is considered safe for meeting animal requirements. Serum magnesium levels varied from 2.10 mg/dl for heifers in Farm 4 up to 3.34 mg/dl for cows in Farm 7 (Table 17). Normal values in serum or plasma range from 1.8 to 3.2 mg/dl (29, 135, 151). De Oliveira (38) reports magnesium concentrations of 3.66±1.59 mg% in blood plasma of grazing cattle sampled during the rainy season in Brazil. These figures were significantly higher when compared with samples for the dry season (3.05±0.39 mg%). Concentrations of 1.87±0.2 mg/dl magnesium in blood plasma are given by Kiatoko et al (84) for grazing cattle from Costa Rica.

Soil to soil correlations for magnesium are given in Table 25 (Appendix). Relationships of soil magnesium with soil calcium and soil pH were not consistent for all data, as could be expected. Soil magnesium and phosphorus where positively correlated with the exception of soils growing Guinea-grass in Region I. Correlation coefficients ranged from .16 to .36, the last figure being also the overall. Magnesium also showed a positive correlation with zinc in

soils (r = .17 to .73, with .56 for the overall). Similar findings for these two interrelations are reported for Brazilian soils by De Sousa (39). The correlations coefficients were 0.457 for magnesium with phosphorus, and 0.488 for magnesium with zinc (double acid extracts).

Grass to grass magnesium correlations are presented in Table 26 (Appendix). Magnesium was directly correlated to calcium (r = .13 to .91, with .53 as the overall). Magnesium was again positively correlated to phosphorus in grasses, and this time the exception was for Grass I (r = -.14). Correlation coefficients varied from .72 to .79, and the overall value was .70. A positive correlation between magnesium and zinc was only shown by the two groups of grasses (r = .26, .65), since the two regions and the overall data had an inverse correlation (r = -.19 to -.61). A primarily negative interrelation among grass magnesium and grass crude protein was found (r = .19 to -.55, with -.21 for the overall). Some speculation could be made with this tendency, since grass crude protein was directly correlated with grass potassium and it is sustained that there is an antagonism among these two cations for absorption from soil to plant, and from plant to the animal (83, 135). A high positive correlation between magnesium and calcium (r = .72) is reported for 30-day-old grasses from Puerto Rico (82). A correlation coefficient of .334 for the same pair is given for Brazilian forages, while r = 0.257 is reported for the magnesium to phosphorus correlation and r = .345 for the magnesium with zinc interrelation (39).

Soil to grass correlations for magnesium are shown in Table 27 (Appendix). There was not a clearly defined relationship between soil and grass magnesium, the same being true for soil calcium-grass magnesium, soil potassium-grass magnesium and soil magnesium-grass potassium. Similar findings are presented by De Sousa (39) for Brazilian samples.

The soil to serum magnesium correlation was variable among livestock types (Table 28). A coefficient of -.24 was found between soils and cows or heifers, while r = .24 was determined for soils to calves. Soil calcium to serum magnesium interrelation was .22 for cows and essentially 0 for heifers or calves. The soil potassium to serum magnesium correlation was 0 for cows, -.44 for heifers and .54 for calves.

Grass to serum magnesium relationships were .52 for cows, -.19 for heifers and 0 for calves (Table 29). Correlations were also variable between grass calcium and serum magnesium (.54 for cows, and 0 for heifers or calves), and between grass potassium and serum magnesium (.13 for cows, -.17 for heifers and .34 for calves).

Low direct correlations were found for serum magnesium among livestock types (Table 30). Coefficients obtained were .19 between cows and heifers, .10 between cows and calves, and .08 between heifers and calves.

The only significant prediction equation for magnesium variable was for soil magnesium with soil pH (Table 31). It should be remembered that correlations between these two variables were not consistent for all data, and that significance of the regression equation may be due to the reason that overall values were used to compute it.

Soil-Plant-Animal Phosphorus Relationships

Mean phosphorus concentrations of soils, grasses, and blood sera of grazing cattle, as well as their standard errors, are presented in Table 8. Phosphorus content of soils did not greatly differ among the two regions or the two groups of soils growing a particular grass ($P<.06$ and $P<.11$, respectively). No differences were found for grass phosphorus among the two regions, but the two grasses differed significantly ($P<.05$), Pangola- being lower than Guinea-grass. Serum

TABLE 8. MEAN PHOSPHORUS CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

			Livestock Type[c]		
	Soils	Grasses[b]	Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Overall	4.13	0.307	4.26	5.77	7.81
	(.62)	(0.016)	(.12)	(.12)	(.12)
Region I	6.19	0.325	4.39	6.07	7.59
(Central)	(1.11)	(.020)	(.12)	(.15)	(.16)
Region II	2.07	0.288	4.13	5.48	8.02
(North)	(.31)	(0.025)	(.21)	(.18)	(.18)
Grass I	2.43	0.228	3.75	5.36	7.21
(Pangola)	(.27)	(.010)	(.18)	(.18)	(.18)
Grass II	5.83	0.386	4.76	6.19	8.40
(Guinea)	(1.16)	(.025)	(.14)	(.14)	(.14)
Region I &	2.37	0.239	4.02	5.83	7.05
Grass I	(.47)	(.013)	(.20)	(.19)	(.22)
Region I &	10.01	0.412	4.76	6.30	8.13
Grass II	(1.77)	(.024)	(.11)	(.22)	(.21)
Region II &	2.48	0.218	3.49	4.89	7.37
Grass I	(.27)	(.017)	(.30)	(.28)	(.28)
Region II &	1.65	0.359	4.77	6.07	8.67
Grass II	(.55)	(.042)	(.12)	(.18)	(.17)

[a]Number in parenthesis are standard errors.
[b]Pangola lower than Guinea ($P<.05$).
[c]Values for animals grazing on Pangola were lower than for those on Guinea ($P<.01$).

phosphorus concentrations for animals grazing on Pangola- were significantly lower than for those on Guinea-grass ($P<.01$). A highly significant difference was found among livestock types ($P<.00001$), which, when tested by the Bonferroni t test proved to exist for the three selected contrasts (cows vs. heifers, cows vs. calves and heifers vs. calves) at the $P<.01$ level. The interaction of region by grass was not strongly significant ($P<.06$) for phosphorus in soils. However, there was a marked difference among the two regions for soils growing Guineagrass (Figure 10). Region-grass effects did not interact for phosphorus in grasses or in livestock serum. The livestock by region interaction resulted highly significantly ($P<.0008$), although not clearly apparent when plotted (Figure 11). Interactions were not significant neither for livestock type with grass effect nor for livestock type by region by grass.

Phosphorus concentrations in soils varied from 0.40 ppm for Farm 7 up to 16.82 ppm for Farm 6 (Table 18), most of them in the low or very low part of what is usually reported as adequate (39, 57, 159). Concentrations of 9.6±19.8 ppm double acid extractable phosphorus are given by De Sousa (39) for Brazilian soils sampled during the wet season. Blue et al (15) report very low values (0.2 to 2.5 ppm) of ammonium acetate extractable phosphorus for soils in Panama. They point out that total phosphorus was in relatively adequate concentrations (375 to 1175 ppm). Grass phosphorus levels in the present study ranged from 0.16% (d.b.) to 0.57% (Table 18), values that range from deficient to adequate when related to the 0.30% level considered as adequate in grazing areas. Lower concentrations for the two grasses studied have been reported in Brazil and other tropical countries (4, 57, 101).

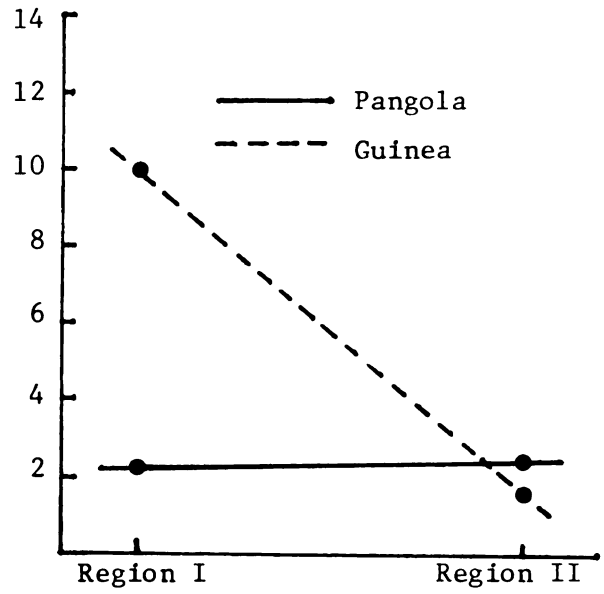


Figure 10. Soil phosphorus (ppm): Region by grass-cover interaction (P<.06).

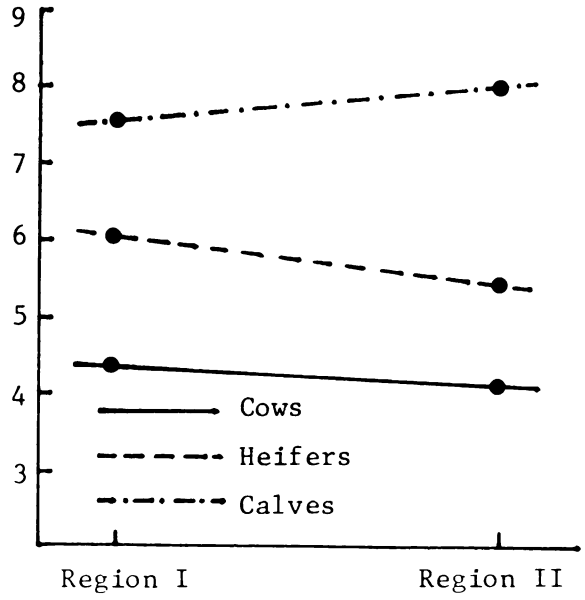


Figure 11. Serum phosphorus (mg/dl): Livestock-type by region interaction (P<.0008).

Serum phosphorus concentrations covered a wide range, varying from 1.77 mg/dl for cows in Farm 8 up to 8.98 mg% for calves in Farm 10 (Table 18). The ranges given as normal are 4 to 6 mg/dl of serum or plasma of adult cattle, and 6 to 8 mg/dl for young cattle, mostly under one year of age (29, 113, 145). Blood serum concentrations of 6.63±1.65 mg% for grazing cattle from Brazil are reported by De Oliveira (38). These values correspond to samples taken during the wet season and were significantly different (P .01) to dry season samples (5.48±1.83 mg/dl). Kiatoko et al (84) found low values (3.1±0.5 mg/dl) in cattle from Costa Rica.

Soil phosphorus correlations with other soil variables are given in Table 25 (Appendix). There was a direct relationship with magnesium (r = .16 to .45) with the exception of soils in Region I growing Guinea-grass (r = -.42). Phosphorus was also positively correlated with zinc in soils (r = 0 to .69, and .55 for the overall). These results differ from the relationships found by De Sousa (39) in a similar study in Brazil. He found positive correlations for soil phosphorus with soil calcium (r = .516), magnesium (r = .457), potassium (r = .370), zinc (r = .379) and soil pH (r = .505).

Grass to grass correlations are presented in Table 26. A positive relationship was found between phosphorus and potassium (r = .40 to .76, with .45 for the overall). The exception was Grass II (r = -.30). Phosphorus correlated with magnesium in grasses (r = .72 to .79; overall r = .70); the exception now was Grass I (r = -.14). Grass phosphorus was negatively correlated with dry matter in forages (r = -.25 to -.67, and -.22 as the overall). Values reported in the Brazilian study (39) include an r = .717 for the phosphorus with potassium correlation, r = .237 for phosphorus with magnesium and

r = .585 for phosphorus with copper in grasses. Kayongo-Male et al (82) found phosphorus in forages from Puerto Rico to be negatively correlated to field dry matter and fibrous constituents (r = -.12 to -.76), and positively related to protein content (r = 0 to .50).

Soil to grass correlations are given in Table 27. There was a positive interrelation between soil and grass phosphorus (r = .44 to .78) with the exception of Grass I (r = -.27). The soil calcium to grass phosphorus correlation was not clear or consistent. De Sousa (39) also found phosphorus to be positively correlated between soils and grasses (r = .419). He reports a coefficient of .309 for the soil calcium with grass phosphorus correlation.

Soil to serum phosphorus correlations were positively consistent, but low (Table 28). Coefficients found were .18 for soil phosphorus to cows' phosphorus, .34 for soil to heifers, and .15 for soils with calves. The soil calcium to serum phosphorus correlation was variable (r = -.02 for soils to cows, -.19 for soil-heifers, and .34 for soils-calves).

Grass to serum phosphorus was directly correlated (Table 29). Correlation coefficients were .64 for grass to cows, .60 for grass to heifers, and .33 for grass to calves. The grass calcium to serum phosphorus relationship was 0 for cows, -.12 for heifers and .62 for calves.

Correlations for serum phosphorus among livestock types were .68 for cows with heifers, .14 for cows to calves, and .06 for heifers to calves (Table 30).

Significant regression equations for phosphorus are presented in Table 31. According to them, variation in grass phosphorus could be explained in about 44% by soil phosphorus (R^2= .44). Other significant equations were cows and heifers phosphorus regressed on grass phosphorus

(R^2= .41 and .37, respectively), and cow phosphorus regressed on soil and grass phosphorus combined (R^2= .52).

Soil-Plant-Animal Copper Relationships

Table 9 shows means and standard errors for copper. Soils did not differ in their copper content among the two regions, but soils growing Pangola- were significantly lower in copper than soils growing Guinea-grass (P<.03). Copper content in forages was not different among regions or grasses. Serum copper for animals from Region I was significantly higher (P<.004) than for cattle from Region II (Figure 12), but no differences were found among livestock types. Interactions among regions and grasses were not significant for copper in soils, grasses or animal sera. There was no interaction of livestock type by region, and of livestock type by region by grass. Livestock type interacted with grass, although not very strongly (P<.057). It can be seen in Figure 13 that serum copper of heifers and calves was higher in grass two than in grass one, while this response was reversed for cows.

Soil extractable copper concentrations in the present study ranged from 0.65 ppm to 4.58 ppm (Table 19). Values of 2 to 100 ppm with a mean of 20 ppm are given in the literature for copper in soils (16). Horowitz and Dantos cited by De Sousa (39) sustain that soils with less than 0.6 ppm of extractable copper are considered deficient for pastures and crops. De Sousa reports mean values of 2.1 and 1.5 ppm for Brazilian soils sampled during the dry and wet seasons, the difference among those means being significant (P .007).

Grass copper values varied from 4.0 to 18.1 ppm (d.b.) among the twelve farms (Table 19). Normal copper concentrations in plant tissues range from 8 to 20 ppm (79, 156), being generally accepted that deficiencies in plants may occur at values below 6 ppm. Values of

TABLE 9. MEAN COPPER CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

			Livestock Type[c]		
	Soils[b]	Grasses	Cows	Heifers	Calves
	ppm	DM ppm	ug/ml serum		
Overall	2.43 (.16)	7.12 (.48)	0.638 (.012)	0.619 (.014)	0.629 (.014)
Region I (Central)	2.26 (.17)	5.89 (.23)	0.683 (.016)	0.687 (.019)	0.678 (.022)
Region II (North)	2.61 (.27)	8.35 (.88)	0.593 (.016)	0.552 (.018)	0.580 (0.16)
Grass I (Pangola)	1.75 (.16)	6.82 (.42)	0.645 (.017)	0.597 (.021)	0.600 (.019)
Grass II (Guinea)	3.12 (.22)	7.42 (.86)	0.632 (.017)	0.642 (.019)	0.658 (.021)
Region I & Grass I	1.77 (.16)	6.27 (.34)	0.683 (.024)	0.663 (.031)	0.643 (.027)
Region I & Grass II	2.76 (.26)	5.51 (.29)	0.683 (.021)	0.710 (.022)	0.713 (.032)
Region II & Grass I	1.73 (.29)	7.37 (.76)	0.607 (.022)	0.530 (.024)	0.557 (.023)
Region II & Grass II	3.48 (.34)	9.34 (1.58)	0.580 (.024)	0.573 (.026)	0.603 (.022)

[a]Numbers in parenthesis are standard errors.
[b]Soils growing Pangola were lower than those growing Guinea ($P<.03$).
[c]Values for animals from Region I were higher than for those from Region II ($P<.0038$).

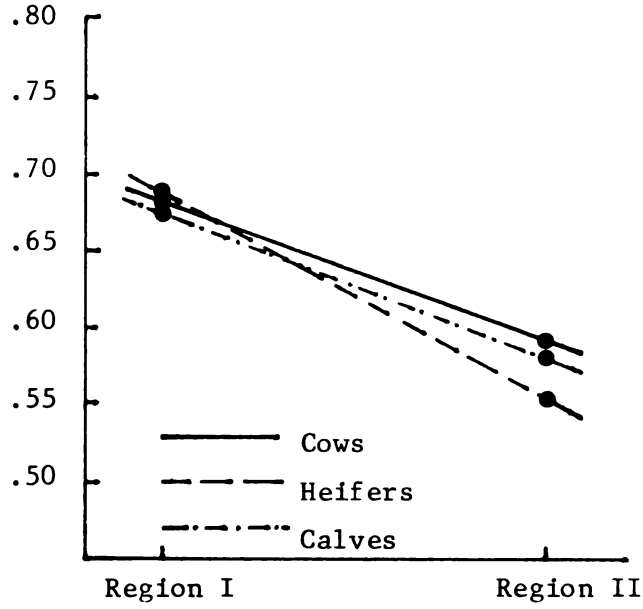


Figure 12. Serum copper (ug/ml): Differences among regions (P<.004).

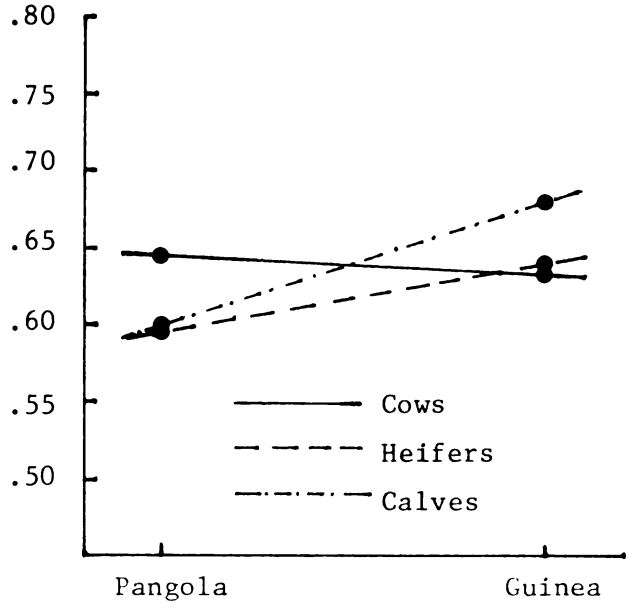


Figure 13. Serum copper (ug/ml): Livestock-type by grass interaction (P<.057).

6.2 ppm for Guinea- and 7.4 ppm for Pangolagrass are reported by Gomez et al (56) for samples from Peru. King and Price (85) give figures of 9.9 and 16.7 ppm for Guinea and Pangola samples from Haiti.

Copper concentrations found in serum ranged from 0.460 to 0.810 ug/ml (Table 19). Plasma or serum normal copper values vary from 0.5 to 1.5 ug/ml (108, 135, 153). Concentrations lower than 0.5 ug/ml are taken as indicative of deficiency.

Soil to soil correlations are presented in Table 25. Soil copper was directly correlated with calcium (r = .20 to .56), potassium (r = 0 to .48), selenium (r = .22 to .71), cobalt (r = .11 to .25) and soil pH (r = .22 to .61), and inversely related to soil iron (r = -.16 to -.62). These relations are reported as low or not significant for Brazilian soils (39), with the exception of soil copper to soil cobalt (r = 0.64).

Correlations between minerals in grasses are shown in Table 26. Relationships of grass copper with the other minerals were not clear or consistent. Exceptions may be the mostly positive correlation with calcium (r = .39 to .49) and selenium (r = 0 to .33), and the inverse relation with grass crude protein (r = 0 to -.23). These results are reported differently in the Brazilian study (39). The grass copper to grass calcium correlation was negative (r = -.28), while copper was positively correlated to phosphorus (r = .59), magnesium (r = .22) and potassium (r = .79). The relation of grass copper to grass protein has been reported as positive (r = .34) for forages from Peru (45), although it is generally accepted that this relationship is not clear.

Soil to grass mineral correlations are given in appendix Table 27. The relationship of soil to grass copper was essentially zero. Soil calcium to grass copper correlations were not consistent, the same

being true for soil copper to grass zinc and for soil pH to grass copper. An inverse relationship was found between soil copper and grass iron (r = 0 to -.56) and between soil iron with grass copper (r = -.09 to -.33). Soil copper and grass selenium showed a low positive correlation (r = 0 to .34). Similar results were found for soil calcium to grass copper, soil copper to grass zinc and soil pH to grass copper for samples from Brazil (39). A low negative relationship is reported for soil to grass copper (r = -.12), and a positive correlation is presented for soil copper to grass iron (r = .28) and for soil iron to grass copper (r = .17), which disagrees with our findings.

Soil to serum copper correlation were variable (Table 28). Values found were r = .10 when relating soils to cows, -.31 with heifers and .17 with calves. A negatively consistent relationship between soil calcium and serum copper was found (r = -.44, -.55 and -.45 for the correlation of soils to cows, to heifers and to calves, respectively). Soil copper was essentially not correlated to serum iron (r = .18 for cows was the highest coefficient) and to serum zinc (r = .19 for heifers). Soil copper correlated positively with serum selenium (r = .14 to .33). Soil copper to blood hemoglobin or blood hematocrit correlations were positive for cows and calves (r = .24 and .36 for hemoglobin; r = .11 and .42 for hematocrit) and negative for heifers (r = -.08 and -.16). The soil zinc to serum copper correlation was direct and consistent (r = .59, .46 and .37 for soils to cows, to heifers and to calves).

Grass copper was negatively correlated to serum copper, showing coefficients of -.48, -.19 and -.22 for cows, heifers and calves (Table 29). As happened with soil calcium to serum copper, correlations were negative for grass calcium to serum copper (r = -.54, -.34 and

—.34 in the usual order). Grass copper directly correlated with serum selenium (r = .46, .61 and .17), serum zinc (r = .30, .37 and .30), and blood hemoglobin (r = .19, .05 and .38). Correlations of grass copper with serum iron, with blood hematocrit, and of grass zinc with serum copper varied among livestock types.

Serum to serum correlations for copper are presented in Table 30. Cows with heifers and heifers with calves did not correlate, while a high positive (r = .74) correlation was found between serum copper of cows and serum copper of calves.

No significant prediction equations were found for the copper variables analyzed.

Soil-Plant-Animal Iron Relationships

Means and standard errors for iron concentrations in soils, plants and animal sera are presented in Table 10. Soil iron levels were significantly higher in Region I ($P<.001$), while the difference was not greatly significant among the two groups of soils growing a particular grass ($P<.08$). No marked differences were found for iron content in forages among the two regions ($P<.12$), but the two grasses differed significantly ($P<.01$). There were no differences for serum iron concentrations of livestock grazing in the two regions or on the two types of grasses, while significant differences were obtained among livestock types ($P<.00001$). Tested by Bonferroni's t procedure, those differences were found between cows and heifers and between cows and calves, but not between heifers and calves ($P<.01$). Region and grass effects did not interact significantly for iron in soils, grasses or animal sera. However, the difference in iron content among the two grasses was much greater in Region I than in Region II

TABLE 10. MEAN IRON CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

			Livestock Type		
	Soils[b]	Grasses[c]	Cows	Heifers	Calves
	ppm	DM ppm		ug/ml serum	
Overall	19.3	188.6	1.77	2.07	2.15
	(2.3)	(16.2)	(.03)	(.03)	(.06)
Region I	35.1	232.7	1.73	2.16	2.20
(Central)	(2.6)	(29.8)	(.04)	(.05)	(.09)
Region II	3.56	144.5	1.80	1.97	2.10
(North)	(.75)	(8.0)	(.05)	(.05)	(.07)
Grass I	24.9	271.5	1.74	2.09	2.25
(Pangola)	(3.6)	(25.4)	(.05)	(.05)	(.09)
Grass II	13.7	105.7	1.79	2.05	2.05
(Guinea)	(2.5)	(4.8)	(.04)	(.05)	(.06)
Region I &	43.8	359.2	1.71	2.16	2.26
Grass I	(3.3)	(41.2)	(.06)	(.07)	(.15)
Region I &	26.3	106.2	1.76	2.16	2.14
Grass II	(2.9)	(8.4)	(.06)	(.07)	(.09)
Region II &	5.93	183.8	1.77	2.01	2.23
Grass I	(1.27)	(7.4)	(.07)	(.07)	(.11)
Region II &	1.19	105.2	1.83	1.93	1.97
Grass II	(.12)	(5.0)	(.06)	(.07)	(.08)

[a]Numbers in parenthesis are standard errors.
[b]Region I higher than Region II ($P<.001$).
[c]Pangola higher than Guinea ($P<.01$).

(P<.12) (Figure 14). The interaction of livestock-type by region was significant (P<.04). Calves and heifers values were lower in Region II than in Region I, while the response for cows was the opposite (Figure 15). The interaction of livestock-type by grass was not strongly significant (P<.06), and there was not a three-way interaction among the type of livestock, region and grass effects.

Extractable iron concentrations in soil ranged from 0.72 ppm for Farm 10 to 58.7 ppm for Farm 5 (Table 20). A level of 20 ppm in the soil solution is said to be sufficient to prevent iron deficiency in crops (134). If based in this criterion, all soils from Region II were deficient in iron. Values of 27±23 ppm are reported by De Sousa (39) for Brazilian soils.

Forage iron concentrations varied from 93 to 507 ppm (d.b.), values within or above the sufficiency range that appears to be 50 to 250 ppm (79). Mean concentrations ranging from 91 to 256 ppm are reported for Pangola- and Guineagrass samples from Haiti (85), Eastern Panama (15) and Venezuela (124).

Iron concentrations in serum ranged from 1.55 ug/ml for cows in Farm 1 to 3.05 ug/ml for calves in the same Farm (Table 20). Reported values for normal cattle range from 1 to 2 ug/ml (126), which means that all farms sampled were within or above the normal level. This agrees with the concept that, under natural conditions, there is no iron deficiency in grazing animals.

Correlations between soil minerals are presented in Table 25. Soil iron was inversely correlated with soil calcium (r = -.61 to -.87), potassium (r = -.64 and -.58 for Regions I and II), copper (r = -.16 to -.62), selenium (r = -.14 to -.84), cobalt (r = -.24 to -.62) and soil pH (r = -.38 to -.94). These negative relationships

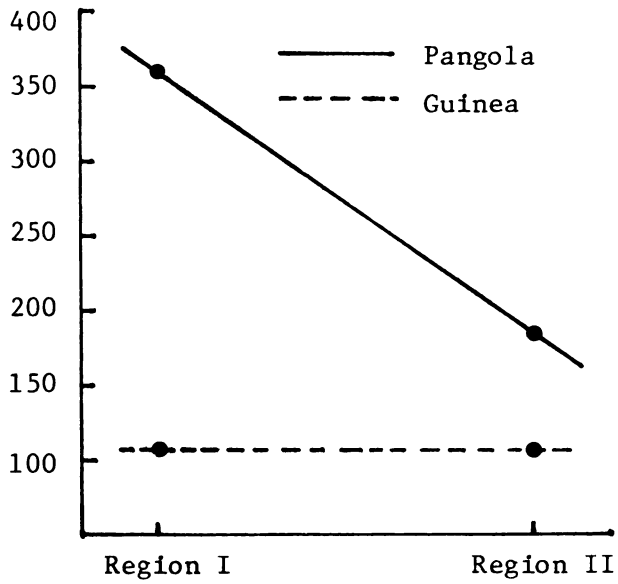


Figure 14. Grass iron (ppm): Region by grass interaction (P<.12).

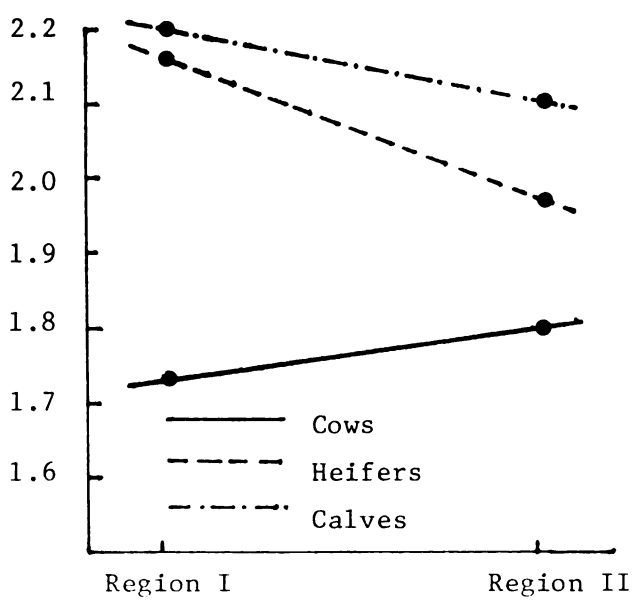


Figure 15. Serum iron (ug/ml): Livestock-type by region interaction (P<.04).

could be explained in the basis of pH, since it is known that greatest availability of iron occurs in acid soils at low pH. It is sustained that for each pH unit increase above pH 4.0, the solubility of Fe^{3+} decreases by a factor of about 1000 (18). The correlation with soil zinc was positive (r = .31 to .79), with the exception of Region I (r = -.20). Similar but lower correlation coefficients are reported by De Sousa (39) for the relationships of iron in soils from Brazil, the relation between iron and zinc being negative (r = -.27).

Grass to grass correlations are given in Table 26. Grass iron was negatively correlated with grass calcium (r = 0 to -.70), potassium (r = -.51 and -.76 for Region I and II), magnesium (r = -.25 to -.57, with the exception of Grass II), phosphorus (r = -.05 to -.51, Grass I excepted), copper (r = 0 to -.29), and grass crude fiber (r = -.40 to -.49, excepting Grass II). Iron was again positively correlated to zinc in grasses (r = 0 to .70), and the opposite was expected, since a clear antagonism exists between these two elements. For instance, it is sustained that excessive uptake of zinc by a plant may disturb the metabolic function of iron, and chlorosis from iron deficiency may develop even though iron is present at normal concentration in the plant (118). Negative, lower correlations are given in the Brazilian study (39), the relationship with zinc being again negative (r = -.17).

Soils to grass correlations are shown in Table 27. Coefficients for the soil to grass iron interrelation varied from 0 to .66, with r = .57 for the overall data. Inverse correlations were found for soil calcium to grass iron (r = -.05 to -.63), soil copper to grass iron (r = 0 to -.56), soil iron to grass copper (r = -.09 to -.33), and soil pH to grass iron (r = -.08 to -.49). The negative correlation with calcium is conditioned to a great extent by soil pH, while the

relationship with copper is the result of a clear antagonism between the two ions. It has been observed that iron deficiency in plants can develop on soils with accumulated copper, especially after long years of copper application (149). Findings by De Sousa in Brazil (39) were no significant correlations between soil calcium and grass iron (r = -.032) and between soil pH and grass iron (r = -.102). On the other hand, positive relationships were reported for soil copper to grass iron (r = .28) and soil iron to grass copper (r = .17), which is the opposite to what we found.

Correlations between soil iron and serum iron were significant for heifers (r = .64), low negative for cows (r = -.17) and non existant for calves (Table 28). Soil iron correlated positively with serum copper (r = .21 for cows, .55 for heifers and .15 for calves), while soil copper was essentially not correlated to serum iron (r = .18 for cows was the highest coefficient). A variable response was found for the correlation between soil iron and blood hemoglobin (r = -.36 for cows, .19 for heifers and -.53 for calves), and between soil iron and blood hematocrit (r = .18 for cows, .46 for heifers and -.52 for calves). It would appear that calves are adversely affected in those two blood parameters by the iron content in soils, which is not explainable.

Grass to serum iron relationships were variable among livestock types: r = -.25 for cows, .22 for heifers, and .43 for calves (Table 29). Variable responses were also found for the correlation between grass iron and serum copper (r = -.24 to .14), grass copper to serum iron (r = -.72 to .55), grass iron to blood hemoglobin (r = -.10 to .20) and grass iron to blood hematocrit (r = -.19 to .38).

Correlations for serum iron among livestock types are presented in Table 30, being all negative ($r = -.10$ between cows and heifers, $r = -.28$ between cows and calves, and $r = -.37$ between heifers and calves).

Significant regression equations for iron variables are presented in Table 31. R squares found were .74 for soil iron regressed on soil pH, .41 for grass iron regressed on soil iron, .42 for heifer iron also regressed on soil iron, and .48 for heifer iron regressed on both soil iron and grass iron.

Soil-Plant-Animal Selenium Relationships

Mean selenium concentrations and standard errors of soils, grasses and blood sera are given in Table 11. The two regions were significantly different in their selenium content in soils ($P<.00001$), grasses ($P<.001$) and animals ($P<.002$), Region I being always lower than Region II. No differences were found due to grass type for selenium in soils, grasses or animals. Livestock types differed significantly in their selenium content in serum ($P<.00001$), cows being different from heifers and calves (Bonferroni's t test, $P<.01$). There was no significant interaction among regions and grasses for selenium in soils, grasses or animal sera. However, selenium content was greater in soils growing Guinea- than those growing Pangolagrass in Region I, while the reverse was true in Region II ($P<.08$). Livestock type interacted significantly with region ($P<.00001$) and grass effects ($P<.0002$). The differences in serum selenium content between cows and heifers or calves was much greater in Region II (Figure 16) and in Grass II (Figure 17) than it was for Region I and Grass I. The three-way interaction, livestock type by region by grass, was also significant ($P<.003$). It was

TABLE 11. MEAN SELENIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

			Livestock Type[d]		
	Soils[b]	Grasses[c]	Cows	Heifers	Calves
	ppm	DM ppm	ug/ml serum		
Overall	0.220 (.013)	0.121 (.006)	0.042 (.003)	0.016 (.001)	0.015 (.001)
Region I (Central)	0.125 (.005)	0.094 (.004)	0.024 (.002)	0.013 (.001)	0.007 (.001)
Region II (North)	0.315 (.012)	0.147 (.008)	0.060 (.003)	0.020 (.002)	0.024 (.001)
Grass I (Pangola)	0.220 (.021)	0.125 (.008)	0.035 (.003)	0.016 (.001)	0.014 (.001)
Grass II (Guinea)	0.220 (.016)	0.116 (.007)	0.048 (.004)	0.017 (.002)	0.017 (.002)
Region I & Grass I	0.110 (.005)	0.096 (.004)	0.022 (.003)	0.013 (.002)	0.005 (.001)
Region I & Grass II	0.139 (.006)	0.092 (.007)	0.026 (.003)	0.013 (.001)	0.009 (.002)
Region II & Grass I	0.330 (.017)	0.154 (.013)	0.049 (.004)	0.018 (.002)	0.023 (.002)
Region II & Grass II	0.300 (.018)	0.140 (.011)	0.071 (.004)	0.022 (.003)	0.025 (.001)

[a]Numbers in parenthesis are standard errors.
[b]Region I lower than Region II ($P<.00001$).
[c]Region I lower than Region II ($P<.001$).
[d]Values for animals from Region I were lower than those from Region II ($P<.002$).

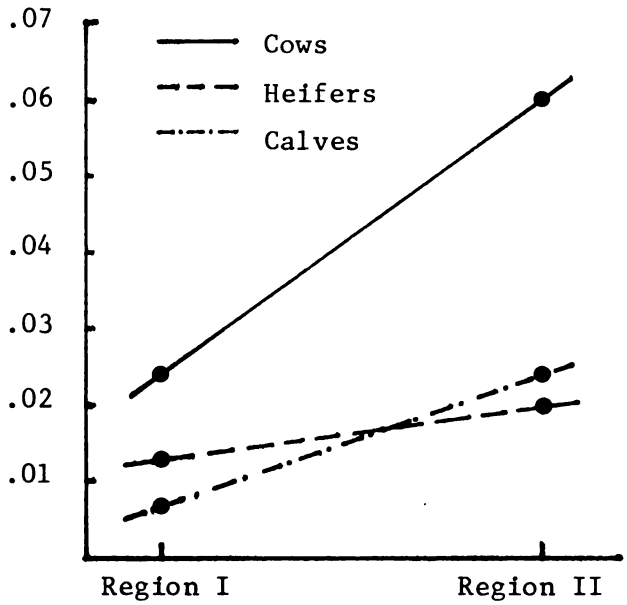


Figure 16. Serum selenium (ug/ml): Livestock-type by region interaction (P<.00001).

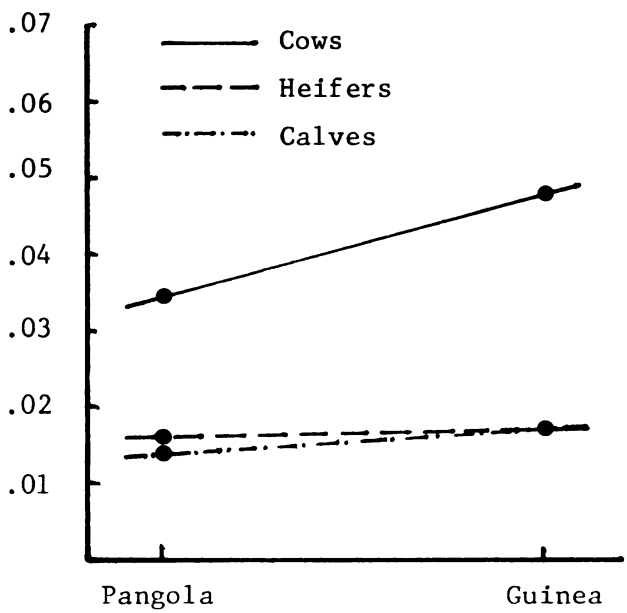


Figure 17. Serum selenium (ug/ml): Livestock-type by grass interaction(P<.0002).

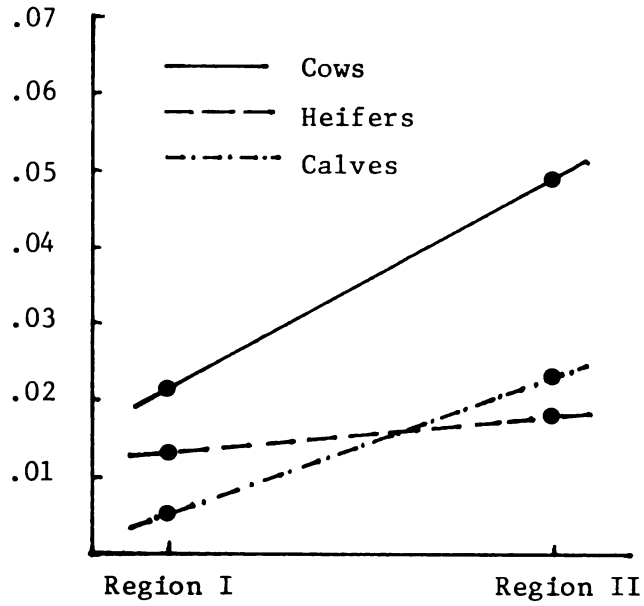
essentially due to the greater difference among regions for cows grazing on Guinea- than for cows grazing on Pangola-grass (Figure 18).

Total selenium in soils varied from 0.103 ppm in Farm 5 to 0.356 for Farm 12 (Table 21). Most soils are said to contain between 0.1 and 2.0 ppm total selenium, with a mean value of 0.2 ppm (16, 142). Several soils sampled from Region I were found to contain less than 0.1 ppm selenium, and they should be considered deficient, since availability of selenium from these soils is even poorer due to the acidity conditions.

Selenium concentrations in forages ranged from 0.086 ppm (d.b.) for Farm 2 to 0.191 ppm for Farm 12. A wide variation of selenium levels in plants has been reported, but a level of 0.1 ppm has been suggested or recommended as the minimum desirable concentration in the food (2, 54).

Serum selenium levels varied from 0.001 ug/ml for calves in Farm 4 to 0.078 ug/ml for cows in Farm 10 (Table 21). In general, blood selenium levels of 0.05 ug/ml are considered satisfactory (29, 62) and concentrations below this level should be considered as indicative of deficiency. Most animals from Region I showed low selenium levels, and complementary studies should be conducted to check the possibility of selenium-responsive diseases in the area.

Correlation coefficients and confidence limits for the relationships between soil minerals are given in Table 25. There was a positive correlation of soil selenium with soil calcium ($r = .27$ to $.92$), copper ($r = .20$ to $.56$), cobalt ($r = 0$ to $.51$) and soil pH ($r = .19$ to $.87$), while the interrelation with iron was negative ($r = -.14$ to $-.84$). Most of these correlations can be explained on the basis of soil pH, since it is well known that availability of selenium is greater in



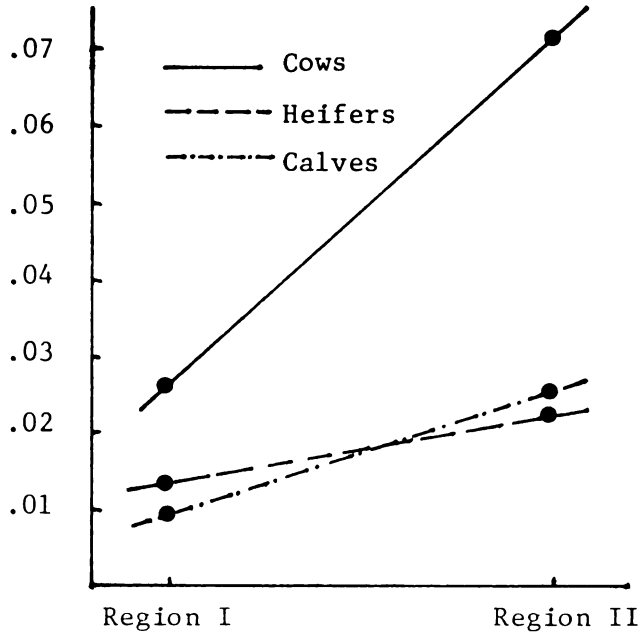


Figure 18. Serum seneium (ug/ml): Livestock-type by region by grass interaction (P<.003). Pangola (top) and Guinea (bottom).

alkaline soils, this being also true for calcium and cobalt. On the other hand, iron is more available in soils with low pH values.

Correlations between grass minerals are reported in Table 26. Selenium was correlated to calcium only for the groups of farms within a particular grass and for the overall data (r = .42 to .52). There was also a low positive correlation with copper (r = .04 to .33) and zinc (r = .16 to .38). The interrelationship between grass selenium and grass iron was not consistent, being negative only for the overall data and when grasses were considered separately (r = -.07 to -.32).

Soil to grass selenium were positively correlated, coefficients varying from .12 to .61 (Table 27). A positive correlation was also found between soil calcium and grass selenium, but only for the two grasses and for the overall data (r = .51 to .59). Low correlations were obtained between soil copper and grass selenium (r = 0 to .34) and between soil selenium and grass copper (r = .02 to .38). The relationship of grass selenium with soil pH was positive (r = 0 to .55), except for Region I (r = -.16).

Soil to serum selenium correlations were positively consistent among livestock types, coefficients being .70 for soil to cows, .34 to heifers and .76 to calves (Table 28). Correlations between soil copper and serum selenium were also positive, but low (r = .14 to .33).

Correlation coefficients found between grass selenium and serum selenium were .55 for grass to cows, .36 for heifers, and .69 for calves (Table 29). Grass copper directly correlated with serum selenium (r = .17 to .61). All those attempts to correlate copper to selenium were made on the premise that there is some kind of nutritional interaction among those two elements, antagonistic effects being expected (137). However, only positive relationships were found through all sets of correlations established.

Correlations for selenium in serum between livestock types were positive and of some significance (Table 30). Cow selenium to heifer selenium correlation coefficient was .49, cows' to calves' was .88 and heifers' to calves' was .34. Selenium was one of the two cases (zinc was the other one) where levels in serum among the three livestock types were significantly correlated. This shows a similar trend in the response of grazing cattle at three different ages to selenium in soils and forages, although the absolute concentrations in serum were different.

Several prediction equations resulted significant for selenium variables (Table 31). Variation in the selenium content of grasses could be explained in about 72% by selenium levels in soils (R^2 = .72). Cows and calves serum selenium variations were also given by the differences in soil selenium in 50 and 58%, respectively (R^2 = .50 and .58). The R square for calves' selenium when regressed on grass selenium was .47. Regression equations were also determined for cows' and calves' selenium regressed on both soil and grass selenium levels. R squares found were .50 for cows and .58 for calves. The highest in significance was for soil selenium regressed on soil pH (R^2 = .80), which is clearly understood since available selenium levels in soils are greater in alkaline pH.

Soil-Plant-Animal Zinc Relationships

Means and standard errors for zinc are presented in Table 12. There were significant differences among regions and grasses in their zinc content. Soils from Region I were higher in their zinc levels than soils from Region II ($P<.01$) and, on the contrary, grasses in Region I had lower zinc concentrations than in Region II, although this difference was not strongly significant ($P<.056$). Differences

TABLE 12. MEAN ZINC CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

			Livestock Type[d]		
	Soils[b]	Grasses[c]	Cows	Heifers	Calves
	ppm	DM ppm	ug/ml serum		
Overall	1.58 (.15)	32.18 (1.18)	0.99 (.02)	0.98 (.02)	1.04 (.02)
Region I (Central)	2.41 (.20)	29.99 (1.80)	0.96 (.03)	0.92 (.03)	0.99 (.03)
Region II (North)	0.76 (.09)	34.36 (1.45)	1.02 (.03)	1.05 (.03)	1.10 (.02)
Grass I (Pangola)	1.58 (.15)	40.09 (1.03)	0.92 (.03)	0.89 (.03)	1.00 (.02)
Grass II (Guinea)	1.58 (.25)	24.26 (.99)	1.06 (.03)	1.08 (.03)	1.10 (.03)
Region I & Grass I	2.02 (.23)	39.03 (1.75)	0.88 (.04)	0.83 (.04)	0.93 (.03)
Region I & Grass II	2.79 (.30)	20.95 (.80)	1.03 (.03)	1.01 (.05)	1.05 (.05)
Region II & Grass I	1.14 (.14)	41.15 (1.08)	0.95 (.03)	0.95 (.03)	1.06 (.03)
Region II & Grass II	0.37 (.03)	25.57 (1.44)	1.08 (.04)	1.15 (.04)	1.14 (.03)

[a]Numbers in parenthesis are standard errors.
[b]Region I higher than Region II ($P<.01$).
[c]Region I lower than Region II ($P<.056$); Pangola higher than Guinea ($P<.0001$).
[d]Values for animals grazing on Pangola were lower than for those on Guinea ($P<.037$).

were highly significant among the two grasses ($P<.0001$), Pangola- being higher than Guineagrass. Animals did not greatly differ in their serum zinc levels among regions, but cattle grazing on Pangola- had lower zinc concentrations than cattle on Guineagrass ($P<.037$), which is the opposite to what happened in grasses. Differences among livestock types were not strongly significant ($P<.068$), existing primarily between heifers and calves (Bonferroni's t test, $P<.10$). Region by grass interactions were not significant for zinc in soils, grasses or animal sera. However, soils growing Guinea- in Region I had higher zinc concentrations than soils growing Pangolagrass while the response was opposite in Region II ($P<.13$). Interactions of livestock type with region, grass, and the three-way interaction were also not significant.

Extractable soil zinc levels ranged from 0.28 ppm in Farm 9 to 3.57 ppm in Farm 6 (Table 22). Tisdale and Nelson (149) report an experiment in which the zinc status of 53 soils was investigated. Sweet corn responded to zinc applications if the soil contained 0.55 ppm extractable zinc or less (dithizone extracting solution). Even though the extracting solutions were not the same (we used a 0.1 N HCl solution), that level of 0.55 ppm could be used as a guide. In that case, soils in four farms from Region II were low in their zinc content. Values reported for Brazilian soils (39) were 2.4±1.8 ppm zinc (double acid extracts) for wet season samples, which were not significantly different from samples taken during the dry season (1.9±1.6 ppm).

Zinc grass concentrations, shown in Table 22, varied from 19.6 to 43.2 ppm (d.b.), most of them within the 20 to 150 ppm range given in the literature as normal (79, 109). When the content is less than

20 ppm, plant tissues are often deficient. Similar values have been reported for the same two grasses in Haiti (85) and Venezuela (124), zinc concentrations being higher in Pangola- than in Guineagrass, as in our study. Zinc requirements for beef cattle appear to be between 20 and 30 ppm of diet dry matter (112), while 40 ppm are recommended for dairy cattle (113).

Zinc concentrations in serum of grazing cattle for individual farms are given in Table 22. Values ranged from 0.73 ug/ml for heifers in Farm 1 to 1.33 ug/ml for calves in Farm 4. Plasma zinc concentrations from 0.60 to 1.40 ug/ml are considered normal for cows (27), and values lower than 0.40 ug/ml would be indicative of zinc deficiency. In general, it is accepted that deficiency of zinc in grazing ruminants rarely occurs under natural conditions (68, 96). In our study, all farms had zinc values within the normal range.

Soil to soil mineral correlations are presented in appendix Table 25. Relationships between zinc and calcium were negative for soils grouped by the grass they were growing and for the overall data ($r = -.48$ to $-.80$), but not for region ($r = 0$ to $.23$). Correlations were also variable between soil zinc and soil potassium, copper and selenium. Zinc showed positive correlations with magnesium in soils ($r = .17$ to $.73$), phosphorus ($r = 0$ to $.69$), and iron ($r = .31$ to $.79$, excepting Region I for which $r = -.20$). A negative relationship was found with cobalt ($r = 0$ to $-.55$) and soil pH ($r = -.14$ to $-.88$). The correlations with calcium, iron and soil pH were expected since zinc is generally more available in acid than in alkaline soils (149, 156). On the other hand, the relationship between zinc and phosphorus was supposed to be negative. It is known that zinc deficiency in plants is observed frequently on high phosphate soils, and it is even

called "phosphorus-induced zinc deficiency" (89, 118). De Sousa (39) found positive correlations between soil zinc and soil calcium (r = .53), potassium (r = .45), magnesium (r = .49), phosphorus (r = .38), cobalt (r = .35) and even for pH (r = .56), which is still more confusing.

Correlations between minerals in grasses are reported in Table 26. Interrelationships found between grass zinc and grass calcium, potassium, magnesium, phosphorus and copper were variable (i.e.: negative for regions, positive for grass types, and vice versa). Zinc correlated positively with iron (r = 0 to .70) and selenium (r = .16 to .38), and negatively with grass dry matter (r = 0 to -.50), crude protein (r = -.15 to -.49) and crude fiber (r = 0 to -.61). Results were not clear, since defined inverse correlations were expected with calcium, phosphorus and copper because of the antagonism existing between these elements and zinc (125). For instance, it has been observed that a high level of phosphorus or zinc may reduce plant uptake of the other element (149). Kayongo-Male et al (82) report that zinc concentration in grasses was negatively related to fiber and field dry matter, but positively related to crude protein. Correlations found in grass samples from Brazil (39) were positive between zinc and calcium (r = .31), potassium (r = .24), magnesium (r = .35), phosphorus (r = .24), copper (r = .14), and negative between zinc and iron (r = -.17), the last one being the only different to our findings.

The correlations between soil zinc and grass zinc were variable (Table 27). The case was the same for the relationship between soil calcium with grass zinc, soil copper with grass zinc, soil zinc with grass copper and soil pH with grass zinc. Correlations found by De Sousa (39) in Brazil were r = .30 for the relation between soil zinc with grass zinc, .27 for soil calcium with grass zinc, .37 for

soil pH to grass zinc, and no significance between soil copper with grass zinc or soil zinc with grass copper. Once again, inverse relationships were expected between zinc and calcium, copper and pH.

Soil to serum correlations are presented in Table 28. A negative relationship was found between soil zinc and serum zinc (r = -.42 for cows, -.23 for heifers and -.37 for calves), while the correlation between soil calcium and serum zinc was positive (r = .40 for cows, .36 for heifers and .46 for calves). These results are not explainable. The relationship between soil copper and serum zinc was essentially zero.

Grass zinc correlated negatively with serum zinc (Table 29). Correlations coefficients were -.58 for cows, -.41 for heifers and -.27 for calves. The grass calcium to serum zinc relationship was positive (r = .61, .61 and .54 for cows, heifers and calves), being also positive the grass copper with serum zinc interrelation (r = .30, .37 and .30 in the usual order). The opposite was expected for these correlations, as was for the relations between soil and serum variables.

Livestock types showed significant correlations for their zinc concentrations in serum (Table 30). Correlations coefficients were .71 between cows and heifers, .67 between cows and calves, and .74 between heifers and calves.

Three prediction equations including zinc variables were significant (Table 31). R square found for zinc concentrations in serum of cows when regressed on soil zinc was .33, and when regressed on both soil and grass zinc was .66. In other equation, 59% of the variation in soil zinc could be explained by differences in soil pH (R^2 = .59).

Soil Cobalt Relationships

Mean concentrations and standard errors for cobalt in soils are presented in Table 13. The two regions were significantly different in their cobalt content ($P<.0002$), Region II being higher. There was no interaction of region by grass effects (Figure 19). Soil cobalt values, extracted with 0.1 N HCl, ranged from .42 ppm for Farm 6 to 0.93 ppm for Farm 9 (Table 23). It is sustained that levels greater than 0.3 ppm Co (extracted with acetic acid), indicate adequate cobalt, while less than 0.1 ppm is considered low (29). De Sousa (39) reports levels of 1.02±1.86 ppm cobalt for wet season soil samples from Brazil (also extracted with 0.1 N HCl).

Direct correlations were obtained for soil cobalt with soil calcium ($r = .13$ to $.58$), potassium ($r = 0$ to $.34$), copper ($r = .11$ to $.25$), selenium ($r = .25$ to $.51$, Region II excepted) and soil pH ($r = .13$ to $.58$). A negative relationship was found with iron ($r = -.24$ to $-.62$) and zinc ($r = 0$ to $-.55$). It would appear that cobalt is better available from soils with neutral to alkaline pH. However, it has been observed that overliming and subsequent rise in soil pH renders cobalt completely unavailable to the plant (69). Correlations in the Brazilian study (39) were higher for soil cobalt with soil magnesium ($r = .53$) and copper ($r = .64$), while the relation with zinc was opposite ($r = .35$). The remaining correlations were similar to our results.

Soil pH Relationships

Soil pH values are reported in Table 13. There was a highly significant difference ($P<.00006$) of pH in soils among the two regions, Region II having higher pH. No interaction was found for region and grass effects (Figure 20). Soil pH values ranged from 5.97 (Farm 3)

TABLE 13. MEAN SOIL COBALT CONCENTRATIONS, SOILS PH, AND GRASSES DRY MATTER, CRUDE PROTEIN AND CRUDE FIBER FOR SAMPLES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	SOCO[b]	SOPH[c]	GRADM	GRACP	GRACF
	ppm		%	DM%	DM%
Overall	0.69	7.05	29.0	7.74	37.3
	(.04)	(.10)	(.4)	(.19)	(.3)
Region I	0.53	6.31	28.0	8.57	36.8
(Central)	(.04)	(.06)	(.5)	(.17)	(.5)
Region II	0.84	7.79	29.9	6.91	37.7
(North)	(.05)	(.09)	(.6)	(.28)	(.4)
Grass I	0.65	6.80	28.7	7.35	36.3
(Pangola)	(.05)	(.15)	(.7)	(.22)	(.5)
Grass II	0.72	7.30	29.3	8.13	38.3
(Guinea)	(.05)	(.13)	(.5)	(.29)	(.3)
Region I	0.50	6.06	26.6	8.28	36.2
Grass I	(.05)	(.05)	(.8)	(.20)	(.9)
Region I	0.56	6.56	29.5	8.87	37.5
Grass II	(.06)	(.07)	(.4)	(.25)	(.4)
Region II	0.81	7.54	30.7	6.43	36.4
Grass I	(.07)	(.15)	(.8)	(.25)	(.6)
Region II	0.88	8.04	29.2	7.38	39.1
Grass II	(.06)	(.02)	(.8)	(.48)	(.5)

[a]The numbers in parenthesis are standard errors.
[b]Region I lower than Region II ($P<.0002$).
[c]Region I lower than Region II ($P<.00006$).

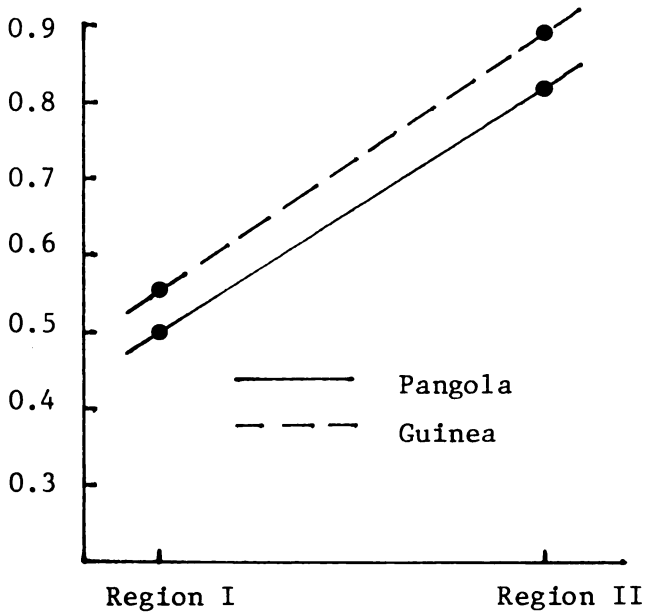


Figure 19. Soil cobalt (ppm): Region by grass-cover interaction (P>.2).

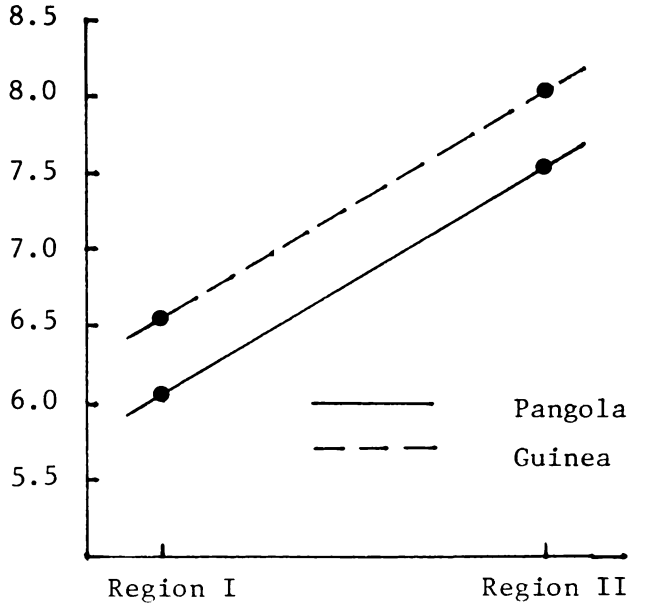


Figure 20. Soil pH: Region by grass-cover interaction (P>.2).

to 8.03 (Farms 7, 9 and 12). The values were higher than what it is found for soils of tropical or subtropical regions, usually having a pH much lower than 6.0. pH values from 5.8 to 7.2 have been reported for Haitian soils (85), while a pH of 6.1 was given for soils from Venezuela (124).

There were clear positive relationships between soil pH and soil calcium (r = .66 to .95), copper (r = .22 to .61), selenium (r = .19 to .87), and cobalt (r = .13 to .58) (Table 25). Inverse correlations were found between soil pH with soil iron (r = -.38 to -.94) and zinc (r = -.14 to -.88). All those interrelations fall within normal expectations since Ca, Cu, Se and Co are more available at neutral to alkaline pH's, while availability of iron and zinc is greatest in acid soils. Variable trends among regions and grasses were observed for the relations of soil pH with soil phosphorus, potassium and magnesium.

Soil pH to grass minerals correlations are given in Table 27. There were clear relationships with grass calcium (r = .42 to .93) and grass iron (r = -.08 to -.49), while the responses were variable with grass copper, selenium and zinc.

Similar correlations in soils were found in Brazil (39) between soil pH and soil calcium, iron and cobalt. The relationship with copper was not significant and with zinc was positive and high (r = .56), which was opposite to what we observed. Another difference was the positive correlations of soil pH with soil potassium (r = .42), magnesium (r = .51) and phosphorus (r = .51). It is also reported in the same reference a low correlation of soil pH to grass calcium (r = .13), a positive relationship with grass zinc (r = .37) and no significant relations between soil pH and grass copper and iron.

Grasses Dry Matter, Crude Protein and Crude Fiber Relationships

Dry matter, crude protein and crude fiber determinations are given in Table 13. There were not significant differences among regions or grasses for any of these parameters. Interactions among main effects (region and grass) were also not significant. Dry matter content varied from 25.8% of fresh weight (Farm 10) to 33.0% (Farm 7). Crude protein values ranged from 5.52% (d.b.) in Farm 9 to 10.01% in Farm 10. Values found for crude fiber varied from 33.2% (d.b.) for Farm 1 up to 40.1% for Farm 7. It is interesting to observe that even when samples were taken at the middle of the rainy season, four farms from Region II had protein levels lower than 7.2%, value that has been suggested as the inferior limit in subtropical pastures to ensure a zero nitrogen balance (107). Forages are known to decrease in protein and mineral content, and increase in fiber, as they mature. Thus, those same farms sampled during the dry season are almost sure to show severe protein and mineral deficiencies.

Correlations between grass variables are shown in Table 26. Grass dry matter positively correlated with grass calcium (r = .06 to .47), while inverse correlations were observed between grass dry matter and grass potassium (r = -.06 to -.78), phosphorus (r = 0 to -.67) and zinc (r = 0 to -.50). Variable responses among regions and grasses were found for the relations between grass dry matter with grass magnesium, copper, iron or selenium. Grass crude protein correlations were positive when paired with grass potassium (r = .41 to .66), negative with copper (r = 0 to -.23) and zinc (r = -.15 to -.49), and variable for calcium, magnesium, phosphorus, iron and selenium. Grass crude fiber was positively correlated with grass calcium (r = .05 to .54) and copper (r = 0 to .41), while the relationship

with zinc was negative (r = -.03 to -.61). Variable responses were observed for correlations between grass crude fiber and grass potassium, magnesium, phosphorus, iron and selenium. Grass dry matter was inversely correlated with grass crude protein (r = -.10 to -.61) and directly with grass crude fiber (r = .03 to .18). The relationship between crude protein and crude fiber was variable.

Correlations between some of these parameters are reported by Kayongo-Male et al (82) for forages from Puerto Rico. They found phosphorus and potassium to be negatively related to fiber constituents and field dry matter (r = -.12 to -.76), but positively related to protein content (r = 0 to .50). Calcium and magnesium positively correlated to lignin, while zinc relationship to fiber and field dry matter was negative, and to crude protein was positive. Some of these responses agree with our findings.

Blood Hemoglobin and Hematocrit Relationships

Means and standard errors for these two blood parameters are presented in Table 14. Hemoglobin values were significantly different among livestock types ($P<.0013$), differences being between cows and heifers (t_B, $P<.01$). The livestock type by region interaction was significant ($P<.00001$). Cows and calves had greater hemoglobin values in Region II than in Region I, while the response for heifers was reversed (Figure 21). The livestock type by grass interaction was also significant ($P<.0001$). This time calves had greater hemoglobin values when grazing on Guinea-, while cows and heifers response was better on Pangolagrass (Figure 22). The three-way interaction was significant at the $P<.00001$ level. Figure 23 shows that hemoglobin values of cows grazing on Guineagrass were higher in Region II than

TABLE 14. MEAN HEMOGLOBIN AND HEMATOCRIT VALUES OF GRAZING COWS, HEIFERS AND CALVES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	COHB	HEHB	CAHB	COHT	HEHT	CAHT
	g/dl			%		
Overall	9.83 (.16)	10.35 (.16)	10.20 (.18)	32.5 (.5)	34.0 (.5)	36.9 (.5)
Region I (Central)	9.47 (.24)	10.58 (.23)	9.53 (.24)	33.4 (.7)	35.1 (.9)	35.2 (.7)
Region II (North)	10.19 (.20)	10.12 (.21)	10.87 (.23)	31.7 (.7)	33.1 (.6)	38.6 (.7)
Grass I (Pangola)	10.32 (.20)	10.59 (.23)	10.06 (.25)	34.4 (.7)	34.4 (.8)	36.9 (.7)
Grass II (Guinea)	9.34 (.24)	10.11 (.21)	10.35 (.26)	30.7 (.6)	33.7 (.7)	36.9 (.7)
Region I Grass I	9.69 (.26)	11.37 (.25)	9.93 (.35)	35.0 (1.)	37.8 (1.1)	36.4 (.9)
Region I Grass II	9.25 (.41)	9.80 (.34)	9.14 (.32)	31.7 (.8)	33.2 (1.2)	34.0 (.9)
Region II Grass I	10.96 (.25)	9.82 (.32)	10.18 (.35)	33.8 (1.)	32.0 (.8)	37.4 (1.1)
Region II Grass II	9.42 (.24)	10.42 (.25)	11.55 (.25)	29.7 (.8)	34.2 (1.0)	39.7 (1.0)

[a]The numbers in parenthesis are standard errors.

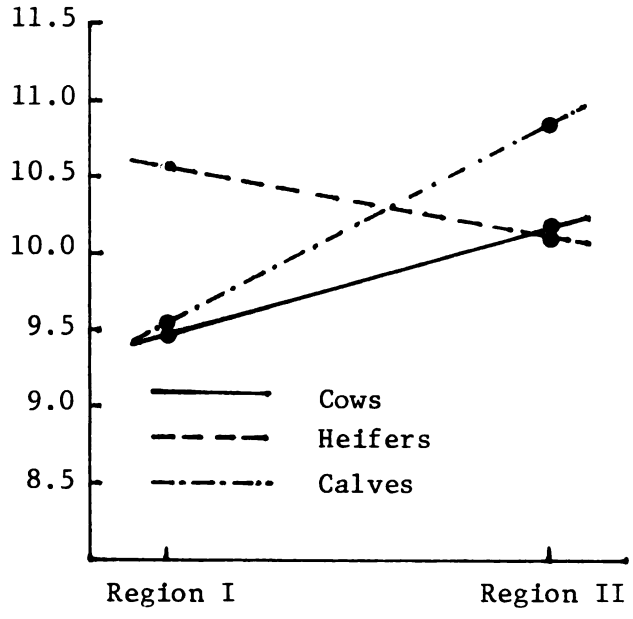


Figure 21. Blood hemoglobin (g/dl): Livestock-type by region interaction (P<.00001).

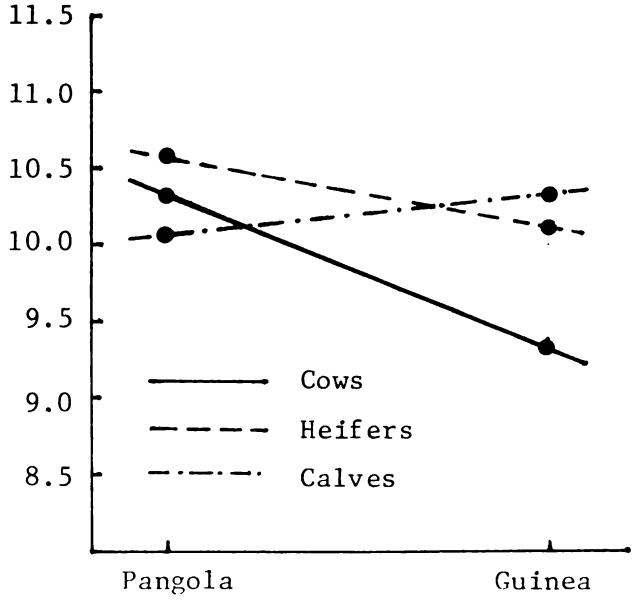


Figure 22. Blood hemoglobin (g/dl): Livestock-type by grass interaction (P<.0001).

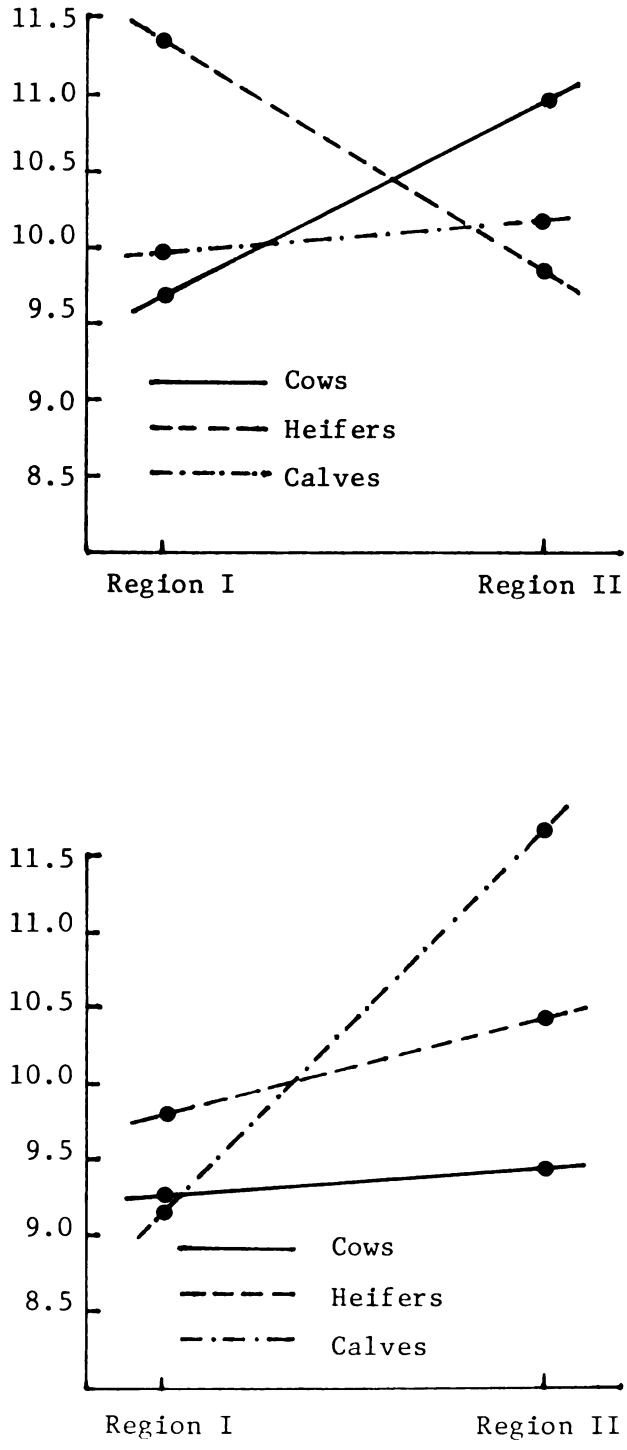


Figure 23. Blood hemoglobin (g/dl): Livestock-type by region by grass interaction (P<.00001). Pangola (top) and guinea (bottom).

in Region I, while heifers response was opposite and calves kept about steady. Grazing on Pangolagrass, calves had greater hemoglobin levels in Region II, while cows and heifers only slightly increased their levels in Region II when compared to Region I.

Blood hemoglobin values varied from 7.35 g/dl for calves in Farm 6 to 12.57 g/dl for heifers in Farm 3 (Table 24). Several of these figures are low, since normal values in blood of beef cattle range from 9.50 to 13.50 g/dl for animals less than one year old, and from 9.63 to 14.25 g/dl for mature cattle (136). Hemoglobin values reported by Rodriguez (133) for grazing zebu cattle under one year of age from the subtropical areas of Mexico were in the average 11.8 g/dl. French and Chicco (53) gave average values of 9.65 and 9.79 g/dl for cows and calves, respectively, from Venezuela. These two authors referred to 8.0 g hemoglobin/dl as to the lower limit for normal ranges.

Correlations between blood hemoglobin and soil or grass copper or iron are presented in Tables 28 and 29. Relationships with soil copper were variable ($r = .24$ for cows, $-.08$ for heifers, and .36 for calves), while relations with grass copper were all positive, though low ($r = .19$ for cows, .05 for heifers and .38 for calves). Blood hemoglobin to soil iron correlations were also variable ($r = -.36$, .19 and $-.53$ for cows, heifers and calves), as well as with grass iron ($r = .05$, .20 and $-.10$). No predictions of the hemoglobin status can then be made based on the iron or copper contents of soils or grasses.

Blood hematocrit values differed significantly among livestock types ($P<.00001$). Bonferroni's t test statistics ($P<.01$) showed that these differences existed for the three selected contrasts (cows vs. heifers, cows vs. calves, and heifer vs. calves). The livestock type effect significantly interacted with regions ($P<.00002$) and grasses

(P<.00001), the three-way interaction being also significant (P<.001). Cows and heifers had higher hematocrit values in Region I than in Region II, while the response for calves was clearly opposite (Figure 24). In the case of the interaction with grass effect, heifers and calves grazing on any of the two grasses had similar hematocrit levels, while cows grazing on Pangola- showed much higher values than cows on Guineagrass (Figure 25). When looking separately at Pangolagrass, heifers had higher hematocrit levels than calves and cows in Region I, while in Region II heifers were the lowest. On Guineagrass, differences between the three types of livestock were much larger in Region II than in Region I (Figure 26).

Blood hematocrit values in the present study ranged from 27.4% for heifers in Farm 4 to 42.4% for calves in Farm 10 (Table 24). Normal ranges for beef cattle are 27.0 to 50.5% for animals less than one-year old, and 31.0 to 49.0% for mature animals (136). According to this, cows from Farms 4, 6, 7, 9 and 12, and heifers from Farms 4 and 12 had low hematocrit levels. It has to be pointed out again that hematocrit determinations were carried out several days apart from the day that samples were taken, and hemolysis was evident in many of the specimens. The average hematocrit value found by Rodriguez (133) for zebu calves under subtropical conditions was 36.7%.

Blood hematocrit correlations with soil or grass minerals are presented in Tables 28 and 29. Relationships with soil copper were variable (r = .11 for cows, -.16 for heifers and .42 for calves), as well as for soil iron (r = .18, .46 and -.52 for cows, heifers and calves). The same variable response among livestock types was

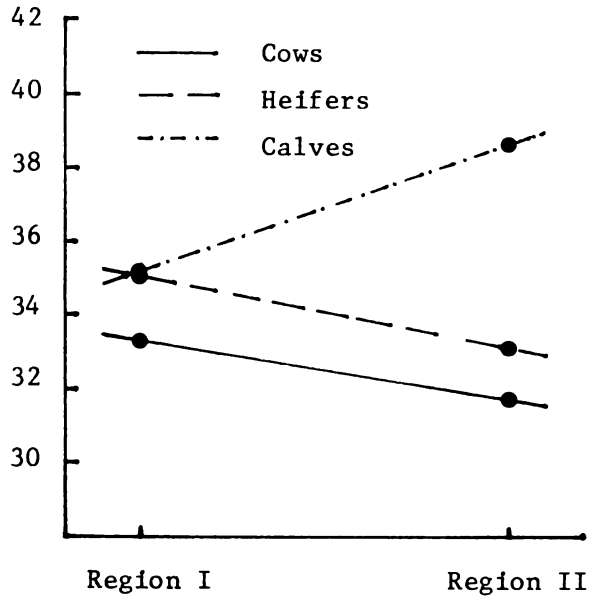


Figure 24. Blood hematocrit (%): Livestock-type by region interaction (P<.00002).

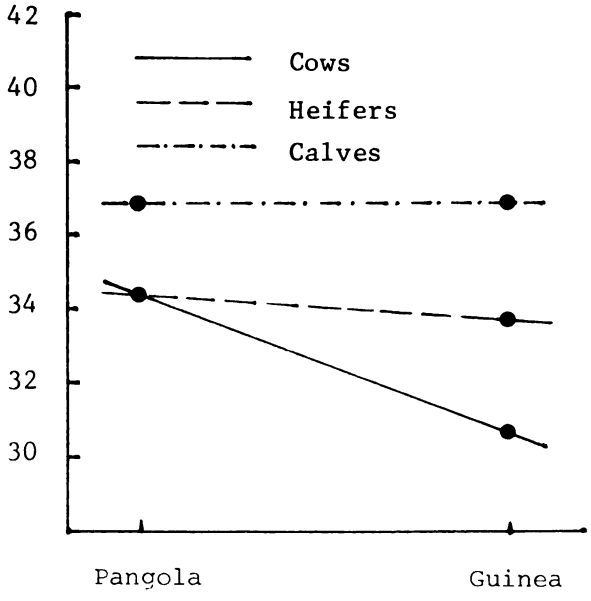
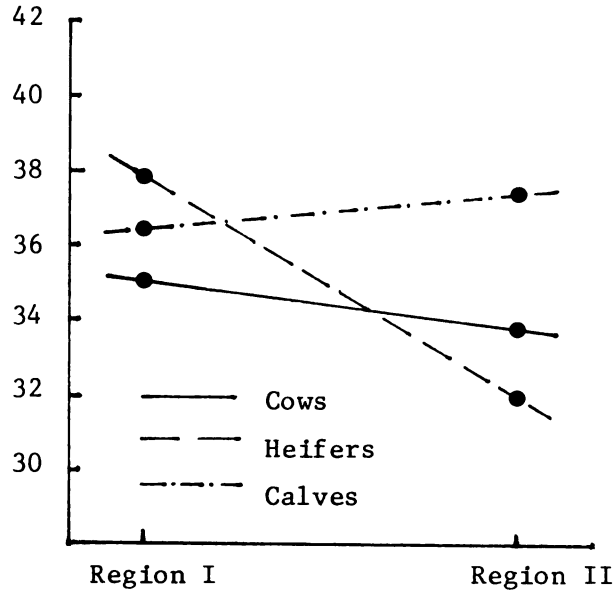


Figure 25. Blood hematocrit (%): Livestock-type by grass interaction (P<.00001).



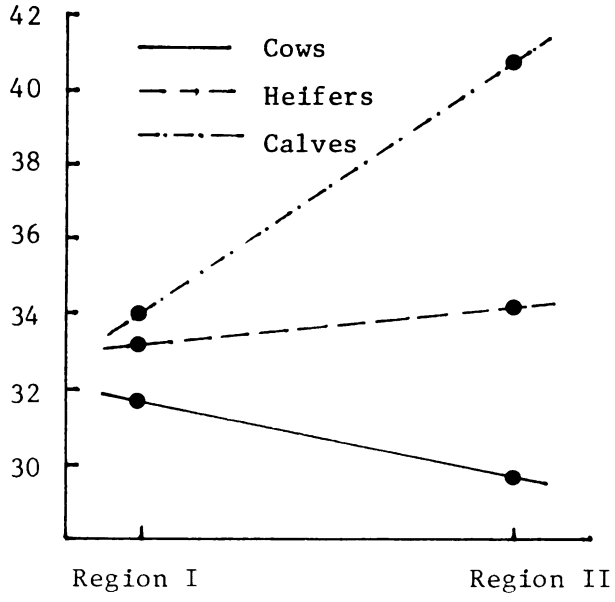


Figure 26. Blood hematocrit (%): Livestock-type by region by grass interaction (P<.001). Pangola (top) and guinea (bottom).

obtained for the correlation between blood hematocrit with grass copper ($r = -.21, -.18$ and $.27$) and with grass iron ($r = .05, .20$ and $-.10$).

No significant regression equations were obtained for variables involving blood hematocrit.

SUMMARY AND CONCLUSIONS

Although soil calcium was high in both regions, deficient levels of calcium were found in Pangolagrass samples from the Veracruz region (Region I). Fourteen out of eighteen samples from that region (or 78%) had less than 0.25% calcium, which is inadequate for grazing beef cattle. Only one Pangolagrass sample was adequate (0.30% calcium) for lactating and young animals. These deficient levels were related to soil calcium concentrations, since all soil samples taken in Veracruz from soils growing Pangolagrass had less than 1500 ppm extractable calcium. On the other hand, all Guineagrass samples were above the 0.30% level, and the soils in which they were growing had more than 1500 ppm, with the exception of one sample.

Despite the findings for soils and grasses, low serum calcium concentrations were found for cattle grazing in the two regions or on the two grasses. If calcium levels of 9.0 to 12.0 mg/dl serum are taken as the normal range, an average of 25% of the animals grazing Pangola- and 29% of cattle on Guineagrass from the Veracruz area had levels lower than 9.0 mg/dl (8% and 11% of the values were lower than 8.0 mg/dl). In the Tuxpam area (Region II) 32% of cattle grazing Pangola- and 11% of the animals on Guineagrass were also lower than 9.0 mg/dl (13% and 3% of the values were lower than 8.0 mg/dl).

High to very high levels of soil extractable magnesium were found in both regions, values being higher in Veracruz than in Tuxpam. Despite this, grass magnesium was considered deficient for lactating beef

cattle in all Pangolagrass samples from Region I, and in 67% of Pangolagrass (12 out of 18) and 22% (4 out of 18) of the Guineagrass samples from Region II. The level taken here as minimum adequate is 0.18% magnesium. The deficiency would be even greater if lactating dairy cattle were considered. On the other hand, the two grasses would meet the requirements of young animals. The results for forages were not reflected on serum magnesium concentrations, since only six animals from each region had levels equal to or less than 1.7 mg/dl, value considered as borderline to deficient.

Phosphorus levels lower than 0.30% were found in most Pangola- samples and in 22% (4 out of 18) of Guineagrass samples from the Veracruz region. In Tuxpam, 78% of the Pangola- samples and 44% of the Guineagrass samples were also below that level. Almost all soils growing Pangola in the two regions and soils growing Guinea in Region II had less than 5 ppm phosphorus. Only 33% of soils growing Guinea in Region I were below this level. For cattle, about 26% of the animals grazing on Pangola and only one cow grazing on Guinea from Region I had low serum phosphorus concentrations. In Tuxpam these figures were 30 and 12% for the two grasses.

Copper levels lower than 6 ppm were found in 44% (8 out of 18) of the Pangola- samples and in 72% of Guineagrass samples from the Veracruz area. About 39% of the Pangola- and 61% of the Guineagrass samples from Tuxpam were also low in copper. However, only 5% of the animals from Region I and 16% of the cattle from Region II were considered deficient in their serum copper values (less than 0.5 ug/ml). It is assumed that the molybdenum and sulphate levels were low and did not interfere with copper utilization.

All soil samples from Tuxpam and 39% of the soils growing Guineagrass in Veracruz had extractable iron contents lower than 20 ppm, which is considered deficient for crops. However, iron concentrations in plants from the two regions were within the normal range and even high for Pangolagrass in Region I. Normal levels were also found in serum of cattle grazing in the two regions or on the two grasses. It seems that iron availability from soil to plant was adequate despite the high pH and high calcium concentrations.

Around 60% of the grass samples from the Veracruz area and 17% from Tuxpam were considered deficient in their selenium content (less than 0.1 ppm). Almost all animals from Region I, all heifers and calves and 35% of the cows from Region II had serum selenium concentrations lower than 0.05 ug/ml. Twenty-two percent of the cows, 40% of the heifers and 75% of the calves from Region I had values lower than 0.01 ug/ml. In Tuxpam, 3% of the cows, 25% of the heifers and 7% of the calves were below the 0.01 level. Selenium deficiency may exist in grazing cattle in both regions or grasses, but especially in the Veracruz area and for young animals.

Soils growing Guineagrass in Region II showed low zinc levels (less than 0.55 ppm), but grasses from that region had adequate zinc. Six Guineagrass samples from Veracruz were lower than 20 ppm. No deficiency was found for zinc in serum of cattle from the two regions.

Soil pH values found were high for tropical or subtropical conditions. Only 6 soil samples from Region I had pH lower than 6.0, while just 3 samples from Tuxpam were lower than 7.0. The diluting effect of heavy rains may be the reason for these results.

Low protein values (less than 7% of dry matter) were found for about two-thirds of the grass samples from Region II. This represents a serious deficiency for livestock raising, since protein levels will be even lower during the dry season.

Low blood hemoglobin values (less than 9.5 g/dl) were observed in about 38% of cattle from Region I, and in 26% of the animals from Region II.

In summary, deficiencies of calcium, phosphorus and selenium were detected in the two regions studied, but especially for Pangolagrass in the Veracruz area. Protein was also deficient for the two grasses in Region II. Low blood hemoglobin levels were observed in about one-third of the animals, and these levels did not correlate with iron or copper concentrations in soils or grasses.

A broader study in the two areas is needed to confirm our findings. The sampling density for soils and grasses may be reduced to one sample per hectare, five subsamples per composite sample.

Recommendations should be given to local farmers for year-round supplementation of a mineral mixture with at least calcium and phosphorus sources included. The selenium problem may need direct application of vitamin E to animals, especially to those younger than two years. It is also imperative to find alternative sources of protein, since protein appears to be the principal limiting factor for livestock raising in those areas. A more efficient management of pastures should be achieved, and adequate fertilization of fields will definitely help to solve the problem.

APPENDIX

TABLE 15. MEAN CALCIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Farm 1	919	0.239	9.52	10.00	9.59
	(65)	(.006)	(.29)	(.34)	(.37)
Farm 2	2226	0.420	9.41	10.02	9.46
	(78)	(.012)	(.50)	(.15)	(.57)
Farm 3	1044	0.220	9.24	8.83	9.98
	(34)	(.028)	(.42)	(.40)	(.46)
Farm 4	2391	0.417	9.01	8.48	10.21
	(266)	(.009)	(.26)	(.27)	(.37)
Farm 5	1162	0.209	10.42	10.44	9.93
	(88)	(.009)	(.18)	(.21)	(.30)
Farm 6	1883	0.403	9.45	9.20	8.79
	(254)	(.007)	(.17)	(.15)	(.36)
Farm 7	6153	0.845	10.21	9.58	10.80
	(93)	(.012)	(.26)	(.48)	(.18)
Farm 8	6488	0.684	10.17	9.50	10.08
	(470)	(.024)	(.27)	(.38)	(.27)
Farm 9	6549	0.802	9.86	9.80	10.01
	(141)	(.026)	(.21)	(.18)	(.26)
Farm 10	6664	0.697	11.04	9.74	10.35
	(125)	(.009)	(.51)	(.30)	(.15)
Farm 11	5664	0.564	10.57	10.08	10.04
	(539)	(.027)	(.53)	(.50)	(.36)
Farm 12	7583	0.574	9.80	8.78	8.38
	(365)	(.027)	(.82)	(.43)	(.64)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 16. MEAN POTASSIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Farm 1	71.7	1.681	18.20	21.44	19.16
	(7.0)	(.157)	(.38)	(1.25)	(1.47)
Farm 2	234.7	2.451	18.69	22.51	21.05
	(17.5)	(.088)	(.45)	(1.22)	(.52)
Farm 3	136.5	1.849	17.56	27.48	21.34
	(26.2)	(.181)	(.48)	(1.20)	(.78)
Farm 4	299.1	2.133	21.89	23.21	26.08
	(20.3)	(.040)	(1.11)	(.74)	(.89)
Farm 5	62.5	1.491	24.43	24.32	24.23
	(4.7)	(.051)	(1.21)	(.89)	(1.40)
Farm 6	212.6	1.872	25.28	26.68	32.62
	(23.5)	(.036)	(.70)	(.58)	(1.63)
Farm 7	106.9	1.966	19.71	17.95	23.50
	(8.0)	(.067)	(.87)	(.73)	(.63)
Farm 8	96.0	1.350	20.13	21.96	22.82
	(7.3)	(.148)	(.75)	(.53)	(.51)
Farm 9	198.3	1.978	24.54	21.24	24.96
	(15.2)	(.039)	(.62)	(.56)	(1.18)
Farm 10	252.1	2.522	21.95	21.04	26.33
	(16.3)	(.044)	(1.71)	(1.17)	(.85)
Farm 11	75.2	1.055	24.60	19.40	26.31
	(10.0)	(.038)	(1.15)	(.51)	(1.11)
Farm 12	112.9	1.541	20.76	20.06	22.81
	(5.5)	(.063)	(1.21)	(.55)	(1.47)

[a] Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b] Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c] Numbers in parenthesis are standard errors.

TABLE 17. MEAN MAGNESIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Farm 1	242.2	0.136	2.87	2.44	2.21
	(12.0)	(.005)	(.07)	(.13)	(.11)
Farm 2	459.2	0.222	2.79	2.68	2.44
	(14.0)	(.009)	(.08)	(.06)	(.07)
Farm 3	266.2	0.118	2.59	2.80	2.73
	(9.2)	(.016)	(.07)	(.08)	(.15)
Farm 4	464.3	0.190	2.91	2.10	2.85
	(84.0)	(.004)	(.14)	(.10)	(.10)
Farm 5	278.2	0.107	2.87	3.00	2.33
	(28.0)	(.001)	(.08)	(.10)	(.10)
Farm 6	385.0	0.235	2.86	2.16	2.16
	(45.8)	(.013)	(.08)	(.12)	(.10)
Farm 7	115.7	0.181	3.34	2.60	2.31
	(3.6)	(.008)	(.07)	(.06)	(.05)
Farm 8	233.5	0.191	3.06	2.48	2.16
	(21.9)	(.011)	(.10)	(.11)	(.10)
Farm 9	155.8	0.304	3.17	2.74	2.49
	(7.2)	(.006)	(.11)	(.06)	(.08)
Farm 10	164.7	0.182	3.06	2.61	2.75
	(4.8)	(.003)	(.12)	(.17)	(.09)
Farm 11	333.3	0.158	3.00	2.78	2.73
	(10.5)	(.012)	(.10)	(.08)	(.12)
Farm 12	182.0	0.124	2.30	2.31	2.20
	(21.6)	(.002)	(.22)	(.09)	(.10)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 18. MEAN PHOSPHORUS CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	% of DM	mg/100 ml serum		
Farm 1	2.60	0.251	3.64	6.49	6.49
	(1.06)	(.027)	(.30)	(.31)	(.37)
Farm 2	4.42	0.303	4.78	5.44	8.08
	(.77)	(.017)	(.13)	(.26)	(.44)
Farm 3	2.00	0.244	4.92	6.11	7.09
	(.18)	(.017)	(.35)	(.23)	(.38)
Farm 4	8.80	0.408	4.89	6.65	8.03
	(2.15)	(.016)	(.25)	(.42)	(.39)
Farm 5	2.52	0.221	3.49	4.88	7.58
	(1.02)	(.022)	(.19)	(.17)	(.34)
Farm 6	16.82	0.526	4.60	6.82	8.29
	(3.32)	(.023)	(.17)	(.29)	(.26)
Farm 7	0.40	0.208	3.73	5.87	8.76
	(.08)	(.023)	(.15)	(.30)	(.28)
Farm 8	3.00	0.196	1.77	4.10	7.99
	(.51)	(.022)	(.13)	(.19)	(.52)
Farm 9	3.97	0.571	5.56	6.08	8.27
	(1.13)	(.058)	(.34)	(.26)	(.36)
Farm 10	0.58	0.297	5.02	6.25	8.98
	(.49)	(.013)	(.53)	(.39)	(.23)
Farm 11	2.87	0.158	3.73	4.02	7.19
	(.23)	(.008)	(.44)	(.22)	(.42)
Farm 12	1.58	0.299	4.96	6.56	6.93
	(.42)	(.012)	(.32)	(.44)	(.47)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 19. MEAN COPPER CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	DM ppm	ug/ml serum		
Farm 1	2.32	6.35	0.640	0.620	0.590
	(.26)	(.21)	(.043)	(.051)	(.023)
Farm 2	3.25	4.90	0.740	0.780	0.710
	(.57)	(.21)	(.031)	(.025)	(.043)
Farm 3	1.68	6.95	0.790	0.590	0.760
	(.21)	(.96)	(.031)	(.060)	(.050)
Farm 4	2.93	6.80	0.700	0.620	0.810
	(.19)	(.55)	(.030)	(.033)	(.046)
Farm 5	1.30	5.52	0.620	0.780	0.580
	(.17)	(.15)	(.025)	(.020)	(.044)
Farm 6	2.08	4.82	0.610	0.730	0.620
	(.39)	(.18)	(.038)	(.037)	(.065)
Farm 7	3.10	18.13	0.520	0.550	0.550
	(.07)	(1.42)	(.033)	(.052)	(.027)
Farm 8	1.52	10.93	0.560	0.590	0.530
	(.35)	(1.38)	(.031)	(.023)	(.030)
Farm 9	4.58	4.03	0.630	0.690	0.570
	(.84)	(.15)	(.030)	(.028)	(.030)
Farm 10	2.75	5.85	0.590	0.480	0.690
	(.30)	(.12)	(.053)	(.020)	(.043)
Farm 11	0.65	5.03	0.650	0.540	0.650
	(.20)	(.19)	(.031)	(.031)	(.034)
Farm 12	3.03	6.13	0.610	0.460	0.490
	(.37)	(.15)	(.050)	(.056)	(.038)

[a] Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b] Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c] Numbers in parenthesis are standard errors.

TABLE 20. MEAN IRON CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	DM ppm		ug/ml serum	
Farm 1	41.4	507.2	1.55	1.96	3.05
	(1.3)	(37.2)	(.14)	(.09)	(.30)
Farm 2	19.1	129.0	1.68	2.20	1.86
	(1.4)	(21.7)	(.11)	(.06)	(.11)
Farm 3	31.5	170.7	1.71	2.10	2.03
	(.5)	(15.8)	(.07)	(.11)	(.12)
Farm 4	19.7	92.7	1.94	1.97	2.45
	(3.1)	(6.1)	(.11)	(.14)	(.15)
Farm 5	58.7	399.8	1.86	2.43	1.69
	(5.5)	(61.9)	(.10)	(.09)	(.12)
Farm 6	40.0	97.0	1.65	2.32	2.10
	(3.9)	(7.0)	(.06)	(.11)	(.13)
Farm 7	1.62	106.3	1.95	1.69	2.05
	(.11)	(13.3)	(.09)	(.11)	(.16)
Farm 8	4.15	168.0	1.76	1.90	2.38
	(1.14)	(14.9)	(.12)	(.09)	(.14)
Farm 9	1.23	108.0	1.70	2.04	1.85
	(.22)	(8.2)	(.07)	(.10)	(.14)
Farm 10	0.72	101.3	1.84	2.06	2.00
	(.06)	(3.4)	(.15)	(.11)	(.10)
Farm 11	12.3	197.5	1.89	2.27	2.16
	(1.5)	(11.9)	(.10)	(.10)	(.17)
Farm 12	1.38	185.8	1.67	1.86	2.16
	(.14)	(10.6)	(.13)	(.12)	(.24)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 21. MEAN SELENIUM CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	DM ppm		ug/ml serum	
Farm 1	0.106 (.009)	0.102 (.003)	0.033 (.005)	0.011 (.002)	0.007 (.002)
Farm 2	0.149 (.015)	0.086 (.015)	0.026 (.003)	0.017 (.001)	0.005 (.001)
Farm 3	0.121 (.005)	0.094 (.012)	0.018 (.003)	0.021 (.002)	0.003 (.001)
Farm 4	0.143 (.009)	0.087 (.006)	0.009 (.002)	0.012 (.003)	0.001 (.000)
Farm 5	0.103 (.013)	0.092 (.006)	0.013 (.002)	0.008 (.002)	0.005 (.001)
Farm 6	0.125 (.006)	0.103 (.012)	0.043 (.005)	0.010 (.002)	0.022 (.003)
Farm 7	0.318 (.006)	0.151 (.021)	0.074 (.007)	0.031 (.005)	0.021 (.001)
Farm 8	0.343 (.036)	0.126 (.027)	0.073 (.004)	0.018 (.002)	0.026 (.002)
Farm 9	0.324 (.041)	0.125 (.019)	0.061 (.004)	0.007 (.002)	0.024 (.001)
Farm 10	0.258 (.032)	0.144 (.018)	0.078 (.009)	0.027 (.006)	0.030 (.002)
Farm 11	0.292 (.019)	0.145 (.017)	0.039 (.003)	0.024 (.003)	0.023 (.003)
Farm 12	0.356 (.028)	0.191 (.013)	0.035 (.007)	0.012 (.002)	0.019 (.002)

[a] Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b] Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c] Numbers in parenthesis are standard errors.

TABLE 22. MEAN ZINC CONCENTRATIONS OF SOILS, GRASSES, AND BLOOD SERA OF GRAZING CATTLE FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

			Livestock Type		
	Soils	Grasses	Cows	Heifers	Calves
	ppm	DM ppm		ug/ml serum	
Farm 1	1.42	40.78	0.78	0.73	0.88
	(.15)	(3.04)	(.03)	(.05)	(.02)
Farm 2	3.22	19.60	1.02	0.80	0.87
	(.57)	(1.48)	(.04)	(.04)	(.05)
Farm 3	3.17	41.50	0.89	0.85	1.02
	(.31)	(3.87)	(.09)	(.09)	(.09)
Farm 4	1.58	21.50	1.13	1.15	1.33
	(.14)	(1.35)	(.07)	(.06)	(.07)
Farm 5	1.48	34.80	0.98	0.91	0.91
	(.14)	(1.24)	(.07)	(.05)	(.04)
Farm 6	3.57	21.75	0.94	1.07	0.96
	(.38)	(1.39)	(.05)	(.11)	(.04)
Farm 7	0.35	24.67	1.06	1.19	1.14
	(.02)	(2.03)	(.04)	(.06)	(.06)
Farm 8	1.52	40.20	1.01	1.09	1.21
	(.16)	(2.38)	(.05)	(.04)	(.04)
Farm 9	0.28	33.70	1.12	1.24	1.13
	(.03)	(2.13)	(.06)	(.07)	(.05)
Farm 10	0.48	24.35	1.07	1.01	1.15
	(.05)	(1.14)	(.10)	(.05)	(.08)
Farm 11	1.40	40.08	0.92	0.95	0.99
	(.17)	(1.26)	(.05)	(.05)	(.05)
Farm 12	0.50	43.17	0.93	0.82	0.97
	(.08)	(1.86)	(.08)	(.04)	(.05)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 23. MEAN SOIL COBALT CONCENTRATIONS, SOIL pH, AND GRASSES DRY MATTER, CRUDE PROTEIN AND CRUDE FIBER FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

	SOCO	SOIL	GRADM	GRACP	GRACF
	ppm	pH	%	DM%	DM%
Farm 1	0.52	5.97	27.4	8.63	33.2
	(.03)	(.09)	(.9)	(.32)	(.6)
Farm 2	0.57	6.35	30.3	9.02	38.3
	(.10)	(.04)	(1.1)	(.44)	(.5)
Farm 3	0.50	5.97	26.4	8.17	39.4
	(.12)	(.03)	(2.0)	(.43)	(1.2)
Farm 4	0.68	6.85	28.7	9.65	36.5
	(.11)	(.02)	(.4)	(.24)	(.8)
Farm 5	0.48	6.25	26.0	8.03	36.0
	(.11)	(.06)	(1.5)	(.33)	(1.4)
Farm 6	0.42	6.47	29.4	7.93	37.7
	(.09)	(.13)	(.3)	(.27)	(.5)
Farm 7	0.83	8.03	33.0	6.62	40.1
	(.12)	(.02)	(.6)	(.20)	(1.0)
Farm 8	0.92	7.63	31.4	6.02	37.9
	(.10)	(.19)	(.9)	(.17)	(.8)
Farm 9	0.93	8.08	28.8	5.52	37.9
	(.08)	(.04)	(1.0)	(.10)	(.9)
Farm 10	0.88	8.00	25.8	10.01	39.1
	(.11)	(.03)	(.6)	(.22)	(.6)
Farm 11	0.73	6.90	32.5	5.62	37.3
	(.16)	(.24)	(1.7)	(.20)	(.3)
Farm 12	0.77	8.08	28.2	7.65	34.0
	(.10)	(.06)	(.7)	(.28)	(.9)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 24. MEAN HEMOGLOBIN AND HEMATOCRIT VALUES OF GRAZING COWS, HEIFERS AND CALVES FOR INDIVIDUAL FARMS FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a, b, c]

	COHB	HEHB	CAHB	COHT	HEHT	CAHT
	----------g/dl----------			----------%----------		
Farm 1	10.39	11.42	11.39	33.5	34.7	36.9
	(.31)	(.30)	(.36)	(1.7)	(1.7)	(1.2)
Farm 2	11.93	11.76	10.39	35.5	40.1	35.6
	(.51)	(.36)	(.51)	(1.2)	(1.3)	(.8)
Farm 3	10.59	12.57	10.83	40.1		40.8
	(.19)	(.33)	(.18)	(1.3)		(.9)
Farm 4	8.46	7.86	9.67	29.8	27.4	35.1
	(.22)	(.15)	(.34)	(1.3)	(.9)	(1.6)
Farm 5	8.08	10.11	7.56	31.4	40.9	31.5
	(.29)	(.24)	(.28)	(1.2)	(.7)	(1.1)
Farm 6	7.37	9.77	7.35	29.9	32.1	31.4
	(.28)	(.34)	(.27)	(1.2)	(1.0)	(1.8)
Farm 7	9.93	10.37	11.91	29.2	33.0	40.1
	(.39)	(.57)	(.47)	(1.2)	(1.8)	(1.7)
Farm 8	11.52	10.90	10.93	32.6	33.0	36.0
	(.40)	(.34)	(.48)	(1.5)	(1.0)	(1.4)
Farm 9	8.62	10.05	10.83	27.7	35.1	36.6
	(.30)	(.37)	(.38)	(1.2)	(1.6)	(1.3)
Farm 10	9.71	10.83	11.92	32.1	34.4	42.4
	(.44)	(.35)	(.38)	(1.4)	(1.8)	(1.6)
Farm 11	11.43	10.82	11.41	38.2	34.4	41.1
	(.30)	(.37)	(.48)	(1.5)	(1.3)	(1.9)
Farm 12	9.92	7.74	8.21	30.5	28.6	35.2
	(.40)	(.22)	(.28)	(1.2)	(1.2)	(1.7)

[a]Central: Farms 1 to 6; Northern: Farms 7 to 12.
[b]Pangola-grass in Farms 1, 3, 5, 8, 11, and 12; Guinea-grass in Farms 2, 4, 6, 7, 9, and 10.
[c]Numbers in parenthesis are standard errors.

TABLE 25. CORRELATION COEFFICIENTS BETWEEN DIFFERENT SOIL MINERALS AND BETWEEN SOIL MINERALS AND SOIL pH DETERMINED FOR SOILS GROWING TWO TYPES OF GRASSES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	SOCA SOK	SOCA SOMG	SOCA SOP	SOCA SOCU	SOCA SOFE	SOCA SOSE	SOCA SOZN	SOCA SOCO
Overall	-.01 (-.24,.23)	-.45 (-.62,-.23)	-.32 (-.52,-.10)	.25 (0,.46)	-.86 (-.91,-.78)	.87 (.82,.92)	-.61 (-.74,-.44)	.56 (.38,.69)
Reg I (Central)	.73 (.58,.82)	.93 (.87,.95)	.32 (.07,.52)	.56 (.38,.69)	-.64 (-.76,-.47)	.64 (.46,.75)	.23 (-.03,.43)	.33 (.08,.53)
Reg II (North)	.29 (.05,.48)	-.22 (-.42,.04)	-.02 (-.26,.23)	.34 (.11,.53)	-.61 (-.74,-.44)	.27 (.04,.47)	-.03 (-.27,.21)	.13 (-.13,.34)
Gra I (Pangola)	.19 (-.05,.40)	-.20 (-.42,.04)	.03 (-.21,.27)	.20 (-.04,.41)	-.86 (-.91,-.78	.92 (.86,.95)	-.48 (-.64,-.28)	.55 (.35,.70)
Gra II (Guinea)	-.37 (-.56,-.15)	-.73 (-.82,-.58)	-.65 (-.77,-.50)	.29 (.05,.48)	-.87 (-.92,-.82)	.80 (.68,.86)	-.80 (-.87,-.71)	.58 (.41,.72)
Reg I Gra I	.10 (-.15,.33)	.86 (.78,.91)	.21 (-.04,.42)	-.06 (-.29,.17)	.05 (-.18,.28)	.32 (.07,.52)	.13 (-.13,.34)	.26 (.03,.46)
Reg I Gra II	.20 (-.04,.41)	.91 (.86,.95)	-.38 (-.57,-.16)	.40 (.17,.57)	-.60 (-.74,-.44)	.52 (.31,.66)	-.13 (-.34,.13)	.48 (.28,.64)
Reg II Gra I	.92 (.86,.95)	-.46 (-.63,-.25)	-.06 (-.29,.17)	.78 (.68,.86)	-.78 (-.86,-.68)	.48 (.28,.64)	-.10 (-.33,.13)	.24 (0,.44)
Reg II Gra II	.66 (.50,.77)	.78 (.68,.86)	-.05 (-.28,.18)	-.22 (-.42,.04)	-.52 (-.66,-.32)	-.33 (-.53,-.11)	-.07 (-.29,.15)	-.23 (-.43,.03)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 25. (cont'd.)

	SOCA SOPH	SOK SOMG	SOK SOP	SOK SOCU	SOK SOFE	SOK SOSE	SOK SOZN	SOK SOCO
Overall	.92 (.86,.95)	.31 (.06,.51)	.40 (.17,.57)	.40 (.17,.57)	-.20 (-.42,.04)	-.11 (-.34,.12)	.20 (-.04,.41)	.12 (-.14,.33)
Reg I (Central)	.66 (.50,.77)	.55 (.35,.70)	.46 (.25,.63)	.45 (.23,.62)	-.64 (-.76,-.47)	.47 (.26,.63)	.30 (.05,.49)	.34 (.11,.53)
Reg II (North)	.67 (.52,.77)	-.42 (-.57,-.17)	.02 (-.23,.23)	.48 (.28,.64)	-.58 (-.72,-.41)	-.12 (-.34,.13)	-.45 (-.62,-.23)	.16 (-.08,.38)
Gra I (Pangola)	.94 (.89,.96)	-.21 (-.42,.04)	-.03 (-.27,.21)	.34 (.11,.53)	-.30 (-.51,-.07)	.14 (-.11,.36)	.52 (.31,.66)	.31 (.06,.51)
Gra II (Guinea)	.95 (.92,.97)	.43 (.18,.58)	.30 (.05,.49)	-.09 (-.14,.33)	.27 (.04,.47)	-.39 (-.57,-.16)	.22 (-.04,.43)	-.09 (-.33,.14)
Reg I Gra I	.20 (-.04,.41)	.03 (-.21,.27)	0 (-.25,.24)	.19 (-.05,.40)	-.47 (-.63,-.26)	.28 (.05,.48)	.84 (.76,.90)	.46 (.25,.63)
Reg I Gra II	.21 (-.04,.42)	-.01 (-.24,.23)	-.05 (-.28,.18)	.04 (-.19,.27)	-.28 (-.47,-.05)	-.04 (-.27,.19)	-.44 (-.61,-.20)	.42 (.17,.57)
Reg II Gra I	.83 (.74,.88)	-.57 (-.71,-.41)	-.15 (-.37,.09)	.70 (.56,.79)	-.84 (-.90,-.76)	.32 (.07,.52)	-.12 (-.34,.13)	.23 (-.03,.43)
Reg II Gra II	-.05 (-.28,.18)	.84 (.76,.90)	.30 (.05,.49)	.03 (-.21,.27)	-.68 (-.78,-.55)	-.06 (-.29,.17)	.32 (.07,.52)	.03 (-.21,.27)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 25. (cont'd.)

	SOK SOPH	SOMG SOP	SOMG SOCU	SOMG SOFE	SOMG SOSE	SOMG SOZN	SOMG SOCO	SOMG SOPH
Overall	.12 (-.14,.33)	.36 (.14,.55)	-.10 (-.33,.13)	.28 (-.47,-.05)	-.42 (-.57,-.17)	.56 (.38,.69)	-.20 (-.42,.04)	-.53 (-.66,-.32)
Reg I (Central)	.66 (.50,.77)	.16 (-.08,.38)	.46 (.25,.63)	-.63 (-.75,-.46)	.62 (.44,.74)	.17 (-.06,.39)	.35 (.13,.54)	.52 (.31,.66)
Reg II (North)	.50 (.30,.65)	.34 (.11,.53)	-.57 (-.71,-.41)	.82 (.73,.87)	.01 (-.24,.23)	.73 (.58,.82)	-.11 (-.34,.12)	-.79 (-.86,-.68)
Gra I (Pangola)	.18 (-.05,.42)	.26 (.03,.46)	-.40 (-.57,-.17)	.16 (-.08,.38)	-.16 (-.38,.08)	.26 (.03,.46)	-.01 (-.24,.23)	-.40 (-.57,-.17)
Gra II (Guinea)	-.36 (-.54,-.14)	.35 (.13,.54)	-.16 (-.38,.08)	.53 (.32,.66)	-.64 (-.76,-.47)	.65 (.49,.76)	-.33 (-.53,-.11)	-.80 (-.87,-.71)
Reg I Gra I	-.41 (-.57,-.17)	.17 (-.06,.39)	-.02 (-.26,.23)	-.21 (-.42,.04)	.29 (.05,.48)	.03 (-.21,.27)	.24 (0,.44)	.20 (-.04,.41)
Reg I Gra II	.50 (.30,.65)	-.42 (-.57,-.17)	.26 (.03,.46)	-.56 (-.69,-.38)	.53 (.32,.66)	-.10 (-.33,.13)	.43 (.18,.58)	.05 (-.18,.28)
Reg II Gra I	.84 (.76,.90)	.45 (.23,.62)	-.52 (-.66,-.32)	.80 (.68,86)	-.25 (-.46,-.03)	.52 (.31,.66)	-.02 (-.26,.23)	-.75 (-.84,-.64)
Reg II Gra II	-.11 (-.34,.12)	.25 (0,.46)	0 (-.25,.24)	-.69 (-.79,-.55)	-.11 (-.34,.12)	.05 (-.18,.28)	.04 (-.19,.27)	-.16 (-.38,.08)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 25. (cont'd.)

	SOP SOCU	SOP SOFE	SOP SOSE	SOP SOZN	SOP SOCO	SOP SOPH	SOCU SOFE
Overall	.07 (-.15,.28)	.31 (.05,.51)	-.28 (-.47,-.05)	.55 (.35,.70)	-.19 (-.42,.04)	-.26 (-.46,-.03)	-.33 (-.53,-.11)
Reg I (Central)	.17 (-.06,.39)	-.04 (-.27,.19)	.10 (-.15,.33)	.44 (.20,.61)	0 (-.25,.24)	.36 (.14,.55)	-.49 (-.65,-.28)
Reg II (North)	.21 (-.04,.42)	.20 (-.04,.41)	.40 (.17,.57)	.27 (.04,.47)	.15 (-.11,.37)	-.17 (-.39,.06)	-.62 (-.74,-.44)
Gra I (Pangola)	-.12 (-.34,.13)	-.01 (-.24,.23)	-.01 (-.24,.23)	-.02 (-.26,.23)	.03 (-.21,.27)	-.03 (-.27,.21)	-.16 (-.38,.08)
Gra II (Guinea)	-.13 (-.34,.13)	.79 (.68,.86)	-.48 (-.64,-.28)	.69 (.55,.79)	-.35 (-.54,-.13)	-.61 (-.74,-.44)	-.32 (-.52,-.10)
Reg I Gra I	-.08 (-.32,.15)	0 (-.25,.24)	-.35 (-.54,-.13)	-.18 (-.42,.05)	-.31 (-.51,-.06)	0 (-.25,.24)	-.32 (-.52,-.10)
Reg I Gra II	-.18 (-.42,.05)	.68 (.55,.78)	-.30 (-.51,-.07)	.46 (.25,.63)	-.05 (-.28,.18)	-.11 (-.34,.12)	-.28 (-.47,-.05)
Reg II Gra I	-.18 (-.42,.05)	.24 (0,.44)	0 (-.25,.24)	.50 (.30,.65)	.42 (.17,.57)	-.23 (-.43,.03)	-.72 (-.82,-.58)
Reg II Gra II	.68 (.55,.78)	-.08 (-.32,.15)	.56 (.38,.69)	-.24 (-.44,0)	.08 (-.15,.32)	.27 (.04,.47)	.02 (-.23,.23)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 25. (cont'd.)

	SOCU SOSE	SOCU SOZN	SOCU SOCO	SOCU SOPH	SOFE SOSE	SOFE SOZN	SOFE SOCO
Overall	.31 (.06,.51)	-.10 (-.33,.13)	.20 (-.04,.41)	.36 (.14,.55)	-.76 (-.84,-.63)	.50 (.30,.65)	-.55 (-.68,-.35)
Reg I (Central)	.71 (.57,.82)	.38 (.16,.57)	.25 (0,.46)	.22 (-.04,.43)	-.50 (-.66,-.32)	-.20 (-.42,.04)	-.29 (-.50,-.06)
Reg II (North)	.34 (.11,.53)	-.57 (-.71,-.41)	.11 (-.14,.33)	.61 (.43,.73)	-.14 (-.36,.11)	.58 (.41,.72)	-.24 (-.44,0)
Gra I (Pangola)	.22 (-.04,.43)	-.12 (-.34,.13)	.19 (-.05,.40)	.28 (.05,.48)	-.84 (-.90,-.76)	.31 (.06,.51)	-.50 (-.66,-.32)
Gra II (Guinea)	.52 (.31,.66)	-.12 (-.34,.13)	.15 (-.11,.37)	.25 (0,.46)	-.72 (-.82,-.58)	.79 (.68,.86)	-.62 (-.74,-.44)
Reg I Gra I	.41 (.17,.57)	.12 (-.14,.33)	.46 (.25,.63)	-.54 (-.67,-.34)	-.23 (-.43,.03)	-.48 (-.64,-.28)	-.06 (-.29,.17)
Reg I Gra II	.72 (.58,.82)	.33 (.08,.53)	.11 (-.14,.33)	-.08 (-.32,.15)	-.35 (-.54,-.13)	.38 (.16,.57)	-.47 (-.63,-.26)
Reg II Gra I	.59 (.43,.73)	-.45 (-.62,-.23)	.15 (-.11,.37)	.74 (.61,.83)	-.46 (-.63,-.25)	.35 (.13,.54)	-.26 (-.46,-.03)
Reg II Gra II	.52 (.31,.66)	-.14 (-.36,.11)	-.09 (-.33,.14)	-.08 (-.32,.15)	.09 (-.14,.33)	-.44 (-.61,-.20)	.06 (-.17,.29)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 25. (cont'd.)

	SOFE SOPH	SOSE SOZN	SOSE SOCO	SOSE SOPH	SOZN SOCO	SOZN SOPH	SOCO SOPH
Overall	-.82 (-.88,-.72)	-.51 (-.66,-.32)	.44 (.20,.61)	.79 (.68,.86)	-.36 (-.54,-.14)	-.67 (-.77,-.53)	.56 (.38,.69)
Reg I (Central)	-.38 (-.57,-.16)	.48 (.28,.64)	.25 (0,.46)	.28 (.05,.48)	-.01 (-.24,.23)	-.14 (-.36,.11)	.13 (-.13,.34)
Reg II (North)	-.94 (-.96,-.89)	.07 (-.15,.29)	-.16 (-.38,.08)	.19 (-.05,.40)	.02 (-.23,.23)	-.51 (-.66,-.32)	.29 (.04,.48)
Gra I (Pangola)	-.81 (-.87,-.72)	-.42 (-.57,-.17)	.51 (.30,.65)	.87 (.82,.92)	-.08 (-.32,.15)	-.52 (-.66,-.32)	.53 (.32,.66)
Gra II (Guinea)	-.83 (-.88,-.74)	-.64 (-.76,-.47)	.37 (.15,.56)	.78 (.68,.86)	-.55 (-.68,-.35)	-.88 (-.94,-.83)	.58 (.41,.72)
Reg I Gra I	.34 (.11,.53)	.51 (.30,.65)	.43 (.18,.58)	-.31 (-.51,-.06)	.30 (.05,.49)	-.36 (-.54,-.14)	-.10 (-.33,.13)
Reg I Gra II	-.18 (-.42,.05)	.30 (.05,.49)	.08 (-.15,.32)	-.06 (-.29,.17)	-.28 (-.47,-.05)	-.67 (-.77,-.53)	.15 (-.11,.37)
Reg II Gra I	-.93 (-.95,-.86)	-.11 (-.34,.12)	.03 (-.21,.27)	.52 (.31,.66)	.23 (-.03,.43)	-.27 (-.47,-.04)	.29 (.05,.48)
Reg II Gra II	.20 (-.04,.41)	-.22 (-.42,.04)	-.32 (-.52,-.10)	-.21 (-.42,.04)	.02 (-.23,.23)	-.31 (-.51,-.06)	.41 (.17,.57)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. CORRELATION COEFFICIENTS BETWEEN DIFFERENT MINERALS IN GRASSES AND BETWEEN GRASS MINERALS AND DRY MATTER, CRUDE PROTEIN AND CRUDE FIBER DETERMINED FOR TWO TYPES OF GRASSES SAMPLED IN THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	GRACA GRAK	GRACA GRAMG	GRACA GRAP	GRACA GRACU	GRACA GRAFE	GRACA GRASE	GRACA GRAZN	GRACA GRADM
Overall	.13 (-.13,.34)	.53 (.32,.66)	.11 (-.14,.33)	.42 (.17,.57)	-.55 (-.68,-.35)	.42 (.17,.57)	-.12 (-.34,.13)	.34 (.11,.53)
Reg I (Central)	.69 (.55,.79)	.91 (.86,.95)	.69 (.55,.79)	-.11 (-.34,.12)	-.67 (-.77,-.53)	.01 (-.24,.23)	-.70 (-.81,-.56)	.38 (.16,.57)
Reg II (North)	.53 (.32,.66)	.62 (.44,.74)	.31 (.06,.51)	.47 (.26,.63)	-.70 (-.81,-.56)	-.26 (-.46,-.03)	-.58 (-.72,-.41)	.06 (-.17,.29)
Gra I (Pangola)	-.38 (-.57,-.17)	.68 (.55,.78)	-.16 (-.38,.08)	.39 (.16,.57)	-.56 (-.69,-.38)	.52 (.31,.66)	.23 (-.03,.43)	.47 (.26,.63)
Gra II (Guinea)	-.12 (-.34,.13)	.13 (-.13,.34)	-.20 (-.42,.04)	.49 (.28,.65)	0 (-.25,.24)	.49 (.28,.65)	.58 (.41,.72)	.13 (-.13,.34)
Reg I Gra I	.48 (.28,.64)	.85 (.76,.90)	.18 (-.05,.42)	.67 (.52,.77)	.06 (-.17,.29)	.66 (.50,.77)	.73 (.58,.82)	-.33 (-.53,-.11)
Reg I Gra II	.43 (.18,.58)	.13 (-.13,.34)	-.19 (-.42,.04)	.20 (-.04,.41)	-.11 (-.34,.12)	-.04 (-.27,.19)	.09 (.33,-.14)	.37 (.15,.56)
Reg II Gra I	.24 (0,.44)	.63 (.46,.75)	-.06 (-.29,.17)	.58 (.41,.72)	-.42 (-.57,-.17)	-.31 (-.51,-.06)	-.14 (-.36,.11)	.05 (-.18,.28)
Reg II Gra II	-.78 (-.86,-.68)	.23 (-.03,.43)	-.09 (-.33,.14)	.52 (.31,.66)	.16 (-.08,.38)	-.15 (-.37,.09)	.17 (-.06,.39)	.66 (.50,.77)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRACA GRACP	GRACA GRACF	GRAK GRAMG	GRAK GRAP	GRAK GRACU	GRAK GRAFE	GRAK GRASE	GRAK GRAZN
Overall	-.44 (-.61,-.20)	.31 (.06,.51)	.43 (.18,.58)	.45 (.23,.62)	.04 (-.19,.27)	-.36 (-.54,-.14)	-.08 (-.32,.15)	-.55 (-.68,-.35)
Reg I (Central)	.23 (-.03,.43)	.11 (-.14,.33)	.69 (.55,.79)	.40 (.17,.57)	.21 (-.04,.42)	-.51 (-.66,.32)	.01 (-.24,.23)	-.42 (-.57,-.17)
Reg II (North)	-.06 (-.29,.17)	.54 (.34,.67)	.34 (.11,.53)	.46 (.25,.63)	.10 (-.15,.33)	-.76 (-.84,-.63)	.05 (-.18,.28)	-.66 (-.77,-.50)
Gra I (Pangola)	-.71 (-.82,-.57)	.05 (-.18,.28)	-.03 (-.27,.21)	.76 (.63,.84)	.36 (.14,.55)	.13 (-.13,.34)	-.08 (-.37,.15)	.18 (-.05,.42)
Gra II (Guinea)	-.55 (-.68,-.35)	.41 (.17,.57)	-.24 (-.44,0)	-.30 (-.51,-.07)	-.26 (-.46,-.03)	.15 (-.11,.37)	.08 (-.15,.32)	-.14 (-.36,.11)
Reg I Gra I	-.46 (-.63,-.25)	-.34 (-.53,-.11)	.76 (.63,.84)	.78 (.68,.86)	.79 (.68,.86)	-.23 (-.43,.03)	.48 (.28,.64)	.37 (.15,.56)
Reg I Gra II	.20 (-.04,.41)	-.20 (-.42,.04)	.03 (-.21,.27)	-.69 (-.79,-.55)	.08 (-.15,.32)	.33 (.08,.53)	-.24 (-.44,0)	-.13 (-.34,.13)
Reg II Gra I	-.10 (-.33,.13)	.33 (.08,.53)	-.06 (-.29,.17)	.83 (.74,.88)	.50 (.30,.65)	-.34 (-.53,-.11)	.30 (.05,.49)	.22 (-.04,.43)
Reg II Gra II	-.69 (-.79,-.55)	.21 (-.04,.42)	-.38 (-.57,-.16)	-.10 (-.33,.13)	-.41 (-.57,-.17)	-.12 (-.34,.13)	.30 (.05,.49)	-.22 (-.42,.04)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRAK GRADM	GRAK GRACP	GRAK GRACF	GRAMG GRAP	GRAMG GRACU	GRAMG GRAFE	GRAMG GRASE	GRAMG GRAZN
Overall	-.39 (-.57,-.16)	.58 (.41,.72)	.20 (-.04,.41)	.70 (.56,.79)	-.08 (-.32,.15)	-.49 (-.65,-.28)	.03 (-.21,.27)	-.35 (-.54,-.13)
Reg I (Central)	-.06 (-.29,.17)	.41 (.17,.57)	.24 (0,.44)	.79 (.68,.86)	-.14 (-.36,.11)	-.57 (-.71,-.41)	.10 (-.15,.33)	-.61 (-.74,-.44)
Reg II (North)	-.57 (-.71,-.41)	.64 (.46,.75)	.24 (0,.44)	.72 (.58,.82)	-.18 (-.42,.05)	-.44 (-.61,-.20)	-.18 (-.42,.05)	-.19 (-.42,.04)
Gra I (Pangola)	-.78 (-.86,-.68)	.57 (.41,.71)	-.15 (-.37,.09)	-.14 (-.36,.11)	.62 (.44,.74)	-.25 (-.46,-.03)	.34 (.11,.53)	.26 (.03,.46)
Gra II (Guinea)	-.43 (-.58,-.18)	.66 (.50,.77)	.04 (-.19,.27)	.74 (.61,.83)	-.49 (-.65,-.28)	.23 (-.03,.43)	-.03 (-.27,.21)	.65 (.03,.46)
Reg I Gra I	-.72 (-.82,-.58)	.10 (-.15,.33)	.12 (-.14,.33)	.57 (.41,.71)	.77 (.65,.85)	.18 (-.05,.42)	.64 (.46,.75)	.61 (.43,.73)
Reg I Gra II	.11 (-.14,.33)	.53 (.35,.70)	.17 (-.06,.39)	.42 (.17,.57)	-.33 (-.53,-.11)	.41 (.17,.57)	.20 (-.04,.41)	.47 (.26,.63)
Reg II Gra I	-.70 (-.81,-.56)	.63 (.46,.75)	-.65 (-.77,-.50)	-.40 (-.57,-.17)	.57 (.41,.71)	-.09 (-.33,.14)	-.10 (-.33,.13)	-.22 (-.42,.04)
Reg II Gra II	-.72 (-.82,-.58)	.88 (.83,.94)	-.05 (-.28,.18)	.87 (.82,.92)	-.60 (-.74,-.44)	.18 (-.05,.42)	-.16 (-.38,.08)	.81 (.72,.87)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRAMG GRADM	GRAMG GRACP	GRAMG GRACF	GRAP GRACU	GRAP GRAFE	GRAP GRASE	GRAP GRAZN	GRAP GRADM
Overall	.11 (-.14,.33)	-21 (-.42,.04)	.20 (-.04,.41)	-.32 (-.52,-.10)	-.31 (-.51,-.06)	.01 (-.24,.23)	-.31 (-.51,-.06)	-.22 (-.42,.04)
Reg I (Central)	.25 (0,.46)	.19 (-.05,.40)	.12 (-.14,.33)	-.11 (-.34,.12)	-.51 (-.66,-.32)	.10 (-.15,.33)	-.57 (-.71,-.41)	.08 (-.15,.32)
Reg II (North)	-.10 (-.33,.13)	-.31 (-.51,-.06)	.23 (-.03,.43)	-.37 (-.56,-.15)	-.39 (-.57,-.16)	.10 (-.15,.33)	-.04 (-.27,.19)	-.39 (-.57,-.16)
Gra I (Pangola)	.24 (0,.44)	-.55 (-.68,-.35)	.02 (-.23,.23)	.19 (-.05,.40)	.18 (-.05,.42)	.26 (.03,.46)	.16 (.08,.38)	-.67 (-.77,-.53)
Gra II (Guinea)	-.14 (-.36,.11)	-.54 (-.67,-.34)	-.20 (-.42,.04)	-.59 (-.73,-.43)	-.05 (-.28,.18)	0 (-.25,.24)	.40 (.17,.57)	-.25 (-.46,-.03)
Reg I Gra I	-.57 (-.71,-.41)	-.10 (-.33,.13)	-.36 (-.54,-.14)	.49 (.28,.65)	.19 (-.05,.40)	.23 (-.03,.43)	.04 (-.19,.27)	-.72 (-.82,-.58)
Reg I Gra II	-.04 (-.27,.19)	-.20 (-.42,.04)	.15 (-.11,.37)	-.03 (-.27,.21)	-.20 (-.42,.04)	.26 (.03,.46)	.35 (.13,.54)	-.34 (-.53,-.11)
Reg II Gra I	.36 (.14,.55)	-.41 (-.57,-.17)	.40 (.17,.57)	.16 (-.08,.38)	-.10 (-.33,.13)	.54 (.34,.67)	.42 (.17,.57)	-.68 (-.78,-.55)
Reg II Gra II	-.15 (-.37,.09)	-.65 (-.77,-.50)	-.40 (-.57,-.17)	-.66 (-.77,-.50)	.06 (-.15,.29)	.07 (-.15,.29)	.70 (.56,.79)	-.24 (-.44,0)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRAP GRACP	GRAP GRACF	GRACU GRAFE	GRACU GRASE	GRACU GRAZN	GRACU GRADM	GRACU GRACP	GRACU GRACF
Overall	.10 (-.15,.33)	-.03 (-.27,.21)	-.15 (-.37,.09)	.22 (-.04,.43)	-.04 (-.27,.19)	.25 (0,.46)	-.20 (-.42,.04)	.25 (0,.46)
Reg I (Central)	.20 (-.04,.41)	.16 (-.08,.38)	.09 (-.14,.33)	.20 (-.04,.41)	.52 (.31,.66)	-.57 (-.71,-.41)	.06 (-.17,.29)	-.04 (-.27,.19)
Reg II (North)	-.04 (-.27,.19)	-.15 (.37,.09)	0.29 (-.50,-.06)	.04 (-.19,.27)	-.36 (-.54,-.14)	.38 (.16,.57)	-.07 (-.29,.15)	.34 (.11,.53)
Gra I (Pangola)	.60 (.43,.73)	-.29 (-.50,-.06)	-.27 (-.47,-.04)	.08 (-.15,.32)	.23 (-.03,.43)	-.12 (-.34,.13)	-.23 (-.43,.03)	.09 (-.14,.33)
Gra II (Guinea)	-.26 (-.46,-.03)	-.42 (-.57,-.17)	-.06 (-.29,.17)	.33 (.08,.53)	-.06 (-.29,.17)	.56 (.38,.69)	-.23 (-.43,.03)	.41 (.17,.57)
Reg I Gra I	.46 (.25,.63)	.05 (-.18,.28)	-.23 (-.43,.03)	.46 (.25,.63)	.61 (.43,.73)	-.58 (-.72,-.41)	-.20 (-.42,.04)	.08 (-.15,.32)
Reg I Gra II	-.24 (-.44,0)	-.09 (-.33,.14)	0 (-.25,.24)	-.01 (-.24,.23)	.48 (.28,.64)	-.44 (-.61,-.20)	.50 (.30,.65)	-.13 (-.34,.13)
Reg II Gra I	.83 (.74,.88)	-.72 (-.82,-.58)	-.54 (-.67,-.34)	-.14 (-.36,.11)	-.03 (-.27,.21)	-.17 (-.39,.06)	-.07 (-.29,.15)	.12 (-.14,.33)
Reg II Gra II	-.42 (-.57,-.17)	-.52 (-.66,-.32)	-.11 (-.34,.12)	.19 (-.05,.40)	-.47 (-.63,-.26)	.76 (.63,.84)	-.14 (-.36,.11)	.42 (.17,.57)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRAFE GRASE	GRAFE GRAZN	GRAFE GRADM	GRAFE GRACP	GRAFE GRACF	GRASE GRAZN	GRASE GRADM	GRASE GRACP
Overall	-.13 (-.34,.13)	.46 (.25,.63)	-.26 (-.46,-.03)	.08 (-.15,.32)	-.45 (-.62,-.23)	.26 (.03,.46)	.04 (-.19,.27)	-.21 (-.42,.04)
Reg I (Central)	.08 (-.15,.32)	.62 (.44,.74)	-.36 (-.54,-.14)	-.12 (-.34,.13)	-.49 (-.65,-.28)	.22 (.04,.43)	-.30 (-.51,-.07)	-.20 (-.42,.04)
Reg II (North)	.12 (-.14,.33)	.70 (.56,.79)	.26 (.03,.46)	-.24 (-.44,0)	-.41 (-.57,-.17)	.16 (-.08,.38)	-.10 (-.33,.13)	.21 (-.04,.42)
Gra I (Pangola)	-.32 (-.52,-.10)	-.09 (-.33,.14)	-.29 (-.50,-.06)	.47 (.26,.63)	-.40 (-.57,-.17)	.24 (0,.44)	.10 (-.15,.33)	-.25 (-.46,-.03)
Gra II (Guinea)	-.07 (-.29,.15	.15 (-.11,.37)	-.20 (-.42,.04)	.10 (-.15,.33)	.18 (-.05,.42)	.38 (.16,.57)	-.03 (-.27,.21)	-.16 (-.38,.08)
Reg I Gra I	.03 (-.21,.27)	-.01 (-.24,.23)	-.01 (-.24,.23)	.13 (-.13,.34)	-.56 (-.69,-.38)	.44 (.20,.61)	-.44 (-.61,-.20)	-.17 (-.39,.06)
Reg I Gra II	.03 (-.21,.27)	.49 (.28,.65)	-.49 (-.65,-.28)	.39 (.16,.57)	.29 (.05,.48)	.19 (-.05,.40)	-.21 (-.42,.04)	-.19 (-.42,.04)
Reg II Gra I	.13 (-.13,.34)	.25 (0,.46)	.24 (0,.44)	.16 (-.08,.38)	-.01 (-.24,.23)	.10 (-.15,.33)	-.31 (-.51,-.06)	.46 (.25,.63)
Reg II Gra II	-.19 (-.05,.40)	-.01 (-.24,.23)	-.02 (-.26,.23)	-.11 (-.34,.12)	.12 (-.14,.33)	.07 (-.15,.29)	.07 (-.15,.29)	.18 (-.05,.42)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 26. (cont'd.)

	GRASE GRACF	GRAZN GRADM	GRAZN GRACP	GRAZN GRACF	GRADM GRACP	GRADM GRACF	GRACP GRACF
Overall	-.12 (-.34,.13)	-.18 (-.42,.05)	-.39 (-.57,-.16)	-.32 (-.52,-.10)	-.49 (-.65,-.28)	.16 (-.08,.38)	-.05 (-.28,.18)
Reg I (Central)	-.08 (-.32,.15)	-.50 (-.66,-.32)	-.34 (-.53,-.11)	-.21 (-.42,.04)	-.10 (-.33,.13)	.08 (-.15,.32)	.13 (-.13,.34)
Reg II (North)	-.39 (-.57,-.16)	.02 (-.23,.23)	-.37 (-.56,-.15)	-.61 (-.74,-.44)	-.60 (-.74,-.44)	.15 (-.11,.37)	0 (-.25,.24)
Gra I (Pangola)	-.26 (-.46,-.03)	-.10 (-.33,.13)	-.15 (-.37,.09)	-.09 (-.33,.14)	-.61 (-.74,-.44)	.18 (-.05,.42)	-.16 (-.38,.08)
Gra II (Guinea)	.19 (-.05,.40)	-.26 (-.46,-.03)	-.49 (-.65,-.28)	-.03 (-.27,.21)	-.50 (-.66,-.32)	.03 (-.21,.27)	-.15 (-.37,.06)
Reg I Gra I	-.23 (-.43,.03)	-.17 (-.39,.06)	-.40 (-.57,-.17)	-.02 (-.26,.23)	-.13 (-.34,.13)	-.05 (-.28,.18)	.23 (-.03,.43)
Reg I Gra II	.14 (-.11,.36)	-.52 (-.66,-.32)	.20 (-.04,.41)	-.06 (-.29,.17)	-.60 (-.74,-.44)	.04 (-.19,.27)	-.20 (-.42,.04)
Reg II Gra I	-.56 (-.69,-.38)	-.34 (-.53,-.11)	.44 (.20,.61)	-.30 (-.51,-.07)	-.65 (-.77,-.50)	.57 (.41,.71)	-.73 (-.82,-.58)
Reg II Gra II	-.12 (-.34,.13)	-.22 (-.42,.04)	-.49 (-.65,-.28)	-.46 (-.63,-.25)	-.57 (-.71,-.41)	.06 (-.17,.29)	.11 (-.14,.33)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 27. CORRELATION COEFFICIENTS BETWEEN MINERALS OR pH IN SOILS AND MINERALS IN FORAGES DETERMINED FOR SOILS AND GRASSES SAMPLED IN THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

	SOCA GRACA	SOK GRAK	SOMG GRAMG	SOP GRAP	SOCU GRACU	SOFE GRAFE	SOSE GRASE
Overall	.86 (.78,.91)	.70 (.56,.79)	.05 (-.18,.28)	.56 (.38,.69)	.04 (-.19,.27)	.57 (.41,.71)	.58 (.41,.72)
Reg I (Central)	.76 (.63,.84)	.63 (.46,.75)	.49 (.28,.65)	.78 (.68,.86)	.04 (-.19,.27)	.56 (.38,.69)	.12 (-.14,.33)
Reg II (North)	-.12 (-.34,.13)	.82 (.73,.87)	-.26 (-.46,-.03)	.44 (.20,.61)	0 (-.25,.24)	.58 (.41,.72)	.24 (0,.44)
Gra I (Pangola)	.90 (.84,.93)	.41 (.17,.57)	.04 (-.19,.27)	-.27 (-.47,-.04)	.20 (-.04,.41)	.66 (.50,.77)	.56 (.38,.69)
Gra II (Guinea)	.92 (.86,.95)	.41 (.17,.57)	-.10 (-.33,.13)	.56 (.38,.69)	-.06 (-.29,.17)	-.07 (-.29,.15)	.61 (.43,.73)
Reg I Gra I	-.12 (-.34,.13)	.48 (.28,.64)	-.25 (-.46,-.03)	-.08 (-.32,.15)	.40 (.17,.57)	.40 (.17,.57)	.09 (-.14,.33)
Reg I Gra II	-.11 (-.34,.12)	.11 (-.14,.33)	-.28 (-.47,-.05)	.75 (.63,.83)	.10 (-.15,.33)	-.19 (-.42,.07)	.26 (.03,.46)
Reg II Gra I	-.04 (-.27,.19)	.63 (.46,.75)	.26 (.03,.46)	-.57 (-.71,-.41)	.16 (-.08,.38)	.33 (.08,.53)	.08 (-.15,.32)
Reg II Gra II	-.43 (-.58,-.18)	.75 (.63,.83)	.25 (0,.46)	.87 (.82,.92)	-.25 (-.46,-.03)	.36 (.14,.55)	.38 (.16,.57)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 27. (cont'd.)

	SOZN GRAZN	SOCA GRAK	SOCA GRAMG	SOCA GRAP	SOCA GRACU	SOCA GRAFE	SOCA GRASE
Overall	-.15 (-.37,.09)	-.08 (-.32,.15)	.22 (-.04,.43)	-.04 (-.27,.19)	.28 (.05,.48)	-.42 (-.57,-.17)	.54 (.34,.67)
Reg I (Central)	-.16 (-.38,.08)	.55 (.35,.70)	.60 (.43,.73)	.46 (.25,.63)	-.16 (-.38,.08)	-.63 (-.75,-.46)	-.09 (-.33,.14)
Reg II (North)	.41 (.17,.57)	.21 (-.04,.42)	-.19 (-.42,.07)	.20 (-.04,.41)	-.02 (-.26,.23)	-.16 (-.38,.08)	.07 (-.15,.29)
Gra I (Pangola)	.13 (-.13,.34)	-.36 (-.54,-.14)	.40 (.17,.57)	.01 (-.24,.23)	.28 (.05,.48)	-.58 (-.72,-.41)	.59 (.43,.73)
Gra II (Guinea)	-.49 (-.65,-.28)	.05 (-.18,.28)	.04 (-.19,.27)	-.21 (-.42,.04)	.32 (.07,.52)	-.05 (-.28,.18)	.51 (.30,.65)
Reg I Gra I	.51 (.30,.65)	.16 (-.08,.38)	-.09 (-.33,.14)	.16 (-.08,.38)	-.08 (-.32,.15)	-.27 (-.47,-.04)	.10 (-.15,.33)
Reg I Gra II	-.09 (-.33,.14)	.13 (-.13,.34)	-.54 (-.67,-.34)	-.47 (-.63,-.26)	.23 (-.03,.43)	-.09 (-.33,.14)	-.06 (-.29,.17)
Reg II Gra I	-.42 (-.57,-.17)	.56 (.38,.69)	-.44 (-.61,-.20)	.66 (.50,.77)	.27 (.04,.47)	-.42 (-.57,-.17)	.13 (-.13,.34)
Reg II Gra II	-.31 (-.51,-.06)	.38 (.16,.57)	.14 (-.11,.36)	.12 (-.14,.33)	-.54 (-.67,-.34)	-.33 (-.53,-.11)	-.23 (-.43,.03)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 27. (cont'd.)

	SOCA GRAZN	SOK GRAMG	SOMG GRAK	SOCU GRAFE	SOCU GRASE	SOCU GRAZN	SOFE GRACU
Overall	.13 (-.13,.34)	.49 (.28,.65)	.08 (-.15,.32)	-.29 (-.50,-.06)	.22 (-.04,.43)	-.24 (-.44,0)	-.29 (-.50,-.06)
Reg I (Central)	-.72 (-.82,-.58)	.66 (.50,.77)	.44 (.20,.61)	-.27 (-.47,-.04)	0 (-.25,.24)	-.32 (-.52,-.10)	-.09 (-.33,.14)
Reg II (North)	.12 (-.14,.33)	.41 (.17,.57)	-.69 (-.79,-.55)	-.56 (-.69,-.38)	.23 (-.03,.43)	-.27 (-.47,-.04)	-.21 (-.42,.04)
Gra I (Pangola)	.18 (-.05,.42)	.03 (-.21,.27)	-.25 (-.46,-.03)	.06 (-.17,.29)	.29 (.05,.48)	.29 (.05,.48)	-.31 (-.51,-.06)
Gra II (Guinea)	.57 (.41,.71)	-.09 (-.33,.14)	.07 (-.15,.29)	.01 (-.24,.23)	.34 (.11,.53)	.37 (.15,.56)	-.33 (-.53,-.11)
Reg I Gra I	-.25 (-.46,-.03)	.21 (-.04,.42)	-.01 (-.24,.23)	.23 (-.03,.43)	.34 (.11,.53)	.62 (.44,.74)	-.32 (-.52,-.10)
Reg I Gra II	-.02 (-.26,.23)	-.56 (-.69,-.38)	.11 (-.14,.33)	.09 (-.14,.33)	-.06 (-.29,.17)	-.22 (-.42,.04)	-.32 (-.52,-.10)
Reg II Gra I	.13 (-.13,.34)	-.32 (-.52,-.10)	-.61 (-.74,-.44)	-.34 (-.53,-.11)	.39 (.16,.57)	.11 (-.14,.33)	-.41 (-.57,-.17)
Reg II Gra II	.16 (-.08,.38)	.14 (-.11,.36)	.51 (.30,.65)	-.08 (-.32,.15)	.37 (.15,.56)	.47 (.26,.63)	.58 (.41,.72)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 27. (cont'd.)

	SOSE GRACU	SOZN GRACU	SOPH GRACU	SOPH GRAFE	SOPH GRASE	SOPH GRAZN	SOPH GRACA
Overall	.34 (.11,.53)	-.24 (-.44,0)	.34 (.11,.53)	-.46 (-.63,-.25)	.47 (.26,.63)	-.02 (-.26,.23)	.87 (.82,.92)
Reg I (Central)	.02 (-.23,.23)	-.17 (-.39,.06)	-.12 (.34,.13)	-.49 (-.65,-.28)	-.16 (-.38,.08)	-.64 (-.76,-.47)	.63 (.46,.75)
Reg II (North)	.16 (-.08,.38)	-.02 (-.26,.23)	.21 (-.04,.42)	-.49 (-.65,-.28)	0 (-.25,.24)	-.29 (-.50,-.06)	.42 (.17,.57)
Gra I (Pangola)	.37 (.15,.56)	.18 (-.05,.42)	.32 (.07,.52)	-.49 (-.65,-.28)	.55 (.35,.70)	.19 (-.05,.40)	.81 (.72,.87)
Gra II (Guinea)	.38 (.16,.57)	-.36 (-.54,-.14)	.38 (.16,.57)	-.08 (-.32,.15)	.49 (.28,.65)	.56 (.38,.69)	.93 (.87,.95)
Reg I Gra I	.25 (0,.46)	.42 (.17,.57)	-.47 (-.63,-.26)	.16 (-.08,.38)	-.14 (-.36,.11)	-.26 (-.46,-.03)	-.31 (-.51,-.06)
Reg I Gra II	.15 (-.11,.37)	-.53 (-.66,-.32)	.57 (.41,.71)	-.31 (-.51,-.06)	-.14 (-.36,.11)	.09 (-.14,.33)	-.13 (-.34,.13)
Reg II Gra I	.43 (.18,.58)	.41 (.17,.57)	.37 (.15,.56)	-.24 (-.44,0)	.15 (-.11,.37)	.29 (.05,.48)	.11 (-.14,.33)
Reg II Gra II	.13 (-.13,.34)	-.07 (-.29,.15)	-.17 (-.39,.06)	.31 (.06,.51)	-.43 (-.58,-.18)	.09 (-.14,.33)	.26 (.03,.46)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 28. CORRELATION COEFFICIENTS BETWEEN MINERALS IN SOILS AND MINERALS IN SERUM, AND BETWEEN SOIL MINERALS AND HEMOGLOBIN OR HEMATOCRIT VALUES DETERMINED IN SAMPLES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

Variable Pairs	Cows	Heifers	Calves
Soil-Serum Calcium	.58 (.41,.72)	-.04 (-.27,.19)	.11 (-.14,.33)
Soil-Serum Potassium	.11 (-.14,.33)	.23 (-.03,.43)	.40 (.17,.57)
Soil-Serum Magnesium	-.24 (-.44,0)	-.24 (-.44,0)	.24 (0,.44)
Soil-Serum Phosphorus	.18 (-.05,.42)	.34 (.11,.53)	.15 (-.11,.37)
Soil-Serum Copper	.10 (-.15,.33)	-.31 (-.51,-.06)	.17 (-.06,.39)
Soil-Serum Iron	-.17 (-.39,.06)	.64 (.46,.75)	.05 (-.18,.28)
Soil-Serum Selenium	.70 (.56,.79)	.34 (.11,.53)	.76 (.63,.84)
Soil-Serum Zinc	-.42 (-.57,-.17)	-.23 (-.43,.03)	-.37 (-.56,-.15)
Soil Iron Serum Copper	.21 (-.04,.42)	.55 (.35,.70)	.15 (-.11,.37)
Soil Iron Blood HB	-.36 (-.54,-.14)	.19 (-.05,.40)	-.53 (-.56,-.15)
Soil Iron Blood HT	.18 (-.05,.42)	.46 (.25,.63)	-.52 (-.66,-.32)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 28. (cont'd.)

Variable Pairs	Cows	Heifers	Calves
Soil Calcium Serum Magnesium	.22 (.04,.43)	-.04 (-.27,.19)	0 (-.25,.24)
Soil Calcium Serum Phosphorus	-.02 (-.26,.23)	-.19 (-.42,.04)	.34 (.11,.53)
Soil Calcium Serum Copper	-.44 (-.61,-.20)	-.55 (-.68,-.35)	-.45 (-.62,-.23)
Soil Calcium Serum Zinc	.40 (.17,.57)	.36 (.14,.55)	.46 (.25,.63)
Soil Potassium Serum Magnesium	.07 (-.15,.29)	-.44 (-.61,-.20)	.54 (.34,.67)
Soil Copper Serum Iron	.18 (-.05,.42)	.06 (-.17,.29)	-.06 (.34,.67)
Soil Copper Serum Selenium	.14 (-.11,.36)	.22 (-.04,.43)	.33 (.08,.53)
Soil Copper Serum Zinc	.08 (-.15,.32)	.19 (-.05,.40)	.03 (-.21,.27)
Soil Copper Blood HB	.24 (0,.44)	-.08 (-.32,.15)	.36 (.14,.55)
Soil Copper Blood HT	.11 (-.14,.33)	-.16 (-.38,.08)	.42 (.17,.57)
Soil Zinc Serum Copper	.59 (.43,.73)	.46 (.25,.63)	.37 (.15,.56)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 29. CORRELATION COEFFICIENTS BETWEEN MINERALS IN GRASSES AND MINERALS IN SERUM, AND BETWEEN GRASS MINERALS AND HEMOGLOBIN OR HEMATOCRIT VALUES DETERMINED IN SAMPLES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

Variable Pairs	Cows	Heifers	Calves
Grass-Serum Calcium	.49 (.28,.65)	.02 (-.23,.23)	.33 (.08,.53)
Grass-Serum Potassium	-.23 (-.43,.03)	.11 (-.14,.33)	.04 (-.19,.27)
Grass-Serum Magnesium	.52 (.31,.66)	-.19 (-.42,.04)	.05 (-.18,.28)
Grass-Serum Phosphorus	.64 (.46,.75)	.60 (.43,.73)	.33 (.08,.53)
Grass-Serum Copper	-.48 (-.64,-.28)	-.19 (-.42,.04)	-.22 (-.42,.04)
Grass-Serum Iron	-.25 (-.46,-.03)	.22 (-.04,.43)	.43 (.18,.58)
Grass-Serum Selenium	.55 (.35,.70)	.36 (.14,.55)	.69 (.55,.79)
Grass-Serum Zinc	-.58 (-.72,-.41)	-.41 (-.57,-.17)	-.27 (-.47,-.04)
Grass Iron Serum Copper	-.09 (-.33,.14)	.14 (-.11,.36)	-.24 (-.44,0)
Grass Iron Blood HB	.05 (-.18,.28)	.20 (-.04,.41)	-.10 (-.33,.13)
Grass Iron Blood HT	.19 (-.05,.40)	.38 (.16,.57)	-.19 (-.42,.04)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 29. (cont'd.)

Variable Pairs	Cows	Heifers	Calves
Grass Calcium Serum Magnesium	.54 (.34,.67)	-.06 (-.29,.17)	.02 (-.23,.23)
Grass Calcium Serum Phosphorus	0 (-.25,.24)	-.12 (-.34,.13)	.62 (.44,.74)
Grass Calcium Serum Copper	-.54 (-.67,-.34)	-.34 (-.53,-.11)	-.34 (-.53,-.11)
Grass Calcium Serum Zinc	.61 (.43,.73)	.61 (.43,.73)	.54 (.34,.67)
Grass Potassium Serum Magnesium	.13 (-.13,.34)	-.17 (-.39,.06)	.34 (.11,.53)
Grass Copper Serum Iron	.55 (.35,.70)	-.72 (-.82,-.58)	.12 (-.14,.33)
Grass Copper Serum Selenium	.46 (.25,.63)	.61 (.43,.73)	.17 (-.06,.39)
Grass Copper Serum Zinc	.30 (.05,.49)	.37 (.15,.56)	.30 (.05,.49)
Grass Copper Serum HB	.19 (-.05,.40)	.05 (-.18,.28)	.38 (.16,.57)
Grass Copper Serum HT	-.21 (-.42,.04)	-.18 (-.42,.05)	.27 (.04,.47)
Grass Zinc Serum Copper	.14 (-.11,.36)	-.38 (-.57,-.16)	-.34 (-.53,-.11)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 30. CORRELATION COEFFICIENTS BETWEEN MINERALS IN SERA OF COWS, HEIFERS, AND CALVES FROM THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

Pair		Pair		Pair	
COCA	.57	COCA	.34	HECA	.23
HECA	(.41,.71)	CALCA	(.11,.53)	CALCA	(-.03,.43)
COK	.02	COK	.81	HEK	.23
HEK	(-.23,.23)	CAK	(.72,.87)	CAK	(-.03,.43)
COMG	.19	COMG	.10	HEMG	.08
HEMG	(-.05,.40)	CAMG	(-.15,.33)	CAMG	(-.15,.32)
COP	.68	COP	.14	HEP	.06
HEP	(.55,.78)	CAP	(-.11,.36)	CAP	(-.17,.29)
COCU	0	COCU	.74	HECU	-.02
HECU	(-.25,.24)	CACU	(.61,.83)	CACU	(-.26,.23)
COFE	-.10	COFE	-.28	HEFE	-.37
HEFE	(-.33,.13)	CAFE	(-.47,-.05)	CAFE	(-.56,-.15)
COSE	.49	COSE	.88	HESE	.34
HESE	(.28,.65)	CASE	(.83,.94)	CASE	(.11,.53)
COZN	.71	COZN	.67	HEZN	.74
HEZN	(.57,.82)	CAZN	(.52,.77)	CAZN	(.61,.83)

[a]The numbers in parenthesis are .95 confidence limits.

TABLE 31. REGRESSION EQUATIONS DETERMINED FOR SOILS, GRASSES AND LIVESTOCK SAMPLED IN THE CENTRAL AND NORTHERN REGIONS OF VERACRUZ, MEXICO[a]

General Equations:

$y = b_o + b_1x$ or $y = b_o + b_1x_1 + b_2x_2$

		R Square
GraCa[b]	= 1982.1 + .7584 SoCa	.81
CoCa	= 9.350 + .1334 x 10^{-3} SoCa	.34
GraK	= 11562 + 43.12 SoK	.65
GraP	= 2286.4 + 189.2 SoP	.44
CoP	= 2.696 + .5091 x 10^{-3} GraP	.41
HeP	= 4.395 + .4525 x 10^{-3} GraP	.37
CoP	= 2.406 + (-.09884 SoP) + .7368 x 10^{-3} GraP	.52
GraFe	= 105.61 + 4.30 SoFe	.41
HeFe	= 1.947 + .6611 x 10^{-2} SoFe	.42
HeFe	= 1.999 + .8736 x 10^{-2} SoFe + (-.4940 x 10^{-3} GraFe)	.48
GraSe	= .06207 + .2658 SoSe	.72
CoSe	= .5239 x 10^{-2} + .1665 SoSe	.50

[a]Only significant regressions are presented.
[b]See list of abbreviations.

TABLE 31. (cont'd.)[a]

General Equations: $y = b_o + b_1x$ or $y = b_o + b_1x_1 + b_2x_2$	R Square
$CaSe^b = (-.1315 \times 10^{-2}) + .07649\ SoSe$	.58
$CaSe = -.01111 + .2208\ GraSe$	.47
$CoSe = .01281 + .1989\ SoSe + (-.1220\ GraSe)$	.50
$CaSe = (-.4610 \times 10^{-2}) + .06238\ SoSe + .05308\ GraSe$	.58
$CoZn = 1.193 + (-.6502 \times 10^{-2}\ GraZn)$	.33
$CoZn = 1.325 + (-.05198\ SoZn) + (-.8030 \times 10^{-2}\ GraZn)$	.66
$SoCa = -16786 + 2950\ SopH$	.89
$SoMg = 881.84 + (-86.109\ SopH)$	.39
$SoFe = 160.19 + (-19.935\ SopH)$	.74
$SoSe = -.5542 + .1095\ SopH$	.80
$SoZn = 9.034 + (-1.053\ SopH)$	.59
$SoCo = -.6796 + .1929\ SopH$	.82

[a]Only significant regressions are presented.
[b]See list of abbreviations.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Aikawa, J.K. 1971. The relationship of magnesium to disease in domestic animals and in humans. Charles C. Thomas (pub.). Springfield, Illinois, U.S.A.

2. Ammerman, C.G., S.M. Miller and L.R. McDowell. 1978. Selenium in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. pp. 91-98.

3. Ancizar-Sordo, J. 1947. Occurence of selenium in soils and plants of Colombia, South America. Soil Science, 63:437.

4. Andreasi, F., J.S.M. Veiga, C.X. de Mendonca, Jr., F. Prada and R.C. Barnabe. 1966-1967. Levantamento dos elementos minerais em plantas forrageiras de areas delimitadas do Estado de Sao Paulo. I. Calcio, Fosforo E Magnesio. Rev. Fac. Med. Vet. Sao Paulo, Brazil, 7:583.

5. Andreasi, F., C.X. de Mendonca, Jr., J.S. Marcondes V., and F. Prada. 1969. Levantamento dos elementos minerais em plantas forrageiras de areas delimitadas do Estado de Sao Paulo. IV. Zinco. Rev. Fac. Med. Vet. Sao Paulo, Brazil, 8(1):177.

6. Anke, M., A. Hennig, M. Grun, M. Partschefeld, B. Groppel and H. Ludke. 1976. Arsenic: A new essential trace element. Arch. Tierernachr, 26(10):742-3.

7. Anonymous. 1976. Analytical methods for atomic absorption spectrophotometry. Perkin-Elmer, Inc., Norwalk, Connecticut, U.S.A.

8. Anonymous. 1978. Calcium and phosphorus in animal nutrition. International Minerals and Chemical Corporation. Mundelein, Illinois, U.S.A.

9. Anonymous. 1979. Determination of serum minerals by atomic absorption spectroscopy. Nutrition Laboratory, Animal Husbandry Dept., Michigan State University. Mimeograph.

10. A.O.A.C. 1975. Official Methods of Analysis (12th Edition). Association of Official Analytical Chemists. Washington, D.C., U.S.A.

11. Beeson, K.C. and G. Guillermo-Gomez. 1970. Concentration of nutrients in pastures in the central Huallaga and Rio Ucayali valleys of the upper Amazon basin of Peru. Proc. of the XI International Grassland Congress, p. 89.

12. Bisbjerg, B. 1972. Studies on selenium in plants and soils. Danish Atomic Energy Commission. Research Establishment Riso. Riso Report No. 200. Denmark.

13. Blasco Lamenca, M. and N. Bohorquez Ampudia. 1967. Composicion quimica de plantas forrajeras (gramineas) comunes en el Valle del Cauca. Acta Agronomica, 17:13.

14. Blue, W.G., and L.E. Tergas. 1969. Dry season deterioration of forage quality in the wet-dry tropics. Symposium: Unique processes in tropical plants and soils. Soil and Crop Science Society of Florida. Proc., 29:224.

15. Blue, W.G., C.B. Ammerman, J.M. Loaiza, and J.F. Gamble. 1969. Compositional analysis of soils, forages, and cattle tissues from beef-producing areas of eastern Panama. Bio. Sci., 19:616.

16. Bowen, H.J.M. 1966. Trace elements in biochemistry. Academic Press, New York, U.S.A.

17. Bray, A.C. and A.R. Tell. 1975. Metabolism of sulphur in the gastro-intestinal tract. In Digestion and Metabolism in the Ruminant. I.W. McDonald and A.C.I. Warner (eds.). The University of New England Publishing Unit, p. 243-260.

18. Brown, J.C. 1976. Genetic potentials for solving problems of soil minerals stress: Iron deficiency and boron toxicity in alkaline soils. In Proc. of Workshop on Plant Adaptation to Mineral Stress in Problem Soils. M.J. Wright (ed.). p. 83-94.

19. Buchanan-Smith, J.G. 1978. Calcium and phosphorus requirements of dairy cattle. Paper Presented at the First Annual International Minerals Conference. St. Petersburg Beach, Florida. Sponsored by: International Minerals & Chemical Corporation, Mundelein, Illinois, U.S.A.

20. Buck, W.B. and R.C. Ewan. 1973. Toxicology and adverse effects of mineral imbalance. Clinical Toxicology, 6(3):459-485.

21. Camberos, H.R., N.A. Marcilese, H.D. Figueiras, and R.M. Valsecchi. 1965. Estudios preliminares sobre pluricarencia de oligo-elementos. Gaceta Veterinaria, 27:99-117.

22. Chicco, C.F. and M.H. French. 1959. Observaciones sobre deficiencies del calcio y fosforo en los animales de las regiones ganaderas del centro y este de Venezuela. Agronomia Tropical, 9(2):41.

23. Christiansen, M.N. 1976. Summary of the workshop session I, Overview of soil mineral stress - worldwide. In Proc. of Workshop on Plant Adaptation to Mineral Stress in Problem Soils. M.J. Wright (ed.). p. 47-48.

24. Church, D.C. and W.G. Pond. 1976. Basic Animal Nutrition and Feeding. D.C. Church (pub.) O & B Books (distrib.) Oregon, U.S.A. p. 99.

25. Clanton, D.C. 1980. Applied potassium nutrition in beef cattle Animal Health and Nutrition Bulletin MB - 17. International Mineral and Chemical Corporation, Mundelein, Illinois, U.S.A.

26. Coelho da Silva, J.F. 1978. Copper and molybdenum in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. pp. 84-91.

27. Committee on Mineral Nutrition. 1973. Tracing and treating mineral disorders in dairy cattle. The Hague. Centre for Agricultural Publication and Documentation, Wageningen, The Netherlands.

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

29. Conrad, J.H. 1978. Soil, plant and animal tissue as predictors of the mineral status of ruminants. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. pp. 143-148.

30. Conrad, H.R. and A.L. Moxon. 1979. Transfer of dietary selenium to milk. J. Dairy Sci. 62:404.

31. Cooper, W.C., K.G. Bennett and F.C. Croxton. 1974. The history, occurrence, and properties of selenium. In Selenium. R.A. Zingaro and W.C. Cooper (eds.). Van Nostrand Reinhold Company, New York, U.S.A. pp. 1-30.

32. Cunha, T.J. 1973. Recent developments in mineral nutrition. A look at the highlights of research involving the mineral requirements for swine, beef cattle and horses. Feedstuffs, May 14, 1973.

33. De Alba, J. 1950. Explotacion de dos haciendas ganaderas. Tierra (Mexico), 5:81.

34. De Alba, J. 1971. Alimentacion del ganado en America Latina. 2a. edicion. La Prensa Medica Mexicana. pp. 127-154.

35. De Alba, J. y G.K. Davis. 1957. Minerales en la nutricion animal en la America Latina. Turrialba, 7:16.

36. De Mondragon, M.C. y W.G. Jaffe. 1971. Selenio en alimentos y en orina de escolares de diferentes zonas de Venezuela. Archivos Latino-americanos de Nutricion, 21:185.

37. Dennis, R.J. and R.W. Hemken. 1978. Potassium requirement of dairy cows in early and midlactation. J. Dairy Sci., 61:757.

38. De Oliveira Mendes, M. 1977. Mineral status of beef cattle in the northern part of Mato Grosso, Brazil, as indicated by age, season, and sampling technique. Ph.D. Dissertation, University of Florida.

39. De Sousa, J.C. 1978. Interrelationships among mineral levels in soil, forage, and animal tissues on ranches in northern Mato Grosso, Brazil. Ph.D. Dissertation, University of Florida.

40. Dick, A.T., D.W. Dewey and J.M. Gawthorne. 1975. Thiomolybdates and the copper-molybdenum-sulphur interaction in ruminant nutrition. J. Agric. Sci., Camb., 85:567-568.

41. Dowdy, R.P. and G. Matrone. 1968. Copper molybdenum interactions in sheep and chicks. J. Nutr., 95:191-196.

42. Dudal, R. 1976. Inventory of the major soils of the world with special reference to mineral stress hazards. In Proc. of Workshop on Plant Adaptation to Mineral Stress in Problem Soils. M.J. Wright (ed.). pp. 3.

43. Dudal, R. 1977. Plant-nutrient relationships in major soils regions. In Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture. Tokyo, Japan. pp. 78.

44. Duthie, D.W. 1939. Mineral deficiency and cattle raising in British Guiana. Agric. J. British Guiana, 10:194.

45. Echevarria, M., R. Soikes, K.C. Beeson and J. Kalinowski. 1970. Interrelacion suelo-planta-nutricion. X. Composicion quimica de los forrajes de Junin. Anales Cientificos, 8:179.

46. Estevez Cancino, J.A. 1960. Influencia de la adicion de fosforo y de cobalto en raciones comunes para vacas lecheras. Acta Agronomica, 10:169.

47. Fenner, H. 1979. Magnesium nutrition of the ruminant. Presented at The Second Annual International Minerals Conference. January 17, 1979, St. Petersburg Beach, Florida, U.S.A.

48. Fernandez, G., C. Albertazzi and R. Bressoni. 1971. Crecimiento de ganado bajo condiciones de pastoreo libre y composicion quimica de los pastos consumidos. Tumialba, 21:157.

49. Fick, K.R., J.R. McDowell and R.H. Houser. 1976. Current status of mineral research in Latin America. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants, 22-26 March, Belo Horizonte, Brazil. pp. 261-292.

50. French, M.H. 1955. Earth-eating and the mineral needs of livestock. The East African Agric. Journal, 20:168-175.

51. French, M.H. y L.M. Chaparro. 1960. Contribucion al estudio de la composicion quimica de los pastos en Venezuela durante la estacion seca. Agronomia Tropical, 10:57.

52. French, M.H. y C.F. Chicco. 1961a. Observaciones sobre deficiencias de calcio y fosforo en los animales de los Andes y sus inmediaciones. Agronomia Tropical, 11(3):157.

53. French, M.H. y C.F. Chicco. 1961b. Niveles de hemoglobina en la sangre del Ganado Vacuno en Venezuela. Agronomia Tropical, 10:161.

54. Ganther, H.E. 1974. Biochemistry of selenium. In Selenium. R.A. Zingaro and W.C. Cooper (eds.). Van Nostrand Reinhold Co., New York, U.S.A. pp. 546-614.

55. Gavillon, O. and A.T.F. Quadros. 1976. O cobre, o molibdenio e o sulfato inorganico em pastagenas nativas do Rio Grande do Sul. Anu. Tec. IPZFO, Porto Alegre, 3:423-453.

56. Gomez, G., T. Aguilar and K.C. Beeson. 1966. Interrelaciones suelo-planta-nutricion. II. Calidad nutritiva de los forrajes del valle del Huallaga Central. Anales Cientificos, 4:147.

57. Gomide, J.A. 1978. Mineral composition of grasses and tropical leguminous forages. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. p. 32-40.

58. Gomide, J.A., C.H. Noller, G.O. Mott, J.H. Conrad and D.L. Hill. 1969. Mineral composition of six tropical grasses as influenced by plant age and nitrogen fertilization. Agronomy Journal, 61:120.

59. Gonzalez, M.H. 1966. Reduccion de nutrientes en los pastizales de Chihuahua durante los meses de sequia. II. Fosforo. Tecnica Pecuaria en Mexico, 7:19.

60. Grimme, H. 1976. Soil factors of potassium availability. Bull. Indian Soc. Soil Sci., 10:144.

61. Gutierrez, J.L., G.S. Smith, J.D. Wallace and A.B. Nelson. 1974. Selenium in plants, water and blood: New Mexico and Chihuahua. J. Anim. Sci., 38:1330.

62. Hartley, W.J. 1967. Levels of selenium in animal tissues and methods of selenium administration. In Selenium in Biomedicine. Proc. of First International Symposium. O.H. Muth (ed.), The AVI Publishing Company, Inc. p. 79-96.

63. Hartmans, J. and M.S.M. Bosman. 1970. Differences in the copper status of grazing cattle and housed cattle and their biochemical backgrounds. In Trace Element Metabolism in Animals. C.F. Mills (ed.). E. & S. Livingstone, Edinburgh, Scotland and London, England. p. 362.

64. Hays, V.W. and M.J. Swenson. 1977. Minerals. In Dukes' Physiology of Domestic Animals. Melvin J. Swenson (ed.). Comstock Publishing Associates, Ithaca, New York, U.S.A. Ninth edition. p. 395-412.

65. Healy, W.B. 1974. Ingested soil as a source of elements to grazing animals. Proceedings of Trace Element Metabolism in Animals - 2. W.G. Hoekstra, J.W. Suttie, H.E. Ganther, and W. Mertz (eds.). University Park Press, Baltimore, Maryland, U.S.A. p. 448-450.

66. Hemken, R.W. 1980. Potassium nutrition in dairy cattle. Animal Health and Nutrition Bulletin MB - 19. International Minerals and Chemical Corp. Mundelein, Illinois, U.S.A.

67. Herrick, J.B. 1974. The role of zinc in nutrition of food-producing animals. Veterinary Medicine/Small Animal Clinician, 69(1):85-89.

68. Hidiroglou, M. 1979. Trace element deficiencies and fertility in ruminants: A review. J. Dairy Sci., 62:1195.

69. Houser, R.H., K.R. Fick, and L.R. McDowell. 1978. Cobalt in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (ed.). University of Florida. p. 80-83.

70. Huisingh, J. and G. Matrone. 1972. Copper-molybdenum interactions with the sulphate-reducing system in the rumen microorganisms. Proc. Soc. Exp. Biol. Med., 139:518-521.

71 Huisingh, J., G.G. Gomez and G. Matrone. 1973. Interactions of copper, molybdenum, and sulphate in ruminant nutrition. Fed. Proc., 32:1921-1924.

72. Huisingh, J., D.C. Milholland and G. Matrone. 1975. Effect of molybdate on sulphate production by ruminal microorganisms of sheep. J. Nutr., 105:1199-1205.

73. Hume, I.D. and P.R. Bird. 1970. Synthesis of microbial protein in the rumen. IV. The influence of the level and form of dietary sulphur. Aust. J. Agric. Res., 21:315-322.

74. Hupkens van der Elst, F.C.C. and J.H. Watkinson. 1976. Effect of topdressing pasture with selenium prills on selenium concentration in blood of stock. N.Z. Journal of Experimental Agriculture, 5:79-83.

75. Jacobson, D.R., R.W. Hemken, F.S. Button and R.H. Hatton. 1972. Mineral nutrition, calcium, phosphorus, magnesium and potassium interrelationships. J. Dairy Sci., 55(7):935.

76. Jaffe, W.G., J.F. Chavez y M.C. De Mondragon. 1967. Contenido de selenio en alimentos venezolanos. Archivos Latinoamericanos de Nutricion, 17:59.

77. Jaffe, W.G., J.F. Chavez y M.C. De Mondragon. 1969. Contenido de selenio en muestras de semillas de ajonjoli (sesamum indicum) procedentes de varios paises. Archivos Latinoamericanos de Nutricion, 19:299.

78. Jardim, W.R., A.M. Peixoto, C.L. de Morais and S. Silveira Filho. 1965. Contribuicao ao estudo da composicao quimica de plantas forrageiras de pastagens do Brasil Central. Anais de IX Congreso Internacional de Pastagens, Sao Paulo, Brasil, p. 699.

79. Jones, J.B., Jr. 1972. Plant tissue analysis for micronutrients. In Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Soil Science Society of America, Inc. Madison, Wisconsin, U.S.A. p. 319-346.

80. Karlen, D.L., R. Ellis, Jr., D.A. Whitney, and D.L. Grunes. 1980a. Soil and plant parameters associated with grass tetany of cattle in Kansas. Agron. J., 72:61-65.

81. Karlen, D.L., R. Ellis, Jr., D.A. Whitney, and D.L. Grunes. 1980b. Influence of soil moisture on soil solution cation concentrations and the tetany potential of wheat forage. Agron. J., 72:73-78.

82. Kayongo-Male, H., J.W. Thomas and D.E. Ullrey. 1973. Mineral composition of tropical grasses. Proc. of Trace Element Metabolism in Animals - 2. W.G. Hoekstra, J.W. Suttie, H.E. Ganther, and W. Mertz (eds.). University Park Press, Baltimore, Maryland, U.S.A. p. 455-457.

83. Kemp, A., W.B. Deijs, O.J. Hemkes and A.J.H. Van Es. 1961. Hypomagnesaemia in milking cows: Intake and utilization of magnesium from herbage by lactating cows. Neth. J. Agric. Sco., 9(2):134.

84. Kiatoko, M., L.R. McDowell, K.R. Fick, H. Fonseca, J. Camacho, J.K. Loosli and J.H. Conrad. 1978. Mineral status of cattle in the San Carlos region of Costa Rica. J. Dairy Sci., 61:324.

85. King, K.W. and N.O. Price. 1966. Nutritional value of Haitian forages. Archivos Latinoamericanos de Nutricion, 16:221.

86. Korte, N.E., J. Skopp, W.H. Fuller, E.E. Niebla and B.A. Alesii. 1976. Trace element movement in soils: Influence of soil physical and chemical factors. Soil Science, 122(6):350.

87. Kronfeld, D.S. 1971. Parturient hypocalcemia in dairy cows. Adv. Vet. Sci. Comp. Med., 15:133-157.

88. Kubota, J. 1968. Distribution of cobalt deficiency in grazing animals in relation to soils, and forage plants of the United States. Soil Science, 106:122-130.

89. Kubota, J. and W.H. Allaway. 1972. Geographic distribution of trace element problems. In Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (eds.). Soil Science Society of America, Inc., Madison, Wisconsin, U.S.A. p. 525-544.

90. Kubota, J., W.H. Allaway, D.L. Carter, E.E. Cary and V.A. Lazar. 1967. Selenium in crops in the United States in relation to selenium-responsive diseases of animals. J. Agr. Food Chem., 15:448.

91. Lakin, H.W. and D.F. Davidson. 1967. The relation of the geochemistry of Se to its occurence in soils. In Selenium in Biomedicine. Proc. of First International Symposium. O.H. Muth (ed.). The AVI Publ. Co., Inc. p. 27-56.

92. Lewis, D. 1954. The reduction of sulphate in the rumen of the sheep. Biochemistry J., 56:391-399.

93. Loosli, J.K. 1978. Mineral problems as related to tropical climates. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.), University of Florida. p. 5-9.

94. Mayer, G.P. 1970. The roles of parathyroid hormone and thyrocalcitonin in parturient paresis. In Parturient Hypocalcemia. J.J.B. Anderson (ed.). Academic Press, New York, U.S.A. p. 177.

95. McCollum, E.V. 1957. A History of Nutrition. The Riverside Press, Cambridge, Massachusetts, U.S.A. p. 266.

96. McDonald, I.W. 1968. The nutrition of grazing ruminants. Nutr. Abstr. Rev., 38:381.

97. McDowell, L.R. 1976a. Determination of mineral deficiencies and toxicities for cattle in Latin America. University of Florida, Gainesville, U.S.A. Mimeograph.

98. McDowell, L.R. 1976b. Mineral deficiencies and toxicities and their effect on beef production in developing countries. Proc. Beef Cattle Production in Developing Countries, University of Edinburgh, Scotland, Centre for Tropical Veterinary Medicine. A.J. Smith (ed.). p. 216-241.

99. McDowell, L.R. 1977. Geographical distribution of nutritional diseases in animals. University of Florida, Gainesville, Florida, U.S.A. A chapter in the "CRC Handbook of Nutrition and Food".

100. McDowell, L.R., J.H. Conrad, J.E. Thomas and L.E. Harris. 1974. Latin American Tables of Feed Composition. University of Florida, Gainesville, Florida, U.S.A. Dept. of Animal Science.

101. McDowell, L.R., J.H. Conrad, J.E. Thomas, L.E. Harris and K.L. Fick. 1977. Nutritional composition of Latin American forages. Trop. Anim. Prod., 2:273-279.

102. McDowell, L.R., R.H. Houser and K.L. Fick. 1978. Iron, manganese, and zinc in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. p. 108-116.

103. McDowell, L.R., C.E. Lang, J.H. Conrad, F.G. Martin and H. Fonseca. 1978. Mineral status of beef cattle in Guanacaste, Costa Rica. Trop. Agric. (Trinidad), 55:343.

104. McDowell, R.E. 1968. Climate versus man and his animals. Nature, 218:641-645.

105. Mexico. 1979a. Secretaria de Agricultura y Recursos Hidraulicos. Comision del Papaloapan. Oficina de Hidrologia. Estaciones: La Posta - Paso del Toro y Campo Cotaxtla.

106. Mexico. 1979b. Secretaria de Agricultura y Recursos Hidraulicos. Direccion General de Distritos y Unidades de Temporal. Representacion General en Veracruz. III Distrito. Tuxpam, Veracruz.

107. Milford, R. and K.P. Haydock. 1965. The nutritive value of protein in subtropical pasture species grown in south-east Queensland. Aust. J. Exp. Agric. Anim. Husb., 5:13-17.

108. Miller, W.J. 1979. Copper and zinc in ruminant nutrition. In Copper and Zinc in Animal Nutrition, by B. O'Dell, E.R. Miller and W.J. Miller. National Feed Ingredients Association (pub.).

109. Mitchell, R.L. 1963. Soil aspects of trace element problems in plants and animals. J. of the Royal Agriculture Society, 124:75-86.

110. Mott, G.O. and H.L. Popenoe. 1977. Grasslands. In Ecophysiology of Tropical Crops. P. de T. Alvim and T.T. Kozlowski (eds.). Academic Press, New York, U.S.A. p. 157.

111. National Academy of Sciences. 1977. Cooper. Committee on Medical and Biologic Effects of Environmental Pollutants. Washington, D.C., U.S.A.

112. National Research Council. 1976. Nutrient Requirements of Beef Cattle. Nutrient Requirements of Domestic Animals Series. National Academy of Sciences. Washington, D.C., U.S.A.

113. National Research Council. 1978. Nutrient Requirements of Dairy Cattle. Nutrient Requirements of Domestic Animals Series. National Academy of Sciences. Washington, D.C., U.S.A.

114. Nie, N.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner and D.H. Bent. 1975. SPSS - Statistical Package for the Social Sciences. Second Edition. McGraw-Hill Book Company (pub.).

115. Nielsen, F.H., S.H. Givand and D.R. Myron. 1975. Evidence of a possible requirement for arsenic by the rat. Fed. Proc., 34(3):923 (abstr.).

116. Nores, J.G. 1944. Contenido de algunos elementos trazas en praderas naturales uruguayas. Revista de la Facultad de Agronomia, Montevideo, Uruguay, 35:23.

117. Nuñez, A. 1969. Oligoelementos en suelos y forrajeras argentinas. Revista de la Facultad de Agronomia y Veterinaria de Buenos Aires, 17(3):7-14.

118. Olsen, S.R. 1972. Micronutrient interactions. In Micronutrients in Agriculture. J.C. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.). Soil Science Society of America, Inc., Madison, Wisconsin, U.S.A. p. 243-264.

119. Olson, A.D. and W.B. Hamlin. 1969. A new method for serum iron and total iron-binding capacity by atomic absorption spectrophotometry. Clin. Chem., 15(6):438-444.

120. Olson, O.E., I.S. Palmer and E.E. Cary. 1975. Modification of the official fluorometric method for selenium in plants. J. Ass. Off. Anal. Chem., 58:117.

121. Ortiz, D.S. and A. Corrasquero R. 1968. Investigacion sobre posible zonas seleniferas en Venezuela. Agronomia Tropical, 18:369.

122. Paredes Zuñiga, M., D.J. Sykes, J.R. Foster and J.A. Gomide. 1967. Determinacao do conteudo de mineral de treze gramineas forrageiras para corte. Revista Ceres, 13(77): 344.

123. Peeler, H.T. 1972. Biological availability of nutrients in feeds: Availability of major mineral ions. J. Anim. Sci., 35:695.

124. Perdomo, J.T., R.L. Shirley and C.F. Chicco. 1977. Availability of nutrient minerals in four tropical forages fed freshly chopped to sheep. J. Anim. Sci., 45:1114.

125. Pond, W.G. 1975. Mineral interrelationships in nutrition: Practical implications. Cornell Vet., 65(4):441-456.

126. Pope, A.L. 1971. A review of recent mineral research with sheep. J. Anim. Sci., 33:1332.

127. Pope, A.L. 1975. Mineral interrelationships in ovine nutrition. JAVMA, 166(3):264.

128. Ramberg, C.F., Jr., G.P. Mayer, D.S. Kronfeld and J.T. Potts, Jr. 1976. Dietary calcium, calcium kinetics and plasma parathyroid hormone concentration in cows. J. Nutr., 106:671-679.

129. Randhawa, N.S. and N.S. Pasricha. 1976. Interaction of potassium with secondary and micronutrient elements. Bull. Indian Soc. Soil Sci., 10:227.

130. Reith, J.W.S. 1970. Soils factors influencing the trace element content of herbage. In Trace Element Metabolism in Animals. Proc. of WAAP/IBP International Symposium. Aberdeen, Scotland. C.F. Mills (ed.). E & S Livingstone. Edinburgh, Scotland and London, England. p. 410.

131. Rettura, G. 1973. Negative copper balance due to penicillin administration. Am. J. Clin. Nutr., 26:xxiii.

132. Reuter, D.J. 1974. The recognition and correction of trace element deficiencies. In Trace Elements in Soil-Plant-Animal Systems. D.J.D. Nicholas and A.R. Egan (eds.). Academic Press, Inc., New York, U.S.A. p. 291.

133. Rodriguez, E. 1979. Parametros hematologicos normales en bovinos cebu (Indobrasil) desde el nacimiento hasta el destete en clima subtropical $A(_F)c$. B.S. Thesis, Universidad Nacional Autonoma de Mexico, Mexico.

134. Sanchez, P.A. 1976. Properties and Management of Soils in the Tropics. John Wiley and Sons (pub.), New York, U.S.A.

135. Sansom, B.F. 1973. Mineral nutrition and production disease in dairy cows. Br. Vet. J., 129:207.

136. Schalm, O.W. 1965. Veterinary Hematology. Second Edition. Lea and Febiger. Philadelphia, Pennsylvania, U.S.A.

137. Stowe, H.D. 1980. Personal Communication.

138. Suttle, N.F. 1973. Effects of age and weaning on the apparent availability of dietary copper to young lambs. Proc. Nutr. Soc., 32, 24A.

139. Suttle, N.F. 1974. Effect of organic and inorganic sulfur on the availability of dietary copper to sheep. Br. J. Nutr., 32:559.

140. Suttle, N.F. 1975a. Trace element interactions in animals. In Trace Elements in Soil-Plant-Animal Systems. D.J.D. Nicholas and A.R. Egan (eds.). Academic Press, Inc., New York, U.S.A. p. 271.

141. Suttle, N.F. 1975b. The role of organic sulphur in the copper-molybdenum-sulphur interrelationships in ruminant nutrition. Br. J. Nutr., 34:411.

142. Swaine, D.J. 1955. The Trace Element Content of Soils. Commonwealth Bureau Soil Sci., Rothamsted Exp. Sta., Harpenden, England, Tech. Comm., 48. p. 91.

143. Tergas, L.E. and W.G. Blue. 1971. Nitrogen and phosphorus in Jaraguagrass (Hyparrhenia rufa) during the dry season in a tropical savanna as affected by nitrogen fertilization. Agronomy J., 63:6.

144. Theiler, A., H.H. Green and P.J. Du Toit. 1928. Studies in mineral metabolism. III. Breeding of cattle on phosphorus deficient pasture. J. Agric. Sci., 18:369.

145. Thompson, D.J. 1978a. Calcium, phosphorus and fluorine in animal nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. p. 47-54.

146. Thompson, D.J. 1978b. Potassium and iodine in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.). University of Florida. p. 73-79.

147. Thorton, I. 1974. Biogeochemical and soil ingestion studies in relation to the trace element nutrition of livestock. Proc. of Trace Element Metabolism in Animals - 2. W.G. Hoekstra, J.W. Suttie, H.E. Ganther and W. Mertz (eds.). University Park Press, Baltimore, Maryland, U.S.A. p. 451-454.

148. Thorton, I. and J.S. Webb. 1970. Geochemical reconnaissance and the detection of trace element disorders in animals. In Trace Element Metabolism in Animals. Proc. of WAAP/IBP International Symposium Aberdeen, Scotland. C.F. Mills (ed.). E & S Livingstone, Edinburgh, Scotland and London, England. p. 397.

149. Tisdale, S.L. and W.L. Nelson. 1975. Soil Fertility and Fertilizers. Macmillan Publ. Co., Inc., New York, U.S.A.

150. Tokarnia, C.H. and J. Dobereiner. 1973. Diseases caused by mineral deficiencies in cattle raised under range conditions in Brazil, a review. Pes. agropec. bras., Ser. Vet., 8 (supl.):1-6.

151. Underwood, E.J. 1966. The Mineral Nutrition of Livestock. The Central Press, Aberdeen, Scotland.

152. Underwood, E.J. 1975. Trace elements and their physiological roles in the animal. In Trace Elements in Soil-Plant-Animal Systems. D.J.D. Nicholas and A.R. Egan (eds.) Academic Press, Inc., New York, U.S.A. p. 227.

153. Underwood, E.J. 1977. Trace Elements in Human and Animal Nutrition. Academic Press, New York, U.S.A. Fourth Edition.

154. Veracruz, Direccion General de Ganaderia. 1976. Ganaderia, Informacion Basica. Estado de Veracruz. Mimeograph.

155. Viana, J.A.C. 1978. Magnesium in ruminant nutrition. In Latin American Symposium on Mineral Nutrition Research with Grazing Ruminants. J.H. Conrad and L.R. McDowell (eds.) University of Florida. p. 59-66.

156. Vitosh, M.L., D.D. Warncke and R.E. Lucas. 1973. Secondary- and Micro-nutrients for Vegetables and Field Crops. Extension Bulletin E-486. Farm Science Series. Cooperative Extension Service. Michigan State University.

157. Wantanabe, F.S. and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from the soil. Soil Sci. Soc. Amer. Proc., 21:400-404.

158. Warncke, D.D. 1979. Personal Communication.

159. Warncke, D.D. and L.S. Robertson. 1976. Understanding the MSU Soil Test Report: Results and Recommendations. Extension Bulletin 937. MSU AG Facts. Cooperative Extension Service. Michigan State University.

160. Warncke, D.D., D.R. Christenson and R.E. Lucas. 1976. Fertilizer Recommendations for Vegetable and Field Crops (For Michigan). Extension Bulletin E-550 Farm Science Series. Cooperative Extension Service. Michigan State University.