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MINERAL STATUS OF GRAZING BEEF CATTLE IN THE TROPICS OF BOLIVIA[1]

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An experiment was conducted in the Bolivian lowlands to determine the mineral status of three beef cattle ranches at San Ignacio de Velasco (región I) and eight at San Borja (región II) during the dry season. Experimental grazing animals were Zebu-Criollo, with varying egrees of crossbreeding, 3 to 5 years old. Five to nine soil and forage samples, 10 serum samples and 10 liver biopsies were collected from region I while 12 soil and forage and 9 to 13 bone and liver samples from slaughterhouses were obtained from region II.
The critical levels (shown in brackets; mg/kg, DM basis) and percent borderline to deficient soil extractable mineral levels for regions I and II respectively were: Ca (<71) 4.5, 7; Mg (<9.1) 0, 7; P (<5.0) 100, 100; K (<60) 90, 100; Cu (<2) 100, 100; Fe (<30) 55, 74; Zn (<8) 100, 100 and Mn (<10) 7 and 26%. Critical levels (%, DM basis) and percent borderline to deficient forage concentrations were: Crude protein (<7) 24, 76; Ca (<0.30) 90, 57; Mg (<0.20) 75, 64; P (<0.25) 100, 100; Na (<0.06) 100, 100; microelements (mg/kg dry basis); and percent borderline to deficient forage concentrations were: Cu (<10) 85, 100; Zn (< 30) 30, 81; Co (<0.10) 0, 48 and Se (<0.10) 88 and 47% of the total samples for the two regions respectively. Forage K, Fe, Mn and Co met the cattle requirements, with Mo not in excess.
Of the total serum samples from region I, the percent containing low to deficient mineral levels was as follows (with critical levels shown in brackets; mg/100 ml): Ca (<8) 43; Mg (<2) 37; and in µg/ml: Cu (<0.65) 27 and Zn (<0.80) 15. Low to deficient levels of bona Ca (<37.6) and P (<17.6) (% bone ash) from region II were found to be 96 and 45% of the total samples, respectively. Finally, the percent low to deficient liver mineral concentrations (mg/kg , dry basis) found for all samples in regions I and II, respectively, were: Cu (<75) 7, 46; Fe (<180) 14, 36; and Zn (<84) 57, 8%. Based on the soil, forage and animal tissue data observed from these two sampled regions, the nutrients most likely to be deficient are protein P, Na, Cu, Zn, Ca and Se.

Key words: Minerals, beef cattle, Bolivia, tropics, soil, forage

In Latin America, natural pastures are the main source of feed for the beef cattle industry. Hutton (1979) indicated it is unrealistic to consider improvement of pastures and cattle productivity on these soils without some inputs of deficient essential elements. The percent of forage mineral concentrations below the requirements for grazing cattle taken from the 1974 Latin American Tables of Feed Composition (McDowell et al, 1977) were as follows: Ca, 31; P, 73; Na, 60; K, 15; Mg, 35; Fe, 24; Zn, 75; Cu, 47; Mn, 21; and Co, 43%.

Of all essential mineral elements, P is the most widespread deficiency for grazing cattle (Underwood, 1981) and reports of improved reproductive rates and weight gains from P-supplemented cattle have been summarized from various world regions (Cohen, 1975; McDowell, 1976; Fick et al, 1978).

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In Bolivia, the lowlands are considered to have the greatest potential for beef cattle production; however, the annual extraction rate from these regions is approximately 12% (Parra, 1979), with a weaning rate of less than 50% (Wilkins et al, 1981). From the Beni region of Bolivia, Bauer (1979) reported increased pregnancy rates of 13.3% when supplementing breeding herds with bone meal. Similarly, higher ($P < 0.001$) weight gains of 96.4 vs 79.4 and 82.7 kg were observed for salt plus bone phosphate compared to common salt and control groups of cattle, respectively (McDowell et al 1982).

Because mineral nutrition research is inadequate in Bolivia, the objective of this study was to determine the current mineral status of two livestock producing areas, based on the analysis of soil, forage and animal tissues.

Materials and Methods

Five to nine soil and forage, as well as ten blood and liver biopsy, samples were collected from three farms located in region I (San Ignacio de Velasco, Santa Cruz) while 12 soil and forage, and nine to 14 bone (3rd and 4th caudal vertebrae) and liver (from slaughtered animals) samples were collected from eight farms located in region II (San Borja, Beni). The sampling period corresponded to the end of the dry season (September-October); however, samples were collected in 1979 and 1980 in regions I and II, respectively. The surveyed grazing cattle were Zebu-Criollo, with varying degrees of crossbreeding, and animals were 3 and 3 to 5- year old steers in the respective regions.

The procedure for soil collection has been described by Bahia (1978), while procedures for sample collection and analysis of mineral concentrations in forage and animal tissues have been described by Fick et al (1979). Minerals were extracted from the soil samples with the double extractant method (0.025 N H_2SO_4 plus 0.5N HCl) described by Mitchell and Rhue (1979). Soil pH was determined using a 1:2 soil to water ratio in a standard glass electrode and a calomel reference electrode.

Mineral analyses as determined by atomic absorption (Perkin-Elmer, 1973) for the following samples were: soil and forage; Ca, Mg, Na, K, Cu, Fe, Zn, Mn); serum; Ca, Mg, Cu, Zn; liver; Cu, Fe, Zn, Mn; and bone; Ca, Mg. Except for liver, P was determined in all samples by the Fiske and Subarrow (1925) method, with modification as described by Fick et al (1979). Liver and forage Co and Mo concentrations were determined using atomic absorption[1] with a graphite furnace and D_2 corrector. Forage and liver Se were analyzed by the fluorometric procedure by Whetter and Ullrey (1978). Forage crude protein determination has been described by Technicon Industrial Systems[7].

Analysis of variance was applied to the data for a nested design with unequal subclass replications (Snedecor and Cochran, 1973), using the General Linear Model Procedure of the Statistical Analysis System (Barr et al, 1976). Only one forage species -Paja carona (*Sporobolus poiretii*)- was collected from region I, while four species were obtained from region II

[1] *Perkin-Elmer Model 503 with 2100 HGA, Norwalk, CT.*

[7] *Technicon Industrial Systems, Industrial Method No. 506-77A, Tarrytown, NY.*

-Gramalote (*Paspalum plicatulum*), paja spp (unknown), Cañuela (*Echinoclhoa* sp.) and Paja toruna (*Andropogon* sp.) . Because no species was found on every farm, forage statistical analysis was broken into three subgroups: subanalysis A examined the difference in Paja carona among farms from region I while subanalysis B and C examined differences between Gramalote and between Cañuela and Paja toruna within region II, respectively.

Appropriate F-tests were constructed for detecting differences between regions and among farms within regions. Also, plant species differences as well as farm x species interaction were measured whenever possible. Correlation coefficients among minerals, soil pH and forage crude protein were estimated in soil, plant and animal tissues.

Results and Discussion

Mean forage and soil mineral concentrations between regions are found in tables 1 and 2, respectively. Differences among farms within regions ($P < 0.01$) were found for all measured soil responses (Ca, Mg, P, Na, K, Cu, Fe, Zn, Mn and pH). Only for Na and Cu were there differences ($P < 0.05$) between regions. With respect to mineral content in the forage species Paja carona within region I, differences were observed among farms for Ca ($P<0.01$) and Mo ($P < 0.05$) only. Six of seven farms from region II reported forage species Gramalote higher ($P < 0.01$) in Ca, Mg, Mn and Co and in Cu ($P < 0.05$) than Paja spp. From this region, a forage species x farm interaction ($P < 0.01$) was also found for Mg, P, Fe, Zn, Mn, Co and Mo as well as for Na and K ($P < 0.05$). Also, forage species Cañuela present in one farm from the same region showed higher ($P < 0.01$) levels of Mg, Na, P, K, Fe and Zn as well as higher ($P < 0.05$) Cu than Paja toruna. Only Co was higher in Paja toruna than Cañuela. No differences ($P > 0.05$) were detected among farms for any of the measured responses (Ca, Mg, P, Cu and Zn) regarding serum samples from region I.

In region II, there were differences ($P < 0.01$) in bone Ca when expressed as both percent dry fat-free bone and as percent dry fat-free bone ash. However, farms differed ($P < 0.05$) in bone P when expressed as percent dry fat-free bone ash only.

Liver mineral differences ($P < 0.01$) between regions were found only for Zn and Co. However, differences ($P < 0.01$) among farms were found for every response (Cu, Fe, Zn, Mn, Mo, Co, Se).

Soil correlation coefficients ($P < 0.05$) above ±0.5 were as follows: Ca-Mg ($r = 0.82$), Ca-pH ($r = 0.55$, Ca-Fe ($r = 0.70$), Mg-pH ($r = 0.63$), Mg-Fe ($r = -0.70$), Na-pH ($r = 0.60$) and Fe-pH ($r = -0.63$). Forage mineral correlations were found from region I as follows: Mg was correlated with P ($r = 0.96$), Na ($r = 0.64$), K ($r = 0.64$), Fe ($r = 0.63$), Zn ($r = 0.89$), Mn ($r = 0.61$), Co ($r = 0.62$), Se ($r = 0.85$) and crude protein ($r = 0.88$). Phosphorus was correlated with Na ($r = 0.79$), K ($r = 0.63$), Cu ($r = 0.60$), Fe ($r = 0.79$), Zn ($r = 0.89$), Co ($r = 0.60$), Se ($r = 0.92$) and crude protein ($r = 0.97$). Sodium was correlated with Cu ($r = 0.55$), Zn ($r = 0.60$) and crude protein ($r = 0.75$). Potassium was correlated with Fe ($r = 0.75$) and Zn ($r = 0.70$). Copper was correlated with Zn ($r = 0.56$), Mg ($r = 0.62$) and crude protein

Table 1:
Mean soil mineral concentrations by region compared to reported critical levels (mg/kg, dry basis)[a]

Element	Critical level[a]	REGION I			REGION II		
		Mean	S.D.	% samples below critical level	Mean	S.D.	% samples below critical level
Ca	< 71	192.0	219.7	4.5	430.0	273.0	7.1
Mg	< 9.1	34.2	29.8	0	157.5	98.6	7.1
P	< 15.0	1.2	0.29	100.0	1.0	0.59	100.0
Na	Unknown	15.5[d]	16.4		157.5[c]	129.6	100.0
K	< 60.0	34.1	21	90.0	38.7	7.2	100.0
Cu	< 2.0	0.3[d]	0.10	100.0	0.5[c]	0.27	100.0
Fe	< 30.0	24.0	14.5	54.0	25.0	20.2	74.0
Zn	< 8.0	1.3	0.35	100.0	0.6	0.19	100.0
Mn	< 10.0	0.3	7.6	6.8	14.7	7.7	26.2

[a] Least square means and standard deviations are based on 22 and 84 samples for regions I and II, respectively.

[b] References for critical levels are as follows: Ca, Mg, P (Breland, 1976); K (Bahia, 1978): Cu, Fe, Zn (Large, 1971); and Mn (Cox, 1968).

[c,d] Means within rows with different superscripts differ ($P < 0.05$).

($r = 0.79$). Iron was correlated with Zn ($r = 0.91$), Mn ($r = 0.57$) and Co ($r = 0.60$). Zinc was correlated with Mn ($r = 0.61$), Co ($r = 0.56$), Se ($r = 0.80$) and crude protein ($r = 0.83$) and finally, a Se-crude protein correlation ($r = 0.95$) was found. From region II, forage Ca was correlated with Mn ($r = 0.80$), Mg ($r = 0.77$) and Co ($r = 0.75$), while Mg was correlated with Cu ($r = 0.52$), Fe ($r = 0.56$), Zn ($r = 0.60$), Mg ($r = 0.77$) and Co ($r = 0.77$). Other mineral correlations from forages within region II were P-crude protein ($r = 0.60$), Fe-Zn ($r = 0.50$), Fe-Co ($r = 0.60$), Zn-Mn($r= 0.62$), Zn-Se ($r = 0.51$) and Mn-Co ($r = 0.71$). Even though some significant ($P < 0.05$) mineral correlations were found in bone, serum and liver data, none of them were greater than or equal to ± 0.5.

Calcium: Mean soil extractable Ca was 192.0 and 430.0 ppm for regions I and II, respectively (Table 1). The minimum and maximum concentrations of extractable Ca for all samples were 36 and 999 ppm, respectively. In spite of this wide range, only 7% of the total soil samples were below 71 ppm Ca. Breland (1976) reported that for Florida soils, normal Ca concentrations would be on the order of 72 to 140 ppm extractable Ca. Six out of eight soil samples showing low to deficient extractable Ca levels came from one particular farm in region II, which also had the lowest soil pH (5.2).

Mean forage Ca for region I was 0.21% (Table 2), with 90% of the samples containing less than the critical level of 0.39% Ca cited by McDowell and Conrad (1977) for grazing cattle. Cunha et al (1964) reported that serum Ca concentrations lower than 8 mg/100 ml were indicative of Ca deficiency in grazing cattle. Based on this criterion, 43% of the sampled animals from region I had borderline to deficient Ca status (Table 3).

Table 2:

Mean forage mineral and crude protein concentrations by region compared to reported critical levels[a,b,c]

Element	Critical level[d]	REGION I			REGION II		
		Mean	S.D.	% samples below critical level	Mean	S.D.	% samples below critical level
Ca %	< 0.30	0.21	0.06	90	0.25	0.12	57.0
Mg %	< 0.20	0.16	0.05	75	0.19	0.07	64.0
P %	< 0.25	0.15	0.05	100	0.12	0.03	100.0
Na %	< 0.06	0.01	0.005	100	0.009	0.003	100.0
K %	< 0.60	1.38	0.43	0	0.85	0.29	1.0
Cu, mg/kg	<10	5.94	3.3	85	1.33	0.58	100.0
Fe, mg/kg	<30	133.6	100	0	121.9	66.9	0
Zn, mg/kg	<30	30.2	9.7	30	25.7	15.7	81.0
Mn, mg/kg	<20	133.2	29.5	0	389.3	251.9	0
Co, mg/kg	< 0.10	0.16	0.03	0	0.13	0.08	47.6
Mo, mg/kg	< 6	0.86	0.60	0	0.85	0.52	0
Se, mg/kg	< 0.10	0.07	0.01	88	0.10	0.04	47.0
Crude protein %	< 7	8.6	2.43	24	5.6	2.13	76.0

a Least square means and standard deviations.

b Means are based on the following number of samples: Region I - 20, except Se and crude protein (19); Region II - 84, except Se and crude protein (42).

c Major forage species are: Region I - Paja carona (*Sporobolus poiretii*) and Region II - Gramalote (*Paspalum dilatatum*), Paja spp (unknown) and Paja toruna (*Andropogon* sp.).

d Reference: McDowell and Conrad (1977).

Table 3:

Mean blood serum mineral concentrations in region 1 compared to critical levels[a,b,c]

Element	Mean	S.D.	Critical level[d]	% samples below critical level
(mg/100 ml)				
Ca	8.0	0.73	< 8.0	43
Mg	2.1	0.35	< 2.0	37
P	6.7	0.10	< 4.5	0
(µg/ml)				
Cu	0.62	0.18	< 0.65	27
Zn	1.11	0.40	< 0.80	15

a Least square means and standard deviations.

b Means are based on the following sample numbers: Ca, Mg and P (30); Cu and Zn (26).

c No differences among farms were found ($P < 0.05$)

d References for critical levels are as follows: Ca (Cunha et al, 1964); Mg (CMN, 1973); P (Underwood, 1966); Cu and Zn (McDowell and Conrad, 1977).

Even though most literature indicates blood Ca levels as not affected by dietary Ca, in the study reported herein, the highest mean forage Ca observed in one farm likewise had the highest mean serum Ca levels. Also, another farm had both the lowest forage and serum Ca concentrations. Forage Ca from region II was 0.25%, of which 57% of the samples were lower than 0.30%.

Ammerman et al (1974) and Campo and Tourtellote (1967) reported bone ash Ca contents from grazing cattle varied from 37.6 to 38.8% on the same basis. Mendes (1977) reported bone ash Ca concentrations to range from 36.96 to 38.45 %. When expressing these means as percent dry fat-free bone, the Ca concentrations ranged from 22.7 to 24.8 %. The mean caudal vertebrae ash Ca contents from grazing animals located in region II ranged from 30 to 33.4 and from 18.2 to 20.5 % when expressed as percent bone ash or percent dry fat-free bone, respectively. Ninety-six percent of the bone samples had Ca levels lower than 34% of bone ash Ca (Table 4).

Table 4:

Mean bone mineral concentrations in region II compared with low to critical levels[a]

Element	Mean	S.D.	Low to critical levels[b]	% samples below critical level
(% dry fat-free basis)				
Ca	19.54	1.64[c]	< 24.5	100
Mg	0.47	0.06	Unknown	
P	10.50	1.10	< 11.5	84
(% ash basis)				
Ca	31.52	2.7[c]	< 37.6	96
Mg	0.76	0.1	< 0.67	0
P	17.10	1.8[d]	< 17.6	45

[a] Least square means and standard deviations are based on 95 samples.

[b] References for low to critical levels are as follows: % dry fat-free basis, Ca and P (Little, 1972); % ash basis, Ca and P (Ammerman et al, 1974) and Mg (Blaxter and Sharman, 1955).

[c] Means in column with superscript differ ($P < 0.01$) among farms.

[d] Means in column with superscript differ ($P < 0.05$) among farms.

Phosphorus: Mean soil extractable P for regions I and II were 1.2 and 1.0 ppm, respectively (Table 1). No difference ($P > 0.05$) between regions was found. Breland (1976) reported the following criteria for Florida soils: 0 to 5 ppm P, very low; 6 to 13 ppm P, low; 14 to 25 ppm P, medium; and 26 to 50 ppm P as a soil rich in this element.

McDowell and Conrad (1977) indicated that the critical forage P level for grazing cattle was lower than 0.25%. The NRC (1976) considers the

Table 5:

Mean liver mineral concentrations by region compared with low to critical levels[a]

Element	Critical level[b]	REGION I			REGION II		
		Mean	S.D.	% samples below critical level	Mean	S.D.	% samples below critical level
Cu	< 75	133.1	68.5	7	93.6	63.4	46
Fe	< 180	246.4	71.4	14	259.0	159.4	36
Zn	< 84	88.9[d]	36.3	57	120.2[c]	28.9	8
Mn	< 6	9.2	2.9	3	9.0	2.0	2
Co	< 0.05	0.57[c]	0.22	0	0.30[d]	0.07	0
Mo	< 6	4.33	0.96	0	4.51	1.42	0
Se	< 0.25				0.70	0.24	0

[a] Least square means and standard deviations are based on 30 samples in region I and 96 in region II.

[b] Reference: McDowell and Conrad (1977).

[c,d] Means not followed by the same superscript differ ($P < 0.01$) between regions.

native pastures showed mean liver Cu and Mo contents of 93.6 and 4.5 ppm for this region, respectively (Table 2). Forty-six percent of these samples were below 75 ppm Cu (Table 5). However, in two farms, 19 out of 23 samples had liver Cu concentrations ranging from 8 to 27 ppm. At the same time, these farms had the highest mean liver Fe contents (500 and 380 ppm), with 11 out of 23 samples ranging from 390 to 392 ppm. Bennets et al (1948) reported cattle liver Fe concentrations ranging from 370 to 7,500 ppm along with 1.4 to 10 ppm Cu. Forage and soil samples were only collected from the farm with the mean of 500 ppm liver Fe. This farm is located on soils with the lowest pH and with flooding conditions. Sanchez (1976) indicated flooding increases solubility of Fe because of its reduction from Fe^{3+} to Fe^{2+}. A possibly increased Fe absorption via water consumption is suggested as interacting with the already low soil and forage Cu levels.

Iron: Mean soil extractable Fe concentrations were 24 and 25 ppm for regions I an II, respectively. Large (1971) indicated that Fe fertilizer recommendations are made if soil Fe levels fall below 30 to 35 ppm. Based on this criterion, 54 and 74 % of the soil samples for the cited regions are considered low to deficient (Table 1). In spite of these low soil Fe levels, mean forage Fe concentrations were 133.5 and 121.9 ppm in both regions (Table 2), with none of the samples containing levels below the requirement range of 10 to 30 ppm suggested by the ARC (1980) and NRC (1976) for beef cattle. These results agree with Sousa(1978) who reported soil Fe from northern Mato Grosso, Brazil ranging from 15 to 42 ppm, with forage containing adequate to high Fe contents for grazing cattle.

Mean liver Fe levels for animals grazing regions I and II were 246 and 259 ppm, respectively (Table 5). Fourteen percent of the sampled animals had liver Fe ranging from 134.2 to 168 ppm, which is considered minimum P requirement of growing and finishing steers and heifers as 0.18%. The mean forage P content reported for region I was 0.15% (Table 2), with 100% of the samples containing less than 0.25%. No difference ($P > 0.05$) among farms was found. Despite these figures, this region showed a mean blood serum P content of 6.7 mg/100 ml (Table 3) which is higher than the critical value of 4.5 mg P/100 ml of serum cited by Underwood (1981) as indicative of P deficiency. Stress, exercise, hemolysis, elevated temperature and increased serum separation time are all factors that cause increases in serum P levels (Dayrell et al, 1973; Fick et al, 1979). Animal stress is suggested as one of the main causes for the high P levels since this factor was difficult to control under the conditions of this experiment.

Ammerman et al (1974) and Campo and Tourtellote (1967) reported dry fat-free bone ash P in grazing cattle varied from 17.6 to 18.1 and from 16.4 to 18.7%, respectively. On dry fat-free bone basis, Cohen (1973), in a preliminary study on yearling steers fed a P supplement, concluded that levels below 13% P can be considered as low to deficient. Mendes (1977) observed dry fat-free bone P ranging from 9.4 to 10.1 % in cattle showing a bone ash P range of 15.1 to 15.5 %. In this study, mean bone ash P was 17.1% (Table 4), with 45% of the samples less than 17%. When P content was expressed as percent dry fat-free bone, the mean was 10.5%, of which 84% of the samples were below 11.5% P (Table 4). The dry fat-free bone P did not show differences ($P > 0.05$) among farms, but the bone ash P did ($P < 0.05$).

Magnesium: Region II had a mean soil extractable Mg content of 157.5 ppm which was higher ($P < 0.01$) than the 34.2 ppm from region I (Table 1). Breland (1976) indicated that for Florida soils, extractable Mg levels between 9.2 and 21.1 ppm are considered as medium, with soils having more than 21.1 ppm Mg as high. None of the samples from region I were below 12 ppm Mg. Mean forage Mg was 0.16% (Table 2), with 75% of the samples containing less than the 0.18% Mg recommended by the NRC (1976) for lactating cows and breeding bulls. The mean blood serum Mg level observed from steers grazing those pastures was 2.08 mg/100 ml (Table 3); however, 37% of the total serum samples were less than 2 mg/100 ml cited by McDowell and Conrad (1977) as critical for grazing cattle. There was no serum Mg difference ($P > 0.05$) among farms.

Regarding the Mg status within region II, 7.1% of the soil samples were below 9.1 ppm extractable Mg (Table 1). All of these samples were found in one farm which also reported the lowest pH (5.2). This region had a mean forage Mg content of 0.19%, with 64% of the samples below the critical level of 0.20% (Table 2). Cattle grazing in region II showed an average of 0.76 and 0.47% Mg when expressed as percent bone ash and percent dry fat-free bone, respectively (Table 4). One-hundred percent of the bone samples were above the 0.60% bone ash Mg level found by Lebdosoekojo (1977) in healthy grazing young bulls. No differences ($P > 0.05$) among farms were detected by either of the Mg bone expressions.

Sodium and Potassium: According to Bahia (1978), less than 60 ppm and more than 120 ppm of soil available K are considered low and high levels of this element, respectively. Mean soil K for regions I and II was reported as 34.1 and 38.7 ppm, respectively. On the basis of cited critical levels, 90 and 100 % of the soil samples were low in extractable K in regions I and II, respectively (Table 1).

The NRC (1976) recommends 0.6 to 0.8 % dietary K for cattle. In spite of low soil extractable K in both regions, forage K content was adequate for supplying the grazing cattle's needs, with concentrations of 1.4 and 0.85 % for regions I and II, respectively.

Soil extractable Na differed ($P < 0.05$) between regions. Observed means were 15.5 and 157.5 ppm Na for regions I and II, respectively (Table 1). McDowell et al (1982) found soil extractable Na levels of 43.5 ppm in the Bolivian lowlands and mean forage Na contents of 0.03%. This level of forage Na is considered as one-half of cattle requirements (0.06%) as recommended by the NRC (1976). Sousa (1978) reported a severe deficiency in northern Mato Grosso, Brazil, with a soil pH of 5.7 and 38 ppm of available Na. Forage Na from that area supplied only 14 to 32 % of the cattle needs. Even though soil extractable Na differed between regions, forage mineral data from both regions showed Na levels fluctuating between 0.002 and 0.02 %, supplying only 3 to 33% of the grazing cattle's needs. Mean forage Na levels for regions I and II are shown in Table 2.

Copper and Molybdenum: Despite the differences ($P < 0.05$) in soil extractable Cu between regions, 100% of the samples from both regions were lower than the 2 ppm soil Cu level cited by Large (1971) as adequate for most crops. In the present study, regions I and II had mean soil extractable Cu values of 0.3 and 0.5 ppm, respectively (Table 1); individual samples ranged from 0.08 to 1.0 ppm Cu.

Mean forage Cu content from region I was 5.9 ppm, with no differences ($P > 0.05$) among farms. Eighty-five percent of the forage samples (Table 2) had levels below the 10 ppm reported by McDowell and Conrad (1977) as generally adequate for grazing cattle. Sampled animals showed a mean serum Cu value of 0.62 μg/ml(Table 3), which is considered borderline to deficient in this microelement (McDowell and Conrad, 1977). Contrary to forage and serum Cu concentrations, only 7% of these animals had liver Cu levels that were borderline to deficient (< 75 ppm) (McDowell and Conrad, 1977), with a mean of 133.1 ppm liver Cu (Table 5). A possible explanation for this situation is based on a report by Miltimore and Mason (1971) related to Cu and Mo interrelationships. They indicated the critical Cu:Mo ratio is considered to be 2:1, with ratios below 2:1 causing "conditioned" Cu deficiency in cattle. In this study, the minimum Cu:Mo ratio was 5:1.

Mean forage Mo content for this region was 0.86 ppm, with none of the samples having levels above 6 ppm Mo (Table 2), considered as critical (Mc Dowell and Conrad, 1977). Mean liver Mo content for these animals was 4.3 ppm (Table 5), with a range of 3 to 6.3 ppm. Lebdosoekojo (1977) reported liver Mo levels in young bulls on native pastures with and without mineral supplementation as 3.9 and 4.5 ppm, respectively.

From region II, mean forage Cu content was 1.33 ppm (Table 2), with 100% of the four forage species collected containing Cu levels below 5 ppm. The same table shows a mean Mo level of 0.85 ppm. Animals grazing these low when compared with the apparently normal cattle liver Fe range of 180 to 300 ppm (Underwood, 1977). On the other hand, from region II, 35% of the liver samples (Table 5) showed a range of 100 to 179 ppm Fe. The species *Paspalum dilatatum*, which is often selected by cattle, contained a mean Mn level of 610 ppm (Table 2), with 79% of the samples ranging from 450 to 1000 ppm Mn. Gavillon and Quadros (1973), studying native grasses from Rio Grande do Sul, Brazil, found Fe contents above the beef cattle requirements. In spite of that, they suggested a possible Fe deficiency due to Mn interference in zones where Fe was lower than 150 ppm and Mn above 400 ppm. The possibility of high Mn intake interfering with Fe absorption in this study is suggested.

Zinc: Mean soil extractable Zn concentrations were 1.3 and 0.6 ppm for regions I and II, respectively (Table 1). Large (1971) indicated soil Zn levels should be maintained between 8 and 10 ppm. One hundred percent of the soil samples were below 6 ppm in region I and below 0.9 ppm in region II (Table 1). Sanchez (1976) reported that soil Zn levels of 1.5 ppm were associated with 14 ppm Zn in plant tissue. The mean forage Zn content from region I was 30.2 ppm (Table 2), with 30% of the samples containing the critical value of less than 30 ppm cited by McDowell and Conrad (1977) for grazing cattle. Animals grazing this region had a mean serum content of 1.1 μg/ml (Table 3), with 15% of the animals showing Zn levels lower than 0.80 μg/ml, indicating a low Zn status (McDowell and Conrad, 1977). Further, liver samples from these animals had a mean Zn level of 88.9 ppm (Table 5); 57% of the samples were below the range of 84 to 132 ppm cited by Miller and Miller (1962) for apparently healthy cattle. With respect to region II, mean forage Zn content was 25.7 ppm, with 81% of the samples containing less than the critical level of 30 ppm (Table 3). Mean liver Zn from this region this region was 120.2 ppm, with only 8% of the sampled animals showing levels below 84 ppm (Table 5). The few samples with low Zn concentrations were uniformly distributed among the eight surveyed farms.

Manganese: Cox (1968) reported the critical value of extractable Mn to be 10 ppm for soils with a pH ranging from 5.2 to 7.1. Mean soil extractable Mn concentrations were 9.3 and 14.7 ppm (Table 1) for regions I and II, with 6.8 and 26.2 % of the samples containing less than the cited critical level, respectively. Forage Mn concentrations for these two regions were 133.2 and 389.3 ppm (Table 2). Liver Mn concentrations were above the critical concentration of 6 ppm (McDowell and Conrad, 1977) in both regions (Table 5). Even though forage Mn was considerably higher than the requirement, liver Mn was considered normal, which is in agreement with Thomas (1970), who summarized data indicating small changes in tissue Mn levels (twofold) by increased dietary Mn 200-fold.

Cobalt: According to Houser et al (1978), less than 0.1 ppm Co in the forage should be considered deficient for grazing cattle. Mean forage Co content from region I was 0.16 ppm (Table 2), with none of the samples below that concentration. From region II, there were forage Co differences ($P < 0.05$), with 47.6% of the total samples containing less than the critical level of 0.10 ppm (Table 2). However, grazing cattle generally select the two species that have the higher Co in preference to the other two and therefore likely meet their Co requirements.

Mean liver Co concentrations were 0.57 and 0.30 ppm for regions I and II, respectively (Table 5), being higher ($P < 0.01$) for region I. None of the liver samples contained levels below 0.05 ppm cited by McDowell and Conrad (1977) as borderline to deficient for grazing cattle.

Selenium: Underwood (1977) indicated that pastures and forages free from Se-responsive diseases contain 0.10 ppm Se or more while in areas with a variable incidence of such diseases, the levels are mostly below 0.05 ppm. Mean forage Se contents from regions I and II were 0.07 and 0.10 ppm (Table 2), with 88 and 47 % of the samples, respectively, containing levels below 0.10 ppm. Forage species collected from region II did not differ ($P > 0.05$) in relation to this micromineral content.

Liver Se analysis was carried out only for region II, from which a mean of 0.70 ppm was observed (Table 5). All animals contained liver Se levels above the 0.25 ppm reported by McDowell et al (1978) as normal for grazing cattle.

Crude protein: Milford (1960) indicated if energy balance is positive and crude protein digestibility is around 49.3%, crude protein concentrations of 7.0% in forage pastures are sufficient to give zero N balance. In the present study, mean forage crude protein from region I was 8.6% (Table 2), with 24% of the samples containing less than the cited critical value. However, from region II, 76% of the forage samples were below 7% crude protein (Table 2).

Conclusion

Based on the soil, forage and animal tissue data observed from the two sampled regions, the nutrients most likely to be deficient are protein, P, Na, Cu, Zn, Ca and Se.

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