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Mineral status of soils, forages and cattle in Nicaragua. I. Microminerals.[1]

Nivel mineral existente en suelos, forrajes y ganado bovino en Nicaragua. I. Microminerales.

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Abstract

A study was conducted to determine the micromineral status of cattle in six important cattle-producing regions of Nicaragua. A total of 14 farms within six regions during the wet season and eight farms within two regions during the dry season were evaluated. States in each region were: I (Esteli), II (Leon and Chinandega), III (Managua), IV (Granada and Rivas), V (Boaco and Chontales), and VI (Matagalpa and Jinotega). On each farm, 14 composite soil and forage samples and 30 blood samples (lactating cows, heifers and calves) were collected and analyzed for micromineral concentrations. Soil Mn was different (P < .05) among regions in the wet season. Soil Cu was higher (P < .05) and Mn and Zn lower (P < .05) in the wet season. Region III showed the highest frequency of soil samples deficient in Fe (< 2.5 ppm), Cu (< 0.3 ppm) and Zn (< 2.5 ppm) in the wet season. In the dry season, soil Cu and Fe deficient samples were higher in region IV. Forage Cu (< 8 ppm). Zn (< 30 ppm) and Co (< 0.1 ppm) deficient samples were close to 100 %, indicating that supplementation of these microminerals may be needed across all regions. Forage Mn was higher (P < .05) in region V than in other regions, except for region II. Percentage of samples below the critical level (< 40 ppm) ranged from 24 to 100 % in the wet season and 86 and 17 % for regions IV and V, respectively, in the dry season. Forage samples deficient in Se (< 0.2 ppm) were less than 50 % among regions, except for region V in the dry season (87 %). Percentage of forage Se and Zn samples were lower and higher, respectively, in the wet season. No differences among regions and animal classes

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were found in serum Cu and Zn. Serum Se was lower (P < .05) in calves than heifers in the dry season. Percentage of serum samples deficient in Se (< 4 µg/ 100 mL) ranged from 13 to 93 % in the wet season. Serum Cu (< 50 µg/100 mL) deficient samples ranged from 0 to 43% in the wet season. Region IV showed the highest frequency of serum Zn (< 60 µg/100 mL) deficient samples (50 %).
Key words: Cattle, Nicaragua, microminerals, forrages, soil.

Resumen

Este estudio fue conducido para determinar el nivel de microminerales de ganado bovino en seis regiones ganaderas de Nicaragua. Se evaluó un total de 14 fincas en seis regiones durante la época lluviosa y un total de ocho fincas en dos regiones durante la época seca. Las regiones comprendieron los siguientes departamentos: I (Esteli), II (Leon y Chinandega), III (Managua), IV (Granada y Rivas), V (Boaco y Chontales), y VI (Matagalpa y Jinotega). De cada finca se obtuvieron 14 muestras de suelo y de forrajes, y 30 muestras de sangre de ganado vacuno (vacas lactantes, novillas y becerros) para determinar el contenido de microminerales. La concentración de Mn en el suelo varió (P < .05) entre las regiones durante la época lluviosa. La concentración de Cu fue más alta (P < .05) y las de Mn y Zn más bajas (P < .05) durante la época lluviosa en todas las regiones. La región III tuvo el más alto porcentaje de muestras de suelo deficientes en Fe (< 2.5 ppm), Cu (< 0.3 ppm) y Zn (< 2.5 ppm) durante la época lluviosa; durante la época seca, las muestras de suelo deficientes en Fe y Cu fueron más altas en la región IV. El porcentaje de muestras de forrajes deficientes en Cu (< 8 ppm), Zn (< 30 ppm) y Co (< 0.1 ppm) fue de casi 100 % en las seis regiones, lo cual demuestra la necesidad de suplementar estos microminerales. La concentración de Mn en el forraje fue más alta (P < .05) en la región V que en las demás regiones, a excepción de la región II. El porcentaje de muestras de forrajes por debajo del nivel crítico (< 40 ppm) fluctuó entre 24 y 100 % durante la época lluviosa, y durante la época seca fue de 86 % y 17 % en las regiones IV y V, respectivamente. El porcentaje de muestras de forrajes deficientes en Se (< 0.2 ppm) fue de menos de un 50 % entre las regiones durante la época seca, excepto en la región V (87 %). Durante la época lluviosa, el porcentaje de muestras de forrajes deficientes en Se y Zn fue más alto y más bajo, respectivamente, que en la época seca. Durante la época lluviosa, no se encontró efecto de región ni de clase de animal en la concentración de Cu y Zn en el suero sanguíneo. Durante la época seca, la concentración de Se en el suero sanguíneo fue más baja (P < .05) en los becerros que en las novillas. Durante la época lluviosa, el porcentaje de muestras de suero sanguíneo deficientes en Se (< 4 µg/100 mL) fluctuó entre 13 y 93 %, y el de las muestras de suero sanguíneo deficientes en Cu (< 50 µg/100 mL) fluctuó entre 0 y 43 %. La región IV tuvo el más alto porcentaje de muestras (50 %) de suero sanguíneo deficientes en Zn (< 60 µg/100 mL).
Palabras claves: Ganado, Nicaragua, microminerales, forraje, suelo.

Introduction

Poor animal performance and reproductive problems in livestock are associated with micromineral deficiencies (39). The concentration of trace elements in plants is influenced by soil genesis, fertilizer practices and plant factors such as plant species and stage of maturity. As soil pH rises, the availability of Mo and Se for the plant increases. However, the availability of Fe, Mn, Zn, Cu and Co decreases (18). Poor soil drainage and aeration increases the availability and uptake of Cu, Co, Fe and Mn by plants (11). As plants mature, mineral concentrations decline due to a natural dilution process and translocation of nutrients to the root system (18).

In tropical regions of Latin America, grazing cattle often do not receive mineral supplements, except from common salt. McDowell (17) recommended a free-choice complete mineral mixture as an insurance for providing minerals where the dietary concentrations are unknown or highly variable due to season, location, forage species, and animal potential. It is important to determine mineral concentrations of soils, forages and animal tissues to estimate the mineral needs of grazing ruminants, as well as the time of the year when they are most required.

The purpose of this study was to evaluate the mineral status of selected cattle-producing regions of Nicaragua. The present article describes the microelement status of soils, plants and animals during the wet season (1991) and dry season (1992), while the companion article (43) dealt with macrominerals and forage organic constituents.

Materials and methods

Location. A total of 14 farms located within six regions during the wet season (July and August, 1991) and eight farms within two regions during the dry season (March, 1992) were sampled. States in each region were: I (Esteli), II (Leon and Chinandega), III (Mana-gua), IV (Granada and Rivas), V (Boaco and Chontales), and VI (Matagalpa and Jinotega). For the two most important cattle-producing regions, the same farms were selected for both the wet and dry seasons. In the wet season, samples were collected from one farm in regions I and III, two in regions II and VI, three in region IV, and five in region V. During the dry season, samples were collected from three farms in region IV and five in region V. Season comparisons were only made for regions IV and V.

Sample collection and analyses. Composite forage and soil samples were collected at 14 sites on each farm during both seasons. Each composite soil sample was derived from three subsamples taken at a depth of 20 cm as described by Sánchez (33). Forage samples from the major species from each farm (*Pennisetum purpureum, Cynodon pectostachyum, Andropogon gayanus, Panicum maximum,* *Hyparrhenia rufa*) were collected. Not all forage species were collected from every farm. On each farm, blood samples were collected from 30 animals (mainly crossbred Zebu × Brown Swiss or Zebu × Holstein) in different physiological states (10 lactating cows, 10 heifers, and 10 suckling calves) for both seasons. Lactating cows ranged in age from 3 to 9 years, and heifers from 1 to 3 years. Suckling calves of both sexes were sampled according to availability. Blood samples were collected by jugular puncture in vacutainers (10 mL). Serum samples were deproteinized with 10 % trichloroacetic acid and 1 % $LaCl_3$.

Soil extractable Cu, Fe, Mn and Zn were determined by Inductively Coupled Argon Plasma (15). Forage and serum Cu, Fe, and Zn, and forage Mn were determined by flame atomic absorption spectrophotometry (28). Forage Co was determined by flameless atomic absorption spectrophotometry (29). Serum and forage Se were determined fluorometrically (46).

Data from each season were statistically analyzed separately using a mixed, nested design model by the General Linear Model procedure (35). Farm was considered a random variable nested within regions. Comparisons between seasons were tested for soil and forage data for regions IV and V. Differences among classes of animals were tested using the following orthogonal contrasts: lactating cows (2) vs heifers (-1) and calves (-1) and heifers (-1) vs calves (1). Differences among regions were tested using t-test.

Soil, forage and serum mineral concentrations were compared to established critical values to determine percentage of deficient samples The critical level for soils indicates the element concentration below which normal growth and(or) mineral composition of grasses may be adversely affected. For forage samples, it indicates the lowest requirement of the element or organic constituent to avoid deficiency signs in cattle. Serum critical levels indicate the concentration below which specific signs of deficiency may occur. Interpretation of these critical values should be done with caution, taking into consideration the many management, nutritional, environmental and individual factors that affect the availability, supply and utilization of each nutrient (31).

Results and discussion

Soil analyses. Average soil extractable Cu in the wet and dry seasons did not vary among regions (table 1). When comparing seasons in regions IV and V (table 2), soil Cu was higher ($P < .05$) in the wet season. Copper availability to plants seems to be affected by soil pH. Aubert and Pinta (2) and Sanders and Bloomfield (34) suggested that available Cu decreases with increasing pH. Soil pH of region IV was higher than region V (table 3), which may have lead to an increase in Cu adhered to soil components and a decrease in Cu in soil solution as cupric ions, which is the available form for plants. Soil Cu availability is related to soil OM. Kabata-Pendias and

Table 1. **Soil micromineral concentrations as related to regions and seasons (dry basis).**

Element	CL[a]		Wet Season I n^b=14	Wet Season II n=28	Wet Season III n=14	Wet Season IV n=42	Wet Season V n=70	Wet Season VI n=24	Dry Season IV n=42	Dry Season V n=70
Cu, ppm	< 0.3[f]	Mean	0.56	1.74	0.72	0.80	2.20	0.79	0.43	1.80
		SE	1.01	0.71	1.01	0.58	0.45	0.78	0.46	0.36
		% Def	29	11	36	21	7	2	43	20
Fe, ppm	< 2.5[g]	Mean	10.3	13.5	2.2	5.6	26.5	12.5	4.5	25.2
		SE	11.0	7.8	11.1	6.4	4.9	8.6	7.2	5.6
		% Def	7	14	93	24	7	17	24	3
Mn, ppm	< 5[f]	Mean	38.5^{hi}	15.8^{i}	23.7^{i}	36.8^{i}	61.0^{h}	40.7^{hi}	62.3	95.1
		SE	14.5	10.3	14.9	8.4	6.5	11.3	18.2	14.1
		% Def	0	11	0	2	0	0	0	1
Zn, ppm	< 2.5[f]	Mean[c]	2.3	1.3	1.5	1.9	2.1	1.8	2.6	2.9
		SE[d]	0.52	0.37	0.52	0.30	0.23	0.40	0.36	0.28
		% Def[e]	7	7	21	7	1	4	12	0

a. Critical level. b. Number of observations. c. Least square mean. d. Standard error of the least square mean. e. Percentage of samples below the critical level. f. Rhue and Kidder (30). g. Viets and Lindsay (43). h,i. Means among regions during the wet season in a row with different superscripts differ ($P < .05$).

Table 2. Seasonal effect on soil micromineral concentrations for regions IV and V (dry basis).

		Wet season 1991			Dry season 1992		
Element	CL[a]	Mean[b]	SE[c]	% Def[d]	Mean	SE	% Def
Cu, ppm	< 0.3[e]	1.49*	0.08	12	1.11	0.08	29
Fe, ppm	< 2.5[f]	16.1	1.78	13	14.8	1.78	1
Mn, ppm	< 5[e]	49.4**	5.5	1	78.7	5.5	1
Zn, ppm	< 0.5[e]	1.96*	0.17	4	2.73	0.17	4

a. Critical level. b. Least square mean from 112 samples from regions IV and V in both seasons. c. Standard error of the least square mean. d. Percentage of samples below the critical level. e. Rhue and Kidder (30). f. Viets and Lindsay (43). * Wet vs dry differ ($P < .05$). ** Wet vs dry differ ($P < .01$).

Pendias (16) reported that Cu binding capacity of any soil and Cu solubility are highly dependent to the amount and kind of OM present. In this study, OM was lower ($P < .001$) in the dry season than in the wet season (table 4), raising a possible explanation of lower soil Cu concentrations found during the dry season. Pastrana *et al.* (27) and McDowell *et al.* (21) found similar results when comparing soil Cu concentrations during the wet and dry seasons in Colombia and Venezuela, respectively. Percentage of deficient soil Cu samples among regions varied from 2 to 36 % in the wet season, and was 43 and 20 % for regions IV and V, respectively, in the dry season. A higher percentage of soil Cu deficient samples was found in the dry season (29%) vs the wet season (12%) for regions IV and V. These results are similar to those found by Tejada *et al.* (38) in Guatemala.

Mean soil extractable Fe did not vary ($P > .1$) among regions during the wet and dry seasons. No differences were found between seasons for regions IV and V. Although Fe concentration in soils seemed to be different among regions during the wet season, its concentration varied widely among and within farms, and likely a larger sample size to detect any differences is required. Percentage of deficient samples among regions, according to the critical level of < 2.5 ppm (44), ranged from 7 to 93 % during the wet season, and was 24 and 3 % for regions IV and V, respectively, during the dry season. Similar percentages were found when comparing both seasons for regions IV and V. Iron availability to plants is highly dependent on soil pH. Kabata-Pendias and Pendias (16) indicated that as soil pH increases, the availability of Fe to plants decreases. Iron in its reduced form (Fe^{2+}) is available to the plant. As pH decreases, more Fe^{3+} is reduced to Fe^{2+}; thus Fe becomes more available in acid soils. When comparing the soil pH of region IV and V during the dry season, region V had lower ($P < .01$) values than region IV, which could have lead to a higher availability of Fe in soil of re-

Table 3. Soil organic matter, pH, al[illegible] and macromineral concentrations as re[illegible] and season (dry basis).

Element	CL[a]		Wet season I n^b=14	Wet season II n=28	Wet season III n=14	Wet season IV n=42	Wet season V n=70	Wet season VI n=24	Dry season IV n=42	Dry season V n=70
OM. %	--	Media[c]	4.5	5.1	5.2	6.2	6.3	7.1	2.3	2.1
		EE[d]	1.4	0.9	1.4	0.8	0.6	1.1	0.4	0.3
pH	--	Mean	6.5[i]	6.6[i]	7.9[h]	6.5[i]	5.5[j]	6.2[ij]	6.6[k]	5.5[l]
		SE	0.4	0.3	0.4	0.2	0.2	0.3	0.2	0.2
Al. ppm	--	Mean	94.6[i]	268.8[h]	153.3[hi]	205.1[hi]	116.0[i]	124.4[hi]	291.4	140.2
		SE	58.7	41.5	58.7	33.9	26.2	45.4	50.6	39.2
Ca. ppm	< 72[f]	Mean	1 989.0	1 858.0	2 546.0	2 243.0	1 810.0	2 313.0	3 086.0	2 343.0
		SE	473.0	334.0	473.0	273.0	211.0	366.0	370.0	286.0
		% Def[e]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K. ppm	< 37[g]	Mean	104.3[ij]	120.8[ij]	630.4[h]	218.7[i]	85.8[j]	179.5[ij]	348.2[k]	111.1[l]
		SE	76.9	54.4	76.9	41.4	34.4	59.6	57.2	44.3
		% Def	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mg. ppm	< 30[g]	Mean	204.7[i]	321.5[i]	703.0[h]	351.3[i]	385.1[i]	335.4[i]	447.4	524.2
		SE	116.5	82.4	116.5	67.2	52.1	90.2	89.9	69.6
		% Def	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Na. ppm	--	Mean	18.7[i]	41.9[i]	675.7[h]	66.3[i]	33.9[i]	23.1[i]	138.2	47.0
		SE	43.8	30.9	43.8	25.3	19.6	33.9	64.4	50.0
P. ppm	< 17[g]	Mean	103.7[h]	33.0[i]	31.6[i]	26.1[i]	13.9[i]	14.8[i]	26.7[k]	7.5[l]
		SE	16.1	11.4	16.1	9.3	7.2	12.5	5.4	4.2
		% Def	0.0	57.0	79.0	64.0	86.0	83.0	48.0	93.0

a: Critical level. b: Number of observations. c: Least square mean. d: Standard error of least square mean. e: Percentage of samples below the critical level. f: Breland (4). g: Rhue and Kidder (35). h, i, j: Means among regions during the wet season in a row with different superscripts differ ($P < .05$). k, l: Means between regions during the dry season in a row with different superscripts differ ($P < .05$).

Table 4. Seasonal effect on soil minerals, OM and pH for regions IV and V (dry basis).

		Wet season (1991)			Dry season (1992)		
Element	CL[a]	Mean[b]	SE[c]	% Def[d]	Mean	SE	% Def
OM, %	--	6.3***	0.3	--	2.2	0.3	--
pH	--	6.0	0.1	--	6.0	0.1	--
Al, ppm	--	161*	13.3	--	216	13.3	--
Ca, ppm	< 72[e]	2027***	71.6	0	2715	71.6	0
K, ppm	< 37[f]	152*	17.7	0	230	17.7	0
Mg, ppm	< 30[f]	368*	20.7	0	485	20.7	0
Na, ppm	--	50	15.8	--	93	15.8	--
P, ppm	< 17[f]	20	4.2	78	17	4.2	76

a. Critical level. b. Least square mean from 112 samples from region IV and V in each season. c. Standard error of the least square mean. d. Percentage of samples below the critical level. e. Breland (4). f. Rhue and Kidder (35). *** Wet vs dry differ P < .001. * Wet vs dry differ P < .05.

gion V. Alkaline soils such as those from region III may have decreased the concentration of available Fe, as indicated by the high percentage of deficient samples. Soil Fe data from this study were lower than those found by Pastrana *et al.* (27) in Colombia and Rojas *et al.* (32) in Venezuela.

Soil Mn was higher (P < .05) in region V than in regions II, III and IV during the wet season. When comparing the two seasons for regions IV and V, soil Mn was higher (P < .01) in the dry season than in the wet season. Manganese is known for its rapid oxidation and reduction under variable soil environments. Oxidizing conditions may reduce Mn availability, and reducing conditions may increase its availability (16). When Mn is reduced, its susceptibility to leaching increases. In region V during the wet season, low soil pH and high rainfall may have been the cause of elevated soil extractable Mn, since the reduced form is available for plants. Differences in Mn concentrations between seasons could be explained, in that solubility increases during the wet season. Due to reducing conditions, the leaching of this mineral could have increased. Results from this study showed higher soil Mn than those found in Florida (9) and Venezuela (21, 32) and similar to those found in Guatemala (38)

Average soil Zn did not differ among regions in the wet or dry season. However, soil Zn was higher (P < .05) in the dry season than in the wet season for regions IV and V. Percentage Zn deficient soil samples, according to the critical level of .5 ppm (30), was less than 22 % for the six regions in the wet season, and was 12 and 0 % for regions IV and V, respectively, in the dry season. Similar percentages (4 %) of deficient soil samples were found in both seasons. Pastrana *et al.* (27) found higher (P < .05) soil Zn concentration in the wet season than in the dry season. Extractable Zn has been found to be affected by low pH and cultivation (2). Zinc may be more soluble and susceptible to leaching in low pH soils and high rainfall areas.

Forage analyses. Mean forage Co, Cu, Fe and Zn concentrations in both seasons did not vary among regions (table 5). There was an interaction for Mn and Co ($P < .05$) between season and region.

Percentage of forage samples deficient in Co for ruminants during the wet season, according to the critical level of < .1 ppm (19), ranged from 82 to 100 % for the six regions in the wet season. During the dry season region IV had 100 % and region V had 89 % of forages below the critical level. Similar percentages of forage Co deficient samples were found for both seasons (table 6). A similar proportion of forage Co deficient samples were found in Florida, USA (9). Rojas *et al.* (32) found marginal to deficient Co levels in forages in Venezuela and no season effect on forage Co concentration. Tejada *et al.* (38) did not find differences in forage Co concentrations among regions in Guatemala, but the percentage of samples below the critical level was lower than the values reported in this study. Cobalt is often the most severe mineral deficiency of grazing livestock in tropical countries, with the possible exception of P and Cu (20). Cobalt uptake by plants is dependent on Co and Mn concentration in soils (75). Soil Mn at high levels depresses uptake of Co by forages. In the present study, although soil Co was not analyzed, high levels of soil Mn were found, which could have lead to reduced Co absorption by plants and subsequently low levels in plant tissue. Analyses of the interaction of season and region resulted in higher ($P < .01$) Co in region V in the wet season (0.05 ± 0.006) than in region IV (0 02 ± 0.008) in the same season, and in region V (0.01 ± 0.006) in the dry season. In a recent review, Kabata-Pendias and Pendias (16) reported great variability in plant analysis of Co by different authors and suggested that analytical errors are an important source of variation.

Percentage of forage Cu deficient samples, according to the critical level of < 8 ppm (26), ranged from 86 to 100 % for the six regions in the wet season. In the dry season, all samples for regions IV and V were Cu deficient. All forage Cu samples were deficient in both seasons for regions IV and V. Similar reports, where Cu deficiencies were found in most forage samples, are from Guatemala (38), Florida, USA (9), and Venezuela (32). McDowell *et al.* (20) reported that, with the exception of P, deficiency of Cu is the most severe limitation to grazing livestock through extension regions of the tropics. Copper interacts strongly with trace minerals and macrominerals for absorption by the plant. These interactions are highly dependent on plant species and soil pH. Iron and Ca are some of the elements that could have had an effect on the absorption of Cu in this study. Calcium, in the form of carbonate, precipitates Cu, making it unavailable for the plant.

Percentage of forage samples deficient in Fe for ruminants, according

Table 5. Forage micromineral concentrations as related to region and season (dry basis).

Element	CL[a]		Wet Season						Dry Season	
			I n^b=14	II n=28	III n=14	IV n=42	V n=70	VI n=24	IV n=42	V n=70
Co. ppm	< 0.1	Mean[c]	0.03	0.04	0.01	0.03	0.01	0.04	0.02	0.05
		SE[d]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		% Def[e]	100.0	93.0	100.0	98.0	100.0	82.0	100.0	89.0
Cu. ppm	< 8	Mean	1.8	3.3	1.7	0.8	1.9	1.3	1.3	1.7
		SE	1.16	0.82	1.16	0.68	0.52	0.90	0.26	0.20
		% Def	100.0	96.0	100.0	100.0	100.0	86.0	100.0	100.0
Fe. ppm	< 50	Mean	60.0	47.2	87.9	48.8	66.9	73.2	94.2	102.5
		SE	19.77	13.98	19.77	11.42	8.91	15.32	39.53	30.62
		% Def	57.0	57.0	7.0	74.0	26.0	21.0	33.0	39.0
Mn. ppm	< 40	Mean	18.8^{gh}	69.5^{fg}	23.9^{gh}	23.0^{h}	78.7^{f}	27.5^{gh}	27.3^{i}	159.4^{j}
		SE	21.66	15.31	21.66	12.50	9.69	16.78	26.38	20.44
		% Def	100.0	39.0	100.0	88.0	24.0	71.0	86.0	17.0
Se. ppm	< 0.2	Mean	0.20	0.41	0.25	0.28	0.22	0.22	0.29^{i}	0.13^{j}
		SE	0.12	0.09	0.12	0.07	0.05	0.09	0.03	0.02
		% Def	29.0	39.0	29.0	31.0	43.0	32.0	38.0	87.0
Zn. ppm	< 30	Mean	16.0	17.6	20.6	9.2	13.4	13.9	22.4	19.0
		SE	6.29	4.45	6.29	3.6	2.81	4.87	3.86	2.99
		% Def	100.0	100.0	93.0	100.0	90.0	79.0	71.0	83.0

a. Critical level (26). b. Number of observations. c. Least square mean. d. Standard error of the least square mean. e. Percentage of samples below the critical level. f, g, h. Means among regions during the wet season in a row with different superscripts differ ($P < .05$). i, j. Means between regions during the dry season in a row with different superscripts differ ($P < .05$).

Table 6. Season effect on forage micromineral concentrations for regions IV and V (dry basis).

		Wet season 1991			Dry season 1992		
Element	CL[a]	Mean[b]	SE[c]	% Def[d]	Mean	SE	% Def
Co, ppm	< 0.1[e]	0.02	0.01	100	0.03	0.01	92
Cu, ppm	< 8[e]	1.3	0.24	100	1.5	0.24	100
Fe, ppm	< 50[e]	58.0	15.9	44	98.3	15.9	37
Mn, ppm	< 40[e]	51*	9.8	48	94.0	9.8	43
Se, ppm	< 0.2[e]	0.25	0.03	38	0.21	0.03	69
Zn, ppm	< 30[e]	11.3**	1.2	94	21.0	1.2	79

a. Critical level. b. Least square mean from 112 samples from regions IV and V in both seasons. c. Standard error of the least square mean. d. Percentage of samples below the critical leve . e. NRC (26). * Wet vs dry differ (P < .05). ** Wet vs dry differ (P < .01).

to the requirement level of 50 ppm (26), ranged from 7 to 74 % for the six regions in the wet season, and was 33 and 39 % for regions IV and V, respectively, in the dry season. In both seasons, similar percentages of Fe deficient forages were found. Espinoza *et al.* (9) found monthly variation in forage Fe concentration and a higher percentage of Fe deficient samples in a study conducted in Florida. In Guatemala, Tejada *et al.* (38) found regional variation in forage Fe concentrations. Vargas *et al.* (42) and Tejada *et al.* (38) in Colombia and Guatemala, respectively, did not find Fe deficient forage samples. The absorption of Fe by plants is not always consistent and is affected by the physiological state of the plant, as well as changing conditions of soil and climate (16).

Mean forage Mn varied among regions in both seasons. In the wet season, region V had higher (P < .05) Mn concentrations than all regions, except region II. In the dry season, region V had higher (P < .05) forage Mn than region IV. Percentage of samples below the estimated requirement of 40 ppm (26) for cattle ranged from 24 to 100 % among regions in the wet season. In the dry season, there were 86 and 17 % deficient forage samples in regions IV and V, respectively. The percentages of forage Mn deficient samples were similar between seasons (43 or 48 %) for regions IV and V. The analyses of the season-by-region interaction showed higher (P < .05) forage Mn concentration in region V in the dry season (159.4 ± 12.3) than in the wet season (78.7 ± 12.3), and region IV had lower (P < .05) forage Mn concentrations in the wet season (23.9 ± 15.9) and dry season (27.7 ± 15.9) than region V in either season.

Mean forage Se did not differ among regions in the wet season In the dry season, forage Se samples from region IV had higher (P < .01) Se concentrations than those from region V. Percentage of samples below the estimated requirement of 0.2 ppm (26) for cattle ranged from 29 to 43 % among regions in the wet season. In the dry season, there were 38 and 87 % deficient forage samples in regions IV and V, respectively. Gerloff (10) reported that Se concentration in plants is positively correlated with soil pH. Other factors affecting the Se uptake are soil P, S and N concentrations. Ehlig *et al.* (8) found that, except for Se accumulator plants such as *Astragalus* sp., the differences in concentration of this element among plant species were small. In this study, soil pH ($P < .01$) and soil P ($P < .05$) concentrations were lower in region V than IV in the dry season (table 4). Both factors may have had an effect on forage Se uptake from the soil. Lower concentrations of forage Se have been reported in Guatemala (38, 41), Venezuela (32), and Florida, USA (9). Ammerman and Miller (1) reported Se forage concentrations below 0.05 ppm in the northwest, northeast and southeast of United States.

Mean forage Zn concentration showed a season effect ($P < .01$) for regions IV and V, with higher concentration during the dry season. Percentage of Zn samples below the critical level (< 30 ppm) for ruminants (20) ranged from 79 to 100 % for the six regions during the wet season, and was 71 and 83 % for regions IV and V, respectively, in the dry season. Higher percentages of forage Zn deficient samples were found in the wet season (94 vs 79 %). Forage Zn varied considerably depending on various ecosystem characteristics, plant species, and stage of maturity. However, Kabata-Pendias and Pendias (16) reported that Zn concentration of certain forages from different countries do not differ widely. This agreed with the lack of differences in Zn concentration among regions in this study. Similar results, where no differences were found among regions, were reported in Venezuela (21). Controversial reports concerning Zn concentrations in plants as they mature have been reported. Underwood (40) reported that as plants mature, their Zn concentration decreases. However, high concentrations of Zn have been found in old leaves of plants (16).

Serum analyses. Serum Cu concentrations did not differ among regions (table 7) nor among animal classes (table 8) in either season. Percentage of deficient serum Cu samples, according to the critical level of 50 µg/100 mL (14), ranged from 0 to 43 % for the six regions in the wet season, and was 0 and 4 % for regions IV and V, respectively, in the dry season. Although a high proportion of cattle maintained only on forages become hypocupremic, many of these animals do not show clinical signs of deficiency (23). Suttle (36) and Mills (24) have suggested that plasma Cu and ceruloplasmin are of limited value in diagnosing Cu status because inflammatory disease would alter these levels. However, erythrocyte Cu-Zn superoxide dismutase activity has been suggested to be correlated with duration of deficiency (37). Copper deficiency is common in ruminants. Hypocuprosis could be provoked by excess Mo, S, Fe, Zn and Ca, and affect all stages of growth and production (12). Balbuena *et al.* (3) in Argentina found a higher percentage of serum deficient Cu

Table 7. Serum micromineral concentrations as related to regions and seasons (ig/100 mL).

Element	CL[a]		Wet Season I n^b=30	Wet Season II n=60	Wet Season III n=30	Wet Season IV n=90	Wet Season V n=150	Wet Season VI n=60	Dry Season IV n=60	Dry Season V n=150
Cu	< 50[f]	Mean[c]	102.7	76.8	92.0	117.3	79.1	101.2	131.8	145.6
		SE[d]	21.6	15.3	21.6	12.5	9.7	15.3	5.8	3.7
		% Def[e]	0.0	43.0	27.0	7.0	29.0	17.0	0.0	4.0
Se	< 4[g]	Mean	3.0	8.2	1.4	7.8	5.2	5.5	8.1	5.5
		SE	2.17	1.56	2.32	1.27	0.98	1.55	0.96	0.60
		% Def	93.0	18.0	83.0	13.0	45.0	28.0	2.0	29.0
Zn <	60[h]	Mean	80.3	95.0	69.8	57.0	97.2	73.7	96.8	96.1
		SE	16.4	11.6	16.4	9.5	7.3	11.6	14.1	8.9
		% Def	10.0	13.0	37.0	50.0	8.0	27.0	43.0	27.0

a. Critical level. b. Number of samples. c. Least square mean. d. Standard error of the least square mean. e. Percent of samples below the critical level. f. Herd (14). g. Miller and Madsen (22). h. McDowell *et al.* (20).

Table 8. Serum micromineral concentrations as related to animal class and season (ig/100 mL).

Item	CL[a]		Wet season			Dry season		
			L[b] n[e]=140	H[c] n=140	C[d] n=140	L n=70	H n=70	C n=70
Cu	< 50[i]	Mean[f]	85.0	94.0	105.0	131.0	124.0	159.0
		SE[g]	9.0	9.0	9.0	18.0	18.0	18.0
		% Def[h]	27.0	23.0	17.0	0.0	7.0	1.0
Se	< 4[j]	Mean	5.7	5.7	4.2	8.2	7.3	5.0
		SE	0.5	0.5	0.5	0.5	0.5	0.5
		% Def	30.0	35.0	49.0	11.0	9.0	44.0
Zn	< 60[k]	Mean	74.0	75.0	86.0	93.0	108.0	87.0
		SE	3.9	3.9	3.9	18.4	18.4	18.4
		% Def	25.0	25.0	18.0	37.0	26.0	31.0

a. Critical level. b. Lactating cows. c. Heifers d. Calves. e. Number of samples. f. Least square mean. g. Standard error of the least square mean. h. Percentage of samples below the critical level. i. Herd (14). j. Miller and Madsen (22). k. McDowell *et al.* (20).

samples than those in this study.

Serum Se concentrations did not differ among regions in the wet and the dry seasons, respectively. Animal class did not affect serum Se levels in the wet season. However, in the dry season, calves had lower (P < .01) serum Se than heifers and lactating cows. Percentage of serum samples deficient in Se, according to the critical level of 4 µg/100 mL (22), ranged from 13 to 93 % for the six regions in the wet season, and was 2 and 29 % for regions IV and V, respectively, in the dry season. Serum and(or) plasma Se has been reported to reflect current supplementation levels and short-term changes in Se supplementation (10). Protein supplementation can alter Se availability to the animals, since a deficiency of sulfur amino acids (methionine) decreases the incorporation of Se into glutathione peroxidase (6). Other factors affecting Se metabolism are Ca at the level of absorption (> 0.8 or < 0.6 %), interaction with heavy metals and animal genetic potential (10), and feeding high levels of cyanogenetic glycosides when Se intake is marginal (13). Tejada *et al.* (38) found a tendency for serum Se concentrations to be higher in lactating than in growing animals. Contrary to these findings, Balbuena *et al.* (4) did not find differences in serum Se concentration between animal classes.

Serum Zn concentration did not differ among regions or animal class in either season. Percentage of serum samples deficient in Zn (< 60 µg/100 mL) ranged from 8 to 50 % for the six regions in the wet season, and was 43 and 27 % for regions IV and V, respectively, in the dry season. Some factors affecting serum Zn concentrations are collection procedure and stress. Corah and Ives (7) reported that serum Zn concentration is increased by hemolysis and decreased by stress. Wegner *et al.* (45) observed that cows under hyperthermic stress showed a decline in serum Zn concentration, and this low serum Zn concentration remained after 192 h post-stress. Graham (12) reported that there is not an accurate biochemical index of Zn status due to the influence of diseases on enzymes such as carbonic anhydrase and alkaline phosphatase. Similar results, where forage Zn concentrations were below the requirement for grazing ruminants but animal tissue levels did not indicate a Zn deficiency, were found in Argentina (5). Also, a low percentage of deficient serum samples was found in Guatemala (38) and Venezuela (21).

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