MINERAL STATUS OF GRAZING CATTLE IN SOUTH SULAWESI, INDONESIA: 2. MICROMINERALS[1,2]

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Summary

Research was conducted to determine the micromineral status of grazing cattle in three climatic regions of the province of South Sulawesi, Indonesia. Soil, forage, blood and liver samples were collected within the Western, Central and Eastern regions in February-March and August-September of 1987. Forages were deficient in copper, selenium and zinc. Serum copper was deficient in all regions but zinc was deficient more in the dry season. Liver copper was deficient in all regions and both seasons except in the central region in the rainy season. Based on the analyses, microminerals most likely deficient in both the rainy and dry seasons for each region were as follows: Western--copper, selenium and zinc; Central--manganese and copper; Eastern--selenium, copper and zinc. Some degree of molybdenum excess was found in the Eastern region.

(Key Words: Mineral Status, Indonesia, Deficiency, Cattle)

Introduction

In many tropical countries, livestock often do not receive mineral supplements. Mineral supplementation, if any, is limited to common salt (McDowell et al., 1984). It has been reported that trace element imbalances, along with poor husbandry and inadequate diets, frequently contribute to sub-clinical deficiencies in grazing ruminants (Conrad et al., 1980).

On the basis of clinical signs (Tillman, 1981) and the limited number of studies reported (Panggabean et al., 1982; Sutrisno et al., 1983; Prabowo et al., 1983; Kumagai et al., 1989; Panggabean and Towers, 1989) it may be concluded that, in addition to phosphorus deficiency in Indonesia, there are marginal deficiencies of iodine, copper, selenium, manganese and zinc. However, Indonesia is a country with large climatic, geographical and vegetation differences so that mineral status of livestock is likely to differ largely among regions. The objective of this study was to evaluate the micromineral status of grazing cattle in three climatic regions of South Sulawesi, Indonesia.

Materials and Methods

Soil, forage and animal tissue samples were collected from 10 different districts within three climatic regions in South Sulawesi, Indonesia during the rainy and dry seasons. For each season, collections were made at three, three and four districts within the Western, Central and Eastern regions, respectively. Sampling periods were February-March and August-September of 1987, corresponding to the end of rainy and dry seasons in each region. Methods of sample collection, location of experimental sites, experimental animals, management procedures and methods of statistical evaluation are presented in the companion paper (Prabowo et al., 1990).

Samples of 30 soils, 60 forages and 100 blood and liver samples from slaughtered animals were obtained for each of the sampling periods. Soil samples were analyzed for copper, iron, manganese and zinc. Minerals were extracted from soils

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using the Mehlich I extracting solution method (.05 N HCl + .025 N H_2SO_4). Forage samples were analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc. Blood serum samples were analyzed for copper, selenium and zinc. Preparation of the liver samples were carried out as described by Fick et al. (1979). The solutions were then analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc.

Copper, iron, manganese and zinc were determined by atomic absorption spectrophotometry (Perkin-Elmer Corp., 1982). Cobalt and molybdenum were determined by flameless atomic absorption Spectrophotometry (Perkin-Dlmer Corp., 1984). Selenium determination was carried out by a modified fluorometric technique (Whetter and Ullrey, 1978).

Results and Discussion

Soil Analyses

Results of soil micromineral analyses as related to season and region are shown in table 1 and the percentages of deficient soil samples are presented in table 2. No seasonal differences ($p > .10$) were found for all microminerals analyzed in soils.

There was no regional effect ($p > .10$) in extractable soil copper. However, variations ($p < .01$) due to the district effect were found for soil copper concentrations. The copper concentration of soil samples below the critical level of .3 mg/kg (Rhue and Kidder, 1983), recommended for Florida soils, was found only in the Central region. The overall samples deficient in extractable soil copper for the rainy and dry seasons, respectively, were 7 and 3%. Sanders (1982) indicated that as the pH increases, the quantity of copper adhered to soil components increased and the proportion of copper in soil solution as cupric ion decreased. Since there were no seasonal differences in soil pH, it is understandable that soil copper concentrations also were found to be similar in both seasons.

Regional differences ($p < .01$) were found for soil iron concentrations. Soils from the Western region were higher ($p < .01$) in iron concentrations than those from the Eastern. The Central region had lower ($p < .05$) soil iron, in comparison to the other two regions. The iron concentration of soil samples below the critical level suggested by Viets and Lindsay (1973) was found only in the Central region. Of all samples analyzed in both seasons, only 3% were deficient in iron. Lindsay (1972) indicated that the solubility of iron in soils is largely controlled by the solubility of hydrous iron (III) oxides. Therefore, these relatively high amounts of extractable soil iron in the Western region may explain the low availability of phosphorus to plants.

TABLE 1. SOIL MICROMINERAL ANALYSES (DRY BASIS) AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance[c]
		Western		Central		Eastern		
		Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	
Cu, mg/kg	Rainy	1.9	.42	1.7	.42	2.6	.36	D(R)**
	Dry	1.3	.42	1.4	.42	3.3	.36	
Fe, mg/kg	Rainy	85.2	10.6	35.2	10.6	33.3	9.2	R**, D(R)*, C_1*, C_2**
	Dry	111.9	10.6	34.4	10.6	49.0	9.2	
Mn, mg/kg	Rainy	13.3	10.0	102.2	10.0	47.2	8.6	D(R)**, C_1^+
	Dry	36.5	10.0	78.8	10.0	49.3	8.6	
Zn, mg/kg	Rainy	3.7	2.3	8.9	2.3	5.9	2.0	D(R)$^+$, SD(R)*
	Dry	5.5	2.3	7.2	2.3	4.7	2.0	

[a] Least squares means of 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

** $p < .01$. * $p < .05$. $^+p < .10$

TABLE 2. PERCENTAGE OF SOIL SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Cu, mg/kg	< .3	Rainy	0.0	22.2	0.0	6.7
		Dry	0.0	11.1	0.0	3.3
Fe, mg/kg	< 2.5	Rainy	0.0	11.1	0.0	3.3
		Dry	0.0	11.1	0.0	3.3
Mn, mg/kg	< 5	Rainy	0.0	11.1	0.0	3.3
		Dry	0.0	11.1	0.0	3.3
Zn, mg/kg	< 1	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0

[a]Percentages based on 3 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b]Concentration below which is deficient, based on recommendations for Florida soils (Viets and Lindsay, 1973; Rhue and Kidder, 1983).

Soil manganese concentrations for the Central region were higher ($p < .10$) than those for the other two regions. The manganese concentrations of soil samples below the suggested critical level of 5 mg/kg (Rhue and Kidder, 1983) were found only in the Central region at 11% in both the rainy and dry seasons. It is important to mention that the mountainous Central region is characterized by soils of volcanic origin (Muljadi, 1977; cited by Adiningsih et al., 1988). Thus, it may explain the relatively high concentrations of manganese in soils from this region, although the concentrations also varied ($p < .01$) due to district effects.

Extractable soil zinc was not different ($p > .10$) among regions for either season. However, variations were found, due to the district ($p < .10$) and the interactions of season by district ($p < .05$). Individual evaluation of samples based on the critical level of 1 mg/kg for normal plant growth (Rhue and Kidder, 1983), when pH is below 6.5, indicated none of the samples analyzed were deficient in zinc during both the rainy and dry seasons.

Forage Analyses

The results of forage micromineral analyses as related to season and region are shown in table 3. The percentages of forage samples deficient in microminerals are presented in table 4. Seasonal differences were observed for cobalt ($p < .05$), copper ($p < .10$) and molybdenum ($p < .05$). Forage cobalt concentrations also were affected ($p < .01$) by season and region interactions.

With the exception of phosphorus and copper, cobalt deficiency is the most severe mineral limitation to grazing livestock in tropical countries (McDowell et al., 1984). In this study, however, none of individual samples were found below the critical level of .1 mg/kg suggested by McDowell (1985) for cobalt deficiency. Furthermore, forage cobalt was not different ($p > .10$) among regions in either the rainy or dry season. Mtimuni (1982) suggested that there is a readily available cobalt in soil for plants grow even on cobalt-deficient soils. Similarly, Reid and Horvath (1980) illustrated that the level or cobalt in soil does not necessarily indicate its availability to plants.

Forage copper concentrations were not different ($p > .10$) among the three regions. However, variations ($p > .10$) were found, due to the district and interactions of season by district. A high percentage of samples was found below the critical level suggested by McDowell (1985) for forage copper (8 mg/kg) in the Western region. The percentages of samples below the critical concentration in this region for the rainy and dry season, were 61 and 56, respectively. With the exception of phosphorus, deficiency of copper is undoubtedly the most severe limitation to grazing livestock throughout extensive regions of the tropics (McDowell et al., 1984).

Forage molybdenum concentrations showed regional differences ($p < .05$). The Central region

TABLE 3. FORAGE MICROMINERAL CONCENTRATIONS (DRY BASIS) AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance[c]
		Western		Central		Eastern		
		Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	
Co, mg/kg	Rainy	.31	.0002	.44	.0002	.42	.0002	S*, SR**, D(R)**
	Dry	.34	.0002	.42	.0002	.41	.0002	
Cu, mg/kg	Rainy	9.9	2.8	22.9	2.8	14.2	2.4	S^+, D(R)**, SD(R)**
	Dry	8.7	2.8	15.9	2.8	10.3	2.4	
Fe, mg/kg	Rainy	608	146	530	146	555	126	D(R)**, SD(R)**
	Dry	876	146	468	146	815	126	
Mn, mg/kg	Rainy	95	49	85	49	155	42	D(R)**, SD(R)**
	Dry	80	49	74	49	154	42	
Mo, mg/kg	Rainy	.75	.19	.42	.19	1.75	.17	S*, R*, D(R)**
	Dry	.31	.19	.26	.19	1.25	.17	C_1^+, C_2*
Se, mg/kg	Rainy	.08	.11	.39	.11	.33	.10	R^+, D(R)**, SD(R)**
	Dry	.11	.11	.48	.11	.62	.10	C_2*
Zn, mg/kg	Rainy	25	5	38	5	38	4	D(R)**, SD(R)**
	Dry	30	5	48	5	35	4	

[a] Least squares means of 6 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

** $p < .01$. * $p < .05$. $^+p < .10$.

had lower ($p < .10$) forage molybdenum concentrations than the other two regions. Higher ($p < .05$) concentrations were found in the Eastern than in the Western region. Molybdenum concentrations of all forage samples analyzed were below the toxic level of 6 mg/kg (McDowell, 1985). The average copper-to-molybdenum ratio in forages was greater than the value of 2:1 suggested by Miltimore and Mason (1971) as the point at which a lower ratio could have resulted in conditioned copper deficiency.

Forage iron concentrations were similar ($p > .10$) in all regions for either season. However, variations ($p < .01$) were found, due to the district and the interactions of season by district. Individual evaluation of samples based on iron requirements of 50 mg/kg (McDowell, 1985) indicated that none of the forage samples were deficient in iron. The zero incidence of iron deficiency in forages during both the rainy and dry seasons is in agreement with generally adequate concentrations found for soil iron.

Forage manganese concentrations were similar ($p > .10$) in all regions for both seasons. Evaluation of samples based on a dietary manganese requirement of 40 mg/kg (McDowell, 1985) indicated a number of deficient samples during both the rainy any dry seasons. Of all samples analyzed, 13 and 20% were deficient in this micromineral for the rainy and dry seasons, respectively. Although extractable soil manganese was high in the Central region, this region also showed the highest percentage of forage samples deficient in manganese among the three regions, at 28% for both the rainy and dry seasons. Variations ($p < .01$) were found, due to the district and the interactions of season by district.

Regional differences ($p < .10$) were found for forage selenium concentrations. Lower ($p < .05$) concentrations were found in the Western region than in the Eastern region. Individual evaluation of forage samples based on the critical level of .2 mg/kg for selenium (McDowell, 1985)

TABLE 4. PERCENTAGE OF FORAGE SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Co, mg/kg	< .1	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Cu, mg/kg	< 8	Rainy	61.1	33.3	4.2	30.0
		Dry	55.6	33.3	16.7	33.3
Fe, mg/kg	< 50	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Mn, mg/kg	< 40	Rainy	5.6	27.8	8.3	13.3
		Dry	22.2	27.8	12.5	20.0
Mo, mg/kg	> 6	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Se, mg/kg	< .2	Rainy	88.9	0.0	50.0	46.7
		Dry	100.0	33.3	25.0	50.0
Zn, mg/kg	< 30	Rainy	88.9	38.9	33.3	51.7
		Dry	44.4	22.2	29.2	31.7

[a] Percentages based on 6 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient or above which, in the case of Mo, is excessive (McDowell, 1985), based on requirements of beef cattle (NRC, 1984).

indicated that the percentage of samples below the critical concentration during the rainy season in each region were as follows: Western, 89%; Central, 0%; and Eastern, 50%. A similar tendency was found during the dry season in which the percentage of deficient samples in each region were as follows: Western, 100%; Central, 33%; and Eastern, 25%. It appeared that the Western region was the region with the most potential selenium deficiency problem.

Forage zinc concentrations varied ($p < .01$) due to the district and the interactions of season by district. Individual evaluation of samples based on the critical value of 30 mg/kg for zinc (McDowell, 1985) also indicated that the Western was the region with the most potential for zinc deficiency problem. During the rainy season, 89% of samples from this region were below the critical level, whereas in the dry season the percentage was 44. The overall percentage of samples found to be deficient also decreased from 52 in the rainy season to 32 during the dry season. In contrast to the statement of Underwood (1981) that zinc concentration in plants decreases with advancing maturity, in this study, a lower incidence of zinc deficiency in the dry season than the rainy season was detected.

Animal Tissue Analyses

Blood

Blood micromineral concentrations as related to season and region are presented in table 5, percentages of deficient blood samples are shown in table 6. Seasonal differences were found for serum selenium ($p < .05$) and zinc ($p < .01$) concentrations. For both elements, concentrations were higher in the rainy than in the dry season.

Regional differences ($p < .05$) were found for serum copper concentrations. The concentration for the Central region was higher ($p < .05$) than the other two regions. Cattle from the Western region had lower ($p < .05$) serum copper concentrations than those from the Eastern region. Individual evaluation of samples based on the 0.65μg/ml serum copper critical level (McDowell, 1985) indicated a higher percentage of samples below the critical concentration in the Western

TABLE 5. BLOOD SERUM MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

Variable	Season	Region						Significance[c]
		Western		Central		Eastern		
		Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	
Cu, μg/ml	Rainy	.61	.06	.80	.06	.75	.06	R*, D(R)**, SD(R)**
	Dry	.61	.06	.76	.06	.69	.06	C_1*, C_2*
Se, μg/ml	Rainy	.11	.02	.14	.02	.13	.01	S*, R*, D(R)**,
	Dry	.05	.02	.10	.02	.11	.01	SD(R)**, C_2*
Zn, μg/ml	Rainy	.90	.08	1.15	.08	.93	.07	S**, D(R)**,
	Dry	.67	.08	.84	.08	.70	.07	SD(R)**, C_1^+

[a] Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

** $p < .01$. * $p < .05$. $^+p < .10$.

TABLE 6. PERCENTAGE OF BLOOD SERUM SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Serum Cu, μg/ml	< .65	Rainy	43.3	20.0	27.5	30.0
		Dry	70.0	26.7	45.0	47.0
Serum Se, μg/ml	< .03	Rainy	0.0	0.0	0.0	0.0
		Dry	10.0	0.0	0.0	3.0
Serum Zn, μg/ml	< .5	Rainy	0.0	0.0	12.5	5.0
		Dry	26.7	3.3	27.5	20.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient (McDowell, 1985).

in comparison to the other two regions. The percentages for the Western region were 43 in the rainy season and 70 in the dry season. Of all samples analyzed, 30 and 47% were deficient during the rainy and dry seasons, respectively.

Regional differences ($p < .05$) were found for serum selenium. Lower ($p < .05$) concentrations were found in the Western region in comparison to the Eastern region. Of all blood samples analyzed for selenium during the dry season, only 3% were deficient, but all of them came from the western region. These results are in agreement with the results on forage analyses in the Western region, where the highest incidence of low forage selenium concentration was found. The average blood selenium concentration of samples from this region, however, was above the critical level of .03 μg/ml (McDowell, 1985).

The average serum zinc values in all regions was above the .6 μg/ml suggested by McDowell (1985) as the critical level, and no differences ($p > .10$) were detected among regions for both seasons. However, as serum zinc concentrations were lower ($p < .01$) for the dry than the rainy season, individual evaluation of samples indicated an increased incidence of zinc deficiency in the dry season. The percentage of samples below the critical level were 5 for the rainy season, and 20 for the dry season. The highest incidence of deficiency (28%) was in the Eastern region during the dry season. Conrad (1978) indicated that serum or plasma zinc is rapidly and markedly reduced with severely deficient diets, although concentrations are not greatly influenced by marginally deficient diets.

Liver

Liver micromineral concentrations as related to season and region are presented in table 7 with percentages of liver samples deficient in microminerals presented in table 8. Seasonal differences were detected for liver cobalt ($p < .05$), copper ($p < .10$), manganese ($p < .01$) and molybdenum ($p < .10$) concentrations.

Liver cobalt concentrations were similar ($p > .10$) for all regions. Variations were found, due to the district ($p < .01$) and season by district interactions ($p < .05$). Cattle from the Central region had lower ($p < .10$) liver cobalt than those from the other two regions. None of the cattle liver samples analyzed were deficient in cobalt, based on a critical level of .05 mg/kg suggested by McDowell (1985). Although cobalt deficiencies have been reported as one of the most severe limitation to grazing livestock in tropical countries (McDowell et al., 1984), no cobalt deficiency was indicated in this study. Similar situations were also found in Malawi (Mtimuni, 1982) and Guatemala (Tejada et al., 1987).

Regional differences ($p < .01$) were found in liver copper. Higher ($p < .01$) concentrations were found for the Central region than the other two regions. Cattle from the Western region had lower ($p < .05$) liver copper than those from the Eastern region. The average liver copper concentration in the Western region was below the critical level of 75 mg/kg (McDowell, 1985) in both seasons. Individual evaluation of samples from this region for the rainy season indicated that 57% of the samples analyzed were deficient. An even higher incidence of deficiency (100%) was encountered in the dry season. The overall percentage of copper deficient liver samples was 29 in the rainy season in comparison to 35 in the dry season;

TABLE 7. LIVER MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

		Region						
		Western		Central		Eastern		
Variable	Season	Mean[a]	S.E.[b]	Mean	S.E.	Mean	S.E.	Significance[c]
Co, mg/kg	Rainy	.51	.04	.43	.04	.48	.03	S*, D(R)**, SD(R)*
	Dry	.54	.04	.50	.04	.59	.03	C_1^+
Cu, mg/kg	Rainy	72	12	138	12	100	10	S^+, R**, D(R)**,
	Dry	43	12	114	12	98	10	SD(R)**, C_1**, C_2*
Fe, mg/kg	Rainy	363	25	270	25	316	21	D(R)**, $SD(R)^+$
	Dry	411	25	325	25	322	21	
Mn, mg/kg	Rainy	9.2	1.11	6.4	1.11	9.4	.96	S**, R**, D(R)**,
	Dry	13.8	1.11	7.9	1.11	9.4	.96	SD(R)**, C_1**
Mo, mg/kg	Rainy	3.1	.16	2.9	.16	3.7	.14	S^+, R*, D(R)**,
	Dry	3.1	.16	3.2	.16	4.1	.14	C_2^+
Se, mg/kg	Rainy	.41	.06	.56	.06	1.04	.06	R**, D(R)**, SD(R)*
	Dry	.39	.06	.57	.06	1.04	.06	C_1*, C_2**
Zn, mg/kg	Rainy	119	5.2	111	5.2	112	4.5	D(R)**, SD(R)*
	Dry	116	5.2	108	5.2	104	4.5	

[a] Least squares means of 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Standard error of least squares means.

[c] S = season, R = region, SR = season × region interaction, D(R) = district within region, SD(R) = season × district within region interaction, C_1 = Central vs Western and Eastern, C_2 = Western vs Eastern.

** $p < .01$. * $p < .05$. $^+p < .10$.

TABLE 8. PERCENTAGE OF LIVER SAMPLES DEFICIENT IN MICROMINERALS[a]

Variable	Critical level[b]	Season	Region			Overall
			Western	Central	Eastern	
Co, mg/kg	< .05	Rainy	0.0	0.0	0.0	0.0
		Dry	0.0	0.0	0.0	0.0
Cu, mg/kg	< 75	Rainy	56.7	0.0	30.0	29.0
		Dry	100.0	0.0	12.5	35.0
Fe, mg/kg	< 180	Rainy	0.0	0.0	5.0	2.0
		Dry	0.0	3.3	7.5	4.0
Mn, mg/kg	< 6	Rainy	20.0	50.0	10.0	25.0
		Dry	0.0	20.0	0.0	6.0
Mo, mg/kg	> 4	Rainy	16.7	3.3	45.0	24.0
		Dry	10.0	0.0	57.5	26.0
Se, mg/kg	< .25	Rainy	30.0	0.0	0.0	9.0
		Dry	23.3	6.7	0.0	9.0
Zn, mg/kg	< 84	Rainy	0.0	10.0	0.0	3.0
		Dry	3.3	6.7	2.5	4.0

[a] Percentages based on 10 samples/district with 3, 3 and 4 districts within Western, Central and Eastern regions, respectively, for each of the seasons.

[b] Concentration below which is deficient or above which, in the case of Mo, is excessive (McDowell, 1985).

none of the deficient samples came from the Central region. According to Owen (1982), liver is the central organ in copper metabolism; it removes ionic copper from blood, excretes a portion into bile, synthesizes ceruloplasmin with another portion, and the remainder could be stored as copper in the liver. Furthermore, liver copper is reported to be the best criterion for assessing the copper status of cattle (NCMN, 1973). Soil, forage, blood serum and liver analyses for the dry season in the Western region indicated 0, 56, 70 and 100% incidence copper deficiency, respectively. A similar observation was made by Tajada et al. (1987) in their study in Guatemala. Therefore, it seems that soil copper has little if any value in aiding the diagnosis of copper deficiencies in animals.

Regional differences ($p < .05$) were found in liver molybdenum. Concentrations for the Eastern region were higher ($p < .10$) than those for the Western region. The average liver molybdenum concentration for the Eastern region in the dry season was above the 4 mg/kg level suggested by McDowell (1985) as excessive. During the rainy season, the percentage of liver samples above the critical level for molybdenum in the Eastern region was 45; in the dry season, the percentage was 58. These results may indicate the negative interrelationship between copper and molybdenum, as suggested by Underwood (1981), which could exist in this region. However, the average liver copper concentration of samples from the Eastern region also was high in both the rainy and dry seasons.

Liver iron concentrations were similar ($p > .10$) in all regions for either season. The average values in all regions were much greater than the level of 180 mg/kg suggested by McDowell (1985) as indicating a deficiency. Therefore, the overall percentage of samples below the critical level was only 2%. During the dry season, no difference ($p > .05$) was found for liver iron concentration among regions. Liver is the central point of mineral metabolism in the animal body and is thus a useful organ for estimation of iron status (Boyazoglu et al., 1972). These results, therefore, suggest that iron deficiency is not a problem for grazing cattle in South Sulawesi, Indonesia.

Regional differences ($p < .01$) were found in liver manganese. Concentrations for the Central region were lower ($p < .01$) than those for the other two regions. The incidence of samples below the critical level of 6 ppm (McDowell, 1985) for different regions were as follows: Western, 20%; Central, 50%; and Eastern, 10%. Of all samples analyzed for the rainy season, 25% were deficient. Regional differences ($p < .05$) in liver manganese were found in the dry season, with the lowest value observed in the Central region. As liver manganese concentrations were higher ($p < .01$) for the dry season than the rainy season, a decreased incidence of manganese dificiency was observed in the dry season. The overall percentage of deficient samples for the dry season was 6. McDowell et al. (1978) suggested that manganese deficiency can be detected when there is a combination of less than 6 mg/kg manganese in the liver and less than 20 mg/kg in the diet. Results on manganese concentration of liver samples from the Central region agree with results on forage manganese concentration of samples from the same region. Both liver and forage samples showed the highest incidence of deficiencies among regions, despite the relatively high concentration of extractable soil manganese.

Regional differences ($p < .01$) were found in liver selenium. Higher ($p < .01$) concentrations were found in the Eastern region in contrast to the Western region. Cattle from the Central region had lower ($p < .05$) liver selenium concentrations than those from the other two regions. The average value of liver selenium in each region also was found to be above the .25 mg/kg critical level suggested by McDowell (1985). The overall incidence of liver samples deficient in selenium was 9% for both seasons with none of them coming from the Eastern region.

Variations were found in liver zinc concentrations due to district ($p < .01$) and interactions of season and district ($p < .05$). The overall percentage of samples below the critical level of 84 mg/kg for liver zinc (McDowell, 1985) was 3 for the rainy season and 4 for the dry season.

Relationship of soil-forage minerals

Soil-to-plant gross correlations were found for iron ($r = .268$, $p < .05$) and zinc ($r = .369$, $p < .01$). Partial correlations did not exist ($p > .10$) for all microminerals analyzed in soils and forages.

Application of results

Results from the companion papers on mineral status of cattle in the specified regions of Indonesia suggest that the minerals most likely deficient for all regions are phosphorus, calcium and copper. Sodium, selenium, manganese and zinc were apparently deficient for one or more regions. Molydenum concentrations in forages were in excess for one region. More studies now are needed to determine if mineral deficiencies or excesses are limiting grazing livestock production. Mineral supplementation studies are needed to evaluate cost-benefit relationships of providing supplemental minerals.

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