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EVALUATING THE NUTRITIONAL STATUS OF BEEF CATTLE HERDS FROM FOUR SOIL ORDER REGIONS OF FLORIDA. I. MACROELEMENTS, PROTEIN, CAROTENE, VITAMINS A AND E, HEMOGLOBIN AND HEMATOCRIT¹

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Summary

The nutrient status of grazing beef cattle from four selected soil order regions of Florida was examined. Liver, blood, hair and feces samples from 14 heifers and 14 cows, plus forage samples, were collected during two periods of the year from nine ranches located in four different regions. Soil samples were collected during one period. The soil order regions were the Histosol (southeast), Spodosol (southwest), Entisol (central) and Ultisol (northwest). Mean forage P values were higher ($P < .05$) in the wet season, while mean hair P levels were higher ($P < .05$) during the dry season. Mean forage, plasma, liver and hair Mg values were higher ($P < .05$) in the wet season. Plasma vitamin E, liver vitamin A and forage carotene levels were higher ($P < .05$) during the wet season. Mean forage P content was deficient ($< .25\%$) during both seasons and varied from .10% in the dry season to .16% during the wet season. Mean forage Mg ($< .18\%$) and K ($< .60\%$)

concentrations were deficient in the dry season. Forage protein was deficient ($< 7.0\%$) in five of seven ranches during the dry season. Extractable soil Ca, exchangeable soil Ca, Mn, Al, H⁺, soil organic matter and effective cation exchange capacity were higher ($P < .05$) in the Histosol region. Extractable soil K was low (< 60 ppm) in all regions, except the northwest. Forage P was critical ($< .25\%$) during the dry season in all regions and varied from .08 to .15%, while plasma P was deficient (< 4.5 mg/100 ml) in animals from the southeast during the dry season only.

(Key Words: Mineral Status, Cattle, Florida, Vitamin A.)

Introduction

In many tropical and warm climate regions, mineral deficiencies, imbalances and excesses are severely inhibiting the cattle industry (McDowell, 1976; Conrad and McDowell, 1978). Often, livestock grazing in warm climate regions do not receive adequate mineral supplementation, and forages rarely satisfy mineral requirements completely. The history and significance of mineral deficiencies and toxicities to the cattle industry in Florida have been summarized by Cunha et al. (1964) and Becker et al. (1965). Florida nutritional deficiencies, as evidenced by low forage and/or animal tissue concentration or decreased performance, have been established for Ca, P, Co, Cu, Fe and protein (Becker et al., 1965), Se (Shirley et al., 1966) and vitamin A (Chapman et al., 1971).

Since studies initiated in 1927 (Becker et al., 1965), little systematic mineral research has focused on the general mineral status of Florida beef cattle. Mineral deficiencies or toxicities in grazing livestock can be predicted by the use of systematic mapping survey technique or by

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regional reconnaissance (McDowell, 1976). In the present experiment, we studied the current mineral status of beef cattle between seasons on the basis of animal tissue, forage and soil nutrient concentrations from four soil regions of Florida. The present paper discussed the nutritional status of macroelements, vitamin A and protein, while a companion paper (McDowell et al., 1982a) evaluates the trace elements.

Experimental Procedure

The study sites were nine beef cattle ranches located in four soil order regions of the southeast (Histosol), southwest (Spodosol), central (Entisol) and northwest (Ultisol), Florida. Three ranches each were selected from the southwest and northwest regions, two from the southeast region and one from the central region. Two classes of animals, growing heifers (1 to 2 yr old) and mature cows (4 to 8 yr old), were sampled from each ranch. During the second collection period, one ranch from the northwest region and heifers from the central region were eliminated from the study due to the owners request. Liver, blood, hair and feces samples were collected from 14 to 17 cows and 14 heifers from each ranch. Free choice mineral supplements were available at each ranch with quality of supplements highly variable. In addition, one to four forage and soil samples were collected in duplicate from each ranch. All samples, except soil, were taken twice during the year, once during the wet season (September to October) and again in the dry season (February to March). Soil samples were collected only during September and October.

Procedures for the collection and analysis of liver biopsy, plasma and forage samples for mineral concentrations have been described (Fick et al., 1979). Hair samples were clipped from the sides of the animals. Feces samples were collected directly from the rectum and were frozen until analyzed. Soil samples were collected with a stainless steel tube at a depth of 15 cm.

Pasture samples were analyzed for Ca, Mg, K and Na by atomic absorption spectrophotometry (Perkin Elmer Corp., 1973), for P (Fiske and Subbarow, 1925), S (Leco Corp., 1974) and carotene (Kohler et al., 1967), and for N, lignin and acid detergent fiber (ADF), by routine procedures (Easley et al., 1965).

Soil extractable Ca, P, Mg, K and Na were extracted by a double acid procedure (Soil Test

Work Group, 1974). Soil exchangeable Ca, Mg, Al, H⁺ and acidity were determined on soil solutions prepared according to procedures described by Yuan (1959).

Liver vitamin A was determined by the method of Gallup and Hoefler (1946), and plasma vitamin E by the procedure of Bieri et al. (1964). Plasma Ca, P and Mg, and liver Mg, were determined by previously noted procedures. In addition, hematocrit (Dukes, 1970) and hemoglobin (Cohen and Smith, 1919) were determined on all blood samples. Fecal samples were analyzed for Ca and P, and hair samples for Ca, Mg and P.

The data were subjected to analyses of variance appropriate for a nested design with unequal subclass numbers (Snedecor and Cochran, 1973), while the multiple range test (Duncan, 1955) was used to test differences among means. Data were analyzed by the General Linear Model procedure of the Statistical Analysis System (Barr et al., 1976). Correlation coefficients among animal tissue traits, between soil and forage minerals and among soil, forage and animal tissue traits were estimated.

The word "critical" is used in this and the companion paper (McDowell et al., 1982) to note a concentration in forages below (or above with excesses) what is considered the requirement for cattle. This assumes the expected consumption as estimated by the NRC (1976). Total grams of minerals consumed per day and not forage concentration determines the true adequacy of a mineral. Critical animal tissue concentrations are levels below or above values associated with specific clinical signs as reported in the literature.

Results and Discussion

Forage and Soil Analysis. Mean analyses of soils, by region, and of forages, by season and region, are presented in tables 1 and 2, respectively. Forage seasonal differences ($P < .05$) were found only for P, Mg, K and carotene, with concentrations higher during the wet season (September to October). Forage nutrient differences between regions within season were only found for Na, with the concentration highest ($P < .10$) in the southeast during the wet season. Differences ($P < .05$) were found only for S among ranches within regions, and the only significant season \times ranch within region interaction was that for Mo. There were no

TABLE 1. SOIL MACROELEMENTS, pH, TOTAL ACIDITY AND ORGANIC MATTER, BY REGION^a

Extractable elements	Region							
	Southeast		Southwest		Central		Northwest	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Ca, %	.17	.06	.12	.04	.04	.13	.04	.05
P, ppm	53.4 ^b	10.1	14.9 ^c	7.1	78.8 ^b	20.2	34.1 ^{bc}	8.2
Mg, ppm	29.6	69.8	116.9	50.3	32.3	140.6	57.6	57.0 ^c
Na, ppm	16.2	3.8	22.1	2.7	10.2	7.6	16.4	3.1
Organic matter, %	22.7	7.6	4.1	5.4	2.0	15.2	2.8	6.2
K, ppm	54.1	10.1	27.2	7.1	32.1	20.2	64.3	8.2
Total acidity, meq/100 g	1.64	.54	.38	.38	.38	1.08	.38	.44
pH	4.2 ^c	.2	4.8 ^c	.2	5.0 ^{bc}	.5	5.5 ^b	.2
Exchangeable elements, meq/100 g								
Ca	1.2 ^b	.2	.24 ^c	.1	.24 ^c	.4	.21 ^c	.2
Mg	.15	.03	.05	.02	.06	.05	.05	.02
Al	.27	.06	.12	.04	.15	.12	.14	.05
H ⁺	1.39	.51	.26	.36	.24	1.01	.25	.41

^aMeans are based on the following number of samples: southeast (4), southwest (8), central (1) and northwest (6). Standard error (SE) of the mean in each case is based on five degrees of freedom.

^{b,c}Means within a row with different superscripts differ ($P < .10$).

($P > .05$) correlations between soil and forage minerals.

Mean forage Ca levels during both the wet and dry seasons were .30 and .32%, respectively, both adequate compared to the NRC (1976) requirement of .30% for growing heifers and mature cows. However, these concentrations would be low for lactating cows during the dry season in the central and northwest regions. Mean extractable Ca varied from .04 to .17% among regions, and from .02 to .27% among ranches. Florida soils with normal Ca concentrations would contain about .0072 to .014% Ca (Breland, 1976). The organic soils of the southeast region contained more ($P < .05$) extractable and exchangeable Ca than soils from the other regions.

Extractable soil P levels were highest in the central region (78.8 ppm) and lowest in the southwest region (14.9 ppm). All mean soil P values by region were above the normal range of 11 to 30 ppm indicated by Bahia (1976). However, extractable soil P was low (4.0 ppm) on one ranch in the southwest region.

Although higher ($P < .05$) during the wet season, forage P was below the suggested requirement (.25%) for mature cows (NRC, 1976). Forage P levels varied from .13 to .19% among the four regions during the wet season and from .08 to .15% during the dry season.

Mean forage P concentrations in Florida pastures have been reported to be low, especially during the dry season with Becker et al. (1965) reporting a decrease in forage P levels from .23% in April to .11% in July. Of all forages analyzed, 57 and 90% were deficient ($< .25\%$) in P during the wet and dry seasons, respectively.

Extractable soil Mg values varied from 29.6 to 116.9 ppm. Exchangeable soil Mg was highest ($P < .10$) in the southeast (.15 meq/100 g), with concentrations in the other three regions ranging from .05 to .06 meq/100 g. Florida soils with adequate concentrations of extractable Mg have been reported to contain 4.2 to 21.1 ppm Mg (Breland, 1976). Mean forage Mg levels were adequate (.22%) in the wet season, but low (.14%) in the dry season. In all regions during the dry season, mean forage Mg content was less than the recommended requirement of .18% (NRC, 1976). Eighty percent of all forages contained less than the requirement during the dry season vs 10% during the wet season.

Mean extractable soil K from the southeast (54.1 ppm), southwest (27.2 ppm) and central (32.1 ppm) regions was deficient (< 61 ppm) for normal forage growth, while soil K levels from the Ultisol (northwest, 64.3 ppm) were borderline (Bahia, 1976). These results agree closely with the research report (Selim et al.,

TABLE 2. MACROELEMENTS, CAROTENE, PROTEIN, ACID DETERGENT FIBER AND LIGNIN IN FORAGES, BY SEASON AND REGION (DRY MATTER BASIS)^a

Nutrient	Season	Region											
		Southeast		Southwest		Central		Northwest		Season mean			
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Ca, %	Wet	.30	.05	.35	.04	.40	.10	.27	.04	.30	.02		
	Dry	.30	.06	.46	.06	.24	.08	.24	.08	.32	.03		
P, %	Wet	.18	.02	.13	.01	.18	.04	.18	.02	.16 ^d	.01		
	Dry	.10	.03	.10	.03	.15	.03	.08	.03	.10 ^e	.01		
Mg, %	Wet	.19	.03	.25	.02	.21	.05	.19	.02	.22 ^d	.01		
	Dry	.14	.04	.15	.04	.13	.04	.14	.04	.14 ^e	.02		
Na, %	Wet	.18 ^b	.02	.08 ^c	.01	.07 ^c	.03	.07 ^c	.01	.10	.01		
	Dry	.09	.02	.07	.02	.08	.02	.10	.02	.09	.01		
S, %	Wet	.14	.03	.28	.02	.20	.06	.20	.02	.22	.01		
	Dry	.11	.03	.30	.03	.20	.04	.10	.04	.18	.02		
K, %	Wet	1.03	.21	.93	.15	1.05	.42	1.22	.17	1.05 ^d	.10		
	Dry	.27	.25	.47	.25	.56	.30	.62	.30	.45 ^g	.13		
Carotene, ppm	Wet	16.48	6.66	22.10	4.71	15.00	13.33	12.77	5.44	17.60 ^d	3.05		
	Dry	.07	7.70	1.07	7.70	1.50	9.43	2.90	9.43	1.22 ^e	4.21		
Protein, %	Wet	9.34	1.98	9.00	1.40	8.77	3.96	10.58	1.61	9.42	.91		
	Dry	6.66	2.29	11.58	2.29	9.94	2.80	5.62	2.80	8.45	1.25		
Acid detergent fiber, %	Wet	36.80	2.77	37.14	1.96	42.24	5.55	42.24	2.26	38.95	4.89		
	Dry	35.07	5.21	32.53	3.21	37.48	3.93	39.40	3.93	35.66	5.15		
Lignin, %	Wet	4.08	1.26	5.74	.89	7.63	2.53	7.80	1.03	6.14	.58		
	Dry	7.83	1.46	4.36	1.46	7.67	1.79	4.78	1.44	6.15	.80		

^a Means are based on the following number of samples: wet season—southeast(4), southwest (8), central (1) and northwest (6); dry season—southeast (3), southwest (3), central (2) and northwest (2). Standard error (SE) of the mean in each case is based on three degrees of freedom.
^{b,c} Means within a row and season with different superscripts differ (P<.10).
^{d,e} Seasonal means within a column with different superscripts differ (P<.05).

1976), supporting the concept that the Red Bay soils (Ultisols) that predominate in the northwestern region of Florida have a greater capacity for K retention than the Lakeland soils (Entisol) of Florida. Gammon (1957) previously indicated that K leaching in some Florida soils was so high that annual application of K was recommended for good crop production. Although adequate during the wet season, forage K was deficient (<.60%) in all but two ranches during the dry season. Forage K was low in the southeast region during the dry season, averaging .27%. Similar K forage seasonal variations have been reported previously (Gomide et al., 1969).

Mean extractable soil Na varied from 10.2 to 22.1 ppm among regions and from 10.2 to 27.2 ppm among ranches. Among regions, forage Na varied from .07 to .18% during the wet season and from .07 to .1% during the dry season. On the basis of the NRC (1976) Na requirement (>.06%), forages would have been adequate. However, by the ARC (1965) Na requirement of .1%, approximately 80% of all forages would have been deficient during both seasons. Becker et al. (1965) observed that certain regions of Florida are characterized by high concentrations of salt in water and forages, which caused cattle to avoid mineral mixtures with high salt contents.

Mean forage S contents varied from .18 to .22% between seasons, from .09 to .39% among ranches and among regions, from .14 to .28% during the wet season and .10 to .30% during the dry season. The NRC (1976) has suggested a minimum S requirement of .10% for mature beef cattle, with the exact amount needed in diets unknown. Other reports (NRC, 1978) indicate a higher requirement of .2% S.

Differences ($P < .05$) in forage carotene concentrations were found between seasons (17.6 ppm in the wet season vs 1.2 ppm in the dry season) and among regions (6.0 to 16.3 ppm). Forage carotene was at low concentrations during the dry season, with all but one ranch averaging less than 2 ppm. Mean forage carotene levels on the order of 8.6 to 25.2 ppm have been reported in Florida forages (Chapman et al., 1971).

Mean forage protein, ADF and lignin contents were 9.6, 39.0 and 6.1% during the wet season, respectively, while in the dry season, these values were 8.6, 38.7 and 6.2%. There were no differences ($P > .05$) between seasons, among regions or among ranches, nor were

there any interactions. During the wet season, forage protein levels in all ranches were above the critical level of 7.0% indicated by Minson (1971) while forages on five of seven ranches were below minimum requirements during the dry season. Of all the forages analyzed, only 16% contained less than the critical level of protein (7.0%) during the wet season vs 60% during the dry season.

Of the nine ranches studied during the wet season, eight, four, three and one had low average forage concentrations of P, Ca, Mg and K, respectively. Of the seven ranches studied during the dry season, seven, three, six, five, three, five and seven had low forage P, Ca, Mg, K, S, protein and carotene contents, respectively.

Mean exchangeable Al varied from .12 to .27 meq/100 g among regions, with no differences ($P > .10$). Average exchangeable Al levels of .19 meq/100 g have been reported in the Astatula soil series (Entisol) of Florida (Khomvilai and Blue, 1977).

Calcium, Phosphorus and Magnesium Tissue Analyses. Mean liver and blood plasma mineral concentrations are presented by region and season in table 3, while concentrations in hair and feces are presented in table 4. Seasonal nutrient differences ($P < .05$) were found, with blood vitamin E, liver Mg and vitamin A, hematocrit and plasma Mg higher in the wet season and hair P higher in the dry season. Region \times season interactions ($P < .05$) were found for liver Mg, hematocrit, hemoglobin, hair Ca and Mg and feces Ca for both seasons, while plasma Ca differences were found only during the dry season. Significant season \times ranch within region interactions ($P < .05$) were found for plasma (Ca, P, Mg, vitamin E), liver vitamin A, hair (Ca, P, Mg), feces (Ca, P), hemoglobin and hematocrit.

Mean plasma, hair and fecal Ca concentrations did not vary ($P > .05$) between season. Mean plasma Ca was 9.6 and 8.8 mg/100 ml in the wet and dry seasons, respectively, both above the critical concentration of 8 mg/100 ml suggested by Cunha et al. (1964). A region effect was found only during the dry season, with concentrations highest ($P < .05$) in the southwest and central regions. Mean Ca concentrations in hair and feces varied from 1.32 and .84% during the wet season to 1.24 and .64% during the dry season, respectively. Correlations among plasma, feces and hair Ca were low ($r < .20$).

TABLE 3. MINERAL AND VITAMINS A AND E CONCENTRATIONS IN TISSUES, HEMOGLOBIN AND HEMATOCRIT, BY SEASON AND REGION^a

Item	Season	Region											
		Southeast		Southwest		Central		Northwest		Season mean			
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Plasma, mg/100 ml	Wet	9.4	.5	10.7	.5	9.2	.8	8.8	.4	9.6	.3		
	Dry	9.3	.5	8.3	.5	8.1	1.1	8.9	.5	8.8	.3		
P	Wet	6.2	.6	6.4	.5	5.2	.9	6.0	.5	6.1	.3		
	Dry	4.0	.6	5.2	.5	6.6	1.3	5.9	.6	5.2	.3		
Mg	Wet	2.4	.2	3.1	.1	2.3	.2	2.3	.1	2.6 ^e	.1		
	Dry	2.2	.2	2.1	.1	1.9	.3	1.9	.2	2.1 ^f	.1		
Vitamin E	Wet	3.74	.25	3.22	.22	4.00	.37	3.06	.21	3.26 ^e	.12		
	Dry	2.59	.26	2.75	.23	1.82	.52	2.08	.24	2.30 ^f	.13		
Liver, ppm	Wet	720.3 ^{cd}	40.1	1,000.2 ^b	30.5	910.7 ^{bc}	60.3	830.5 ^c	30.5	870.4 ^e	19.3		
	Dry	370.5 ^b	40.2	360.3 ^b	30.6	370.8 ^b	80.5	340.6 ^b	40.7	360.3 ^f	20.5		
Vitamin A	Wet	634.4	67.2	618.7	60.9	416.1	102.6	213.6	56.2	471.2 ^e	33.3		
	Dry	226.4	69.7	256.3	64.9	367.3	145.1	73.9	69.0	231.0 ^f	37.9		
Blood	Wet	48.3 ^b	1.4	46.8 ^b	1.2	39.3 ^c	2.0	46.8 ^b	1.2	45.3 ^c	.7		
	Dry	53.9	1.4 ^b	41.2	.2 ^c	28.5	2.9 ^d	36.3	1.3 ^{cd}	40.0 ^f	.7		
Hematocrit, %	Wet	11.4 ^{bc}	.7	12.4 ^{bc}	.6	14.2 ^b	1.0	11.0 ^c	.6	12.3	.3		
	Dry	13.0	.7	12.1	.6	10.0	1.4	11.5	.7	11.8	.4		

^a Means are based on the following number of samples for the wet and dry seasons, respectively: (1) plasma minerals, hemoglobin and hematocrit—southeast (52,52), southwest (68,64), central (24,12) and northwest (75,55); (2) liver Mg—southeast (31,29), southwest (40,36), central (14,7) and northwest (45,48); (3) vitamin A—southeast (14,13), southwest (17,15), central (6,3) and northwest (20,13). Standard error (SE) of the mean in each case is based on four degrees of freedom.

^{b,c,d} Means within a row with different superscripts differ (P<.05).

^{e,f} Seasonal means within a column with different superscripts differ (P<.05).

TABLE 4. MINERAL CONTENT OF HAIR AND FECES, BY SEASON AND REGION (DRY MATTER BASIS)^a

Mineral	Season	Region											
		Southeast		Southwest		Central		Northwest		Season mean			
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
Hair Ca, %	Wet	1.85	.40	1.19	.36	.88	.61	1.33	.34	1.32	.20		
	Dry	1.81	.41	1.56	.37	.58	.90	.99	.40	1.24	.22		
P, ppm	Wet	111.4	9.6	101.8	8.4	101.4	14.1	104.8	8.0	104.9 ^c	4.7		
	Dry	241.7	9.6	230.7	8.5	180.7	20.8	224.0	9.3	219.3 ^d	5.0		
Mg, ppm	Wet	312.8 ^b	23.0	196.9 ^c	20.3	134.2 ^c	33.9	214.8 ^c	19.2	214.7 ^d	11.2		
	Dry	146.4 ^b	23.0	140.6 ^b	20.6	33.5 ^c	50.1	123.4 ^{bc}	22.4	111.0 ^e	12.3		
Feces Ca, %	Wet	.82	.16	.63	.14	1.15	.27	.74	.14	.84	.08		
	Dry	.98	.16	.56	.14	.53	.33	.47	.16	.64	.09		
P, %	Wet	.73	.20	.38	.18	.38	.35	.56	1.9	.52	.10		
	Dry	.48	.20	.38	.18	.57	.43	.54	.20	.49	.11		

^aMeans are based on the following number of samples for the wet and dry season: (1) hair minerals—southeast (52,52), southwest (67,65), central (24,11) and northwest (75,55); (2) fecal minerals—southeast (52,52), southwest (67,63), central (18,12) and northwest (61,52). Standard error (SE) of the mean in each case is based on four degrees of freedom.

^{b,c}Means within a row with different superscripts differ ($P < .05$).

^{d,e}Seasonal means within a column with different superscripts differ ($P < .05$).

Mean plasma P in all regions was above the critical level of 4.5 mg/100 ml (Underwood, 1966) during the wet season, while during the dry season, concentrations in the southeast region were below this level. In agreement, forage P concentrations in the southeast were among the lowest (.10% during the dry season). Of all the animals studied, 13% had low plasma P during the wet season, while 36% had low plasma P during the dry season. On the basis of extremely low forage P levels during both seasons (.16% wet, .10% dry), a higher proportion of critical plasma P concentrations (<4.5 mg/100 ml) would have been expected. Two likely explanations for the relatively high blood P levels were the use of P supplements by the ranches and the less than optimum conditions for the collecting and processing of blood P. Factors that elevate plasma minerals, particularly P (De Souza Dayrell et al., 1973; Fick et al., 1979), including stress, exercise, hemolysis, temperature and plasma separation time, were difficult to control during the experiment. Data from Brazil (Mendes, 1977) and Bolivia (L. R. McDowell, unpublished data) have previously illustrated high serum P levels in spite of low forage P concentrations as a result of unfavorable blood collecting and processing conditions.

Fecal P did not differ ($P > .05$) between seasons or among regions within seasons. Differences ($P < .05$) were found in hair P concentrations, which were higher in the dry season than in the wet season (219.3 vs 104.8 ppm) and higher in heifers than in mature cows (176.4 vs 160.1 ppm). These results do not agree with the report from Australia indicating no season effect on hair concentration (Cohen, 1973). However, Van Niekerk (1974) suggested that during the wet season, energy and protein supplies for grazing cattle are adequate, and cattle make rapid weight gains, and thus require high mineral intake, while during the dry season, because of a lack of protein and energy, animals are normally losing weight, thus requiring little P for metabolic activity. In the research reported herein, accumulation of P in hair during the dry season could have been physiological means of mineral storage during a period when the P requirement was low.

P deficiency in grazing cattle has been a serious problem in Florida. Becker et al. (1965) reported stiffness, lameness and depraved appetite among cattle with plasma P levels as low as .83 mg/100 ml (average of 2.4 mg/100 ml). Similar results were reported by Hodges et al.

(1964) for cattle grazing pastures on Immokalee fine sand soils (Entisol) in central Florida.

Mg concentrations were higher ($P < .05$) during the wet than the dry season in plasma (2.6 vs 2.1 mg/100 ml), liver (870.4 vs 360.3 ppm) and hair (214.7 vs 110.0 ppm). Although low, significant ($P < .01$) correlations were observed for plasma Mg with hair Mg ($r = .25$), plasma Mg with liver Mg ($r = .43$) and hair Mg with liver Mg ($r = .22$). Mean plasma Mg concentrations from all ranches were adequate compared to the critical level of 1.8 mg/100 ml (Underwood, 1966). Only a small percentage of all animals had plasma Mg concentrations below the critical level (<1.8 mg/100 ml), 1 and 8% during the wet and dry seasons, respectively.

Vitamin A, Vitamin E, Hemoglobin and Hematocrit Analyses. Mean liver vitamin A, plasma vitamin E, hemoglobin and hematocrit values for cattle from the four regions during each season are presented in table 3. Mean liver vitamin A varied from 231.0 to 471.2 ppm between seasons, from 313.6 to 350.8 ppm between the two classes of animals, from 143.7 to 437.5 ppm among the four regions and from 127.5 to 518.4 ppm among the nine ranches. Differences ($P < .05$) in liver vitamin A concentrations were found between seasons, between classes of animals and among regions, with levels being lower during the dry season in cows than in heifers, and in animals from the Ultisol (northwest) region than in those from the other soil order regions. Under the conditions in Florida, vitamin A is more critical during the dry season (Chapman et al., 1971). Liver vitamin A levels on the order of 261 to 304 ppm (dry basis) have been reported in control and vitamin A-supplemented cattle in Florida (Chapman et al., 1971).

Beeson et al. (1965) suggested that liver vitamin A concentrations of 23 to 36 ppm are close to the level at which vitamin A deficiency occurs. Only 5% of all the livers analyzed during the dry season contained less than 36 ppm.

Mean plasma vitamin E levels ranged from 2.30 to 3.26 mg/100 ml between seasons, from 2.77 to 2.96 mg/100 ml between the two classes of animals, from 2.63 to 3.19 mg/100 ml among regions and from 1.88 and 3.59 mg/100 ml among ranches. Differences ($P < .05$) were significant only between seasons and ranches with levels higher in the wet season. Bayfield and Mylrea (1969) reported that serum vitamin E concentrations increased from

2.20 mg/100 ml in calves to 3.70 mg/100 ml in weanlings, while heifers and cows had levels between 5.40 and 9.00 mg/100 ml.

Mean hemoglobin levels differed ($P < .05$) between the two classes of animals, while hematocrit values differed ($P < .05$) between seasons, regions and ranches. Hemoglobin levels were higher in heifers than in cows, while hematocrit values were higher during the wet season and in cattle grazing on Histosol and Spodosol in south Florida. Hemoglobin and hematocrits were correlated ($P < .05$, $r = .37$). Hemoglobin (< 11 g/100 ml) and hematocrit ($< 38\%$) values observed during the two seasons, in the two classes of animals, in all regions and all ranches were adequate on the basis of reported critical levels (Dukes, 1970). However, season \times region interaction showed low hemoglobin levels (10.0 g/100 ml) during the dry season in cattle from the central region (Entisol), and low hematocrit levels in the central (28.5%) and northwest (36.5%) regions.

Mineral Interrelationships in Soil, Forage and Animal Tissues. Significant ($P < .05$) correlations were found for nutrients analyzed in soils, forages and animal tissues. Plasma Ca was positively correlated with forage carotene ($r = .50$). Forage carotene was positively correlated with liver vitamin A ($r = .51$) and plasma vitamin E ($r = .56$).

Fecal P levels were positively related to forage Na ($r = .70$) and soil Mg ($r = .72$). Liver Mg was positively related to forage Mg ($r = .66$), but negatively related to soil K ($r = -.72$). High K intake by ruminants has been found to reduce Mg absorption (Newton et al., 1972). Soil ingestion, as reported by Healy (1973), could have played an important role between liver Mg and soil K.

Although mineral deficiencies are often "area" problems, the present study indicated that P deficiencies were present in all of the four regions studied. Protein, vitamin A, K and Mg deficiencies were found in certain regions and were most pronounced during the dry season.

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