Cobalt and Copper Contents of Some Tropical Soils and Grasses from Puerto Rico

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INTRODUCTION AND LITERATURE REVIEW

Copper deficiency symptoms have been observed mostly in fruit trees where the young growing tips stop their growth and die. In Puerto Rico copper deficiency symptoms have been observed in some citrus fruits but no report has been published.

Cobalt deficiency in cattle in Puerto Rico has not been reported, but the literature is abundant in cases of cobalt deficiency in cattle from various other countries. As scientific literature regarding these elements in tropical soils and crops is nil, it was considered that data gathered about this subject would help in closing the gap in our knowledge.

Copper deficiency symptoms were observed in sugarcane growing in saw-grass peat soils (*16*).[2] A tremendous response was observed when the soil was treated with copper salts. Harmer, (*5*) working with several crops on organic soils, showed that a considerable response to copper is obtained if the soil pH is around 6.0 or below.

A deficiency of copper in forage areas has caused diarrhea, loss of appetite, and anemia in cattle. In Australia, a chronic copper deficiency resulting from a low content in the herbage has been responsible for a cattle disease known as the "falling disease". This disease is characterized by staggering, falling, and instantaneous death (*10*).

MATERIALS AND METHODS

Soil and grass species samples were taken at random from square plots with an area of 16 square feet in each of the location and soil types shown in the tabulation that follows.

Location	*Soil type*
Sucesión Ricardo La Costa Barrio Higuillar, Dorado	Coloso silt loam
Finca Hnos. Piñero, Barrio Canovanillas West of Canovanillas River and North of Carolina, Canóvanas Road	Toa silt loam
	Coloso silty clay
Finca Agustín López-Ramírez in Barrio Canóvanas, East of Canóvanas and South of Canóvanas Río Grande Road	Toa silt loam
	Coloso silty clay
Finca Celestino Pérez Compañía Agrícola Bairoa Caguas	Caguas clay
Nicasio Betancourt	Toa sandy loam
Humacao	Cayaguá sandy loam

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[2] Italic numbers in parentheses refer to Literature Cited, pp. 355–6.

Table 1 shows the common and scientific names of the plant material analyzed and the soil types where the grasses were growing. The grass species consisted of malojilla, malojillo, merker grass, and a mixture of native grasses and legumes as indicated in the table.

The soil samples were mostly taken at a depth of 0–6 inches although some samples were taken at 0–12 inches and some at 6–12 inches. The grass samples were dried in an oven at 70° C, ground in a Wiley mill, mixed and a representative subsample taken. This subsample was placed in an oven at 80° C for several days.

TABLE 1.—*Plant material and soil types analyzed*

Soil type	Kinds of plants or species	
	Common name	Scientific name
Coloso silt loam	*Malojilla*	*Eriochloa polystachya*
Toa silt loam	*Pasto Amargo*	*Paspalum conjugatum*
Coloso silty clay	*Yerba Dulce*	*Eleusine indica*
	Carpet Grass	*Taxonopus compressus*
	Coquí	*Cyperus* (spp.)
	Escobilla	*Vernonia sericea*
Coloso silty clay	*Zarzabacoa*	*Meibomia supina*
	Moriviví	*Mimosa pudica*
	Cerrillo	*Sporobolus indicus*
	San Agustín	*Stenotaphrum secundatum*
	Grama de Costa	*Chloris radiata*
	Arrocillo	*Setaria geniculata*
	Botoncillo Blanco	*Borreria verticillata*
Caguas clay	Merker Grass	*Pennisetum purpureum*
Cayaguá sandy loam	*Malojillo*	*Panicum purpurascens*
Toa sandy loam		

The pH of the soil samples was determined in a 1:2.5 soil-water ratio by means of a potentiometer. Soil samples in which total copper and cobalt were determined, were previously digested with perchloric acid according to the method of Holmes (*7*). Cobalt was determined by a modified procedure of the method of McNaught, and the methods of Kidson and Askew as quoted by Piper (*14*). Copper was determined by a modification of the procedures of Coulson (*2*), and Marston and Dewey (*9*), as quoted by Parks *et al.* (*13*).

The grass samples were analyzed for total copper following the method of Holmes (*7*). Cobalt was determined by a modified procedure of the method of McNaught, and the method of Kidson and Askew as quoted by Piper (*14*).

RESULTS AND DISCUSSION

Tables 2 and 3 give the minimum, maximum, and average cobalt and copper content in the different soil types studied. Tables 4 and 5 give the minimum, maximum, and average cobalt and copper content of the grasses analyzed.

Of the soils studied, the Cayaguá sandy loam had the lowest average cobalt content, and the highest average copper content. The Toa sandy

TABLE 2.—*Cobalt content in different soil types*

Soil type	Cobalt content expressed in parts per million			
	Samples	Minimum	Maximum	Average
	Number	*p.p.m.*	*p.p.m.*	*p.p.m.*
Coloso silt loam	4	0.2	0.5	0.4
Toa silt loam	3	.3	3.5	1.6
Coloso silty clay	4	.1	1.5	.7
Caguas clay	5	.1	1.3	.4
Toa sandy loam	4	.9	5.6	2.8
Cayaugá sandy loam	4	.2	.2	.2

TABLE 3.—*Copper content in different soil types*

Soil type	Copper content expressed in parts per million			
	Samples	Minimum	Maximum	Average
	Number	*p.p.m.*	*p.p.m.*	*p.p.m.*
Coloso silty loam	4	49	83	65.8
Toa silt loam	4	54	74	67.0
Coloso silty clay	4	35	93	63.8
Caguas clay	5	60	91	74.3
Toa sandy loam	4	38	51	44.5
Cayaguá sandy loam	5	52	114	81.6

loam had the highest cobalt content and the lowest copper content. All the soils studied had a much higher copper content than cobalt. The amount of copper was 16 times more than that of cobalt in the Toa sandy loam. In the case of the Cayaguá sandy loam, the copper content was more than 400 times the amount of the cobalt present. The difference between the copper and cobalt content of the soils can be explained on the basis of the presence of more copper-containing minerals in the parent material from which the soils were derived.

According to Johnson and Graham (*8*) the copper and cobalt levels in the soil are a function of (a) the parent material from which the soil is derived,

(b) the conditions prevailing during the period of soil development, (c) the amount of organic matter present in the soil, (d) soil texture, and (e) soil reaction.

The range of values for the cobalt content of the soils studied varied from

TABLE 4.—*Cobalt content in grasses*

Grass spp.	Cobalt content			
	Samples	Minimum	Maximum	Average
	Number	*p.p.m.*	*p.p.m.*	*p.p.m.*
Mixture of grasses and legumes[1]	3	0.5	1.4	0.8
Pasto amargo[2]	1	.5	.5	.5
Cerrillo[2]	1	.4	.4	.4
Mixture of grasses and legumes[3]	3	.7	4.6	2.1
Merker grass	8	.1	.4	.3
Malojillo	8	.1	.4	.3

[1] The mixture consisted of the following: *Pasto amargo*, *yerba dulce*, carpet grass, *coquí*, *escobilla*, *zarzabacoa* and *moriviví*.

[2] These are composite samples.

[3] Same grass-legume combination as in 1 plus *San Agustín*, *grama de costa*, *arrocillo* and *botoncillo blanco*.

TABLE 5.—*Copper content in the grasses*

Grass spp.	Copper content			
	Samples	Minimum	Maximum	Average
	Number	*p.p.m.*	*p.p.m.*	*p.p.m.*
Mixtures of grasses and legumes[1]	3	43	57	49
Pasto amargo[2]	1	27	27	27
Cerrillo[2]	1	33	33	33
Mixture of grasses and legumes[3]	3	31	74	50
Merker grass	8	27	42	34
Malojillo	8	35	43	39

[1] Same grass-legume mixture in call No. 1 of table 4.

[2] These are composites samples.

[3] Same grass-legume mixture in call No. 4 of table 4.

a low of 0.1 p.p.m. to a high value of 5.6 p.p.m. These values are lower than values reported by Fujimoto and Sherman (*4*) for some Hawaiian soils. They report values ranging from 5 to 156 p.p.m. with an average of 36.1 p.p.m. of cobalt. This difference in cobalt content is mostly due to the difference in parent material. Hawaiian soils are volcanic in nature and it is possible that the presence of ferromagnesian mineral in them induces the presence of more cobalt in those soils than there is present in the soils of Puerto Rico. Because of its ionic size and charge cobalt tends to concentrate as an impurity in ferromagnesian minerals (*6*).

The average cobalt content of the topmost 6 inches of soil was lower than the average cobalt content of the first 12 inches of soil. This, in part, agrees with the work of Hill *et al.* (*6*) who found that the cobalt content of New Jersey soils increased with decreasing particle size, and within each particle size-range, the cobalt content tended to increase with depth. The cobalt content of the grasses analyzed compares favorably with the ones reported in the literature. Hill *et al.* (*6*) report values ranging from 0.04 p.p.m. to 0.24 p.p.m. as the average cobalt content of crops collected in the field in New Jersey. If the cobalt values are compared with values reported in the literature (*6, 17*) it can be seen that Puerto Rican grasses are well supplied with cobalt. Table 6 compares cobalt levels of grasses of Puerto Rico with values obtained elsewhere for various grasses, legumes, and crops. White clover is the only pasture legume that has a relatively higher cobalt content than our tropical grasses in the above-ground portion of the plant.

As in the work of Fujimoto and Sherman (*4*) no significant relationship was found between the cobalt content of the soils and that of the grasses.

According to data gathered by Mitchell (*11*) unhealthy animals can be found grazing in pastures whose cobalt content varies from 0.005 to 0.17 p.p.m. Hill *et al.* (*6*) report that sheep suffer from cobalt deficiency when their feed contains less than 0.07 p.p.m. In the case of cattle, this situation develops when feed contains less than 0.04 p.p.m. The data gathered in our laboratory strongly suggest that cattle grazing in the areas where the grass samples were taken could not possibly suffer from cobalt deficiency. The author has not been able to find evidence in the literature published in Puerto Rico about symptoms in our cattle similar to the bush-sickness disease in both North and South Island in New Zealand and to the Enzootic Marasmus which occurs near the south coast of West Australia and in the southern part of South Australia. Both diseases are very similar and sheep and cattle grazing in cobalt deficient pastures exhibit the characteristic symptoms of these diseases.

The copper content (table 6) of the soils studied range from a minimum of 35 p.p.m. to a maximum of 144 p.p.m. The average copper content at 0–6 inches was 69.0 p.p.m. while the average at 0–12 inches was 60.3 p.p.m. The data suggest that copper accumulates in the surface soil. This agrees in part with the data obtained by Pack *et al.* (*12*) in which he found that the copper content of A horizon was generally higher than that of B horizon in New Jersey soils. Veermat and Van Der Bie (*18*) report an average copper content of 31 p.p.m. for soils of Java irrespective of the depth of the sample taken. The soils analyzed in Puerto Rico had an average of

67 p.p.m. of copper irrespective of the depth of the sample taken. Thus, our soils analyzed three times as much as those from New Jersey (*12*) and twice as much than those of Java (*18*).

In order further to help interpret the data, soils were divided into two groups. In one group were placed the soils whose parent material consisted of transported alluvial deposits and the other group in which the parent material was granite and quartz-diorite as shown in the following tabulation:

TABLE 6.—*Comparison of the average cobalt content of some grasses from Puerto Rico, and values for grasses, legumes and crops obtained elsewhere and reported in the literature (6, 19, 13)*

Crop or plant product	Cobalt	Crop or plant product	Cobalt
	p.p.m.		*p.p.m.*
Red clover	0.14	Coffee, bean	0.002
Orchard grass	.12	Corn, grain	.015
Alfalfa	.10	Lime, dried leaves	.20
Timothy	.04	Peas, green (edible portion)	.03
Ryegrass	.05	Rice, polished	.006
Ladino clover	.05	Bermuda grass	.093
Meadow fescue	.09	Dallis grass	.072
Bird's foot-trefoil	.21	Carpet grass	.079
Bromegrass	.24	Oats (whole plants)	.070
Blue grass	.24	Wheat (whole plants)	.089
Alfalfa hay	.01	Timothy hay	.01
Beets, tops	.40	Puerto Rico Merker grass	.23
Clover, white (above ground portion)	2.44	Puerto Rico mixture of grasses and legumes	1.43
Water cress	.15	Puerto Rico *Malojillo* grass	.28
Lettuce, dried leaves	.14	Puerto Rico *Pasto amargo*	.50
Oat hay	.02	Puerto Rico *Cerrillo*	.40

Transported alluvial deposits	*Granite, quartz-diorite*
Coloso silty loam	Caguas clay
Toa silt loam	Cayaguá sandy loam
Toa sandy loam	
Coloso silty clay	

The average copper content of the soils derived from transported alluvial deposits was 60 p.p.m. while the average of those derived from granite and quartz-diorite was 78 p.p.m.

When the soils were grouped into two pH groups of acid to slightly acid and slightly acid to neutral it was found that there was no difference in copper content of the soils. The acid to slightly acid group had an average copper content of 66 p.p.m. and the slightly acid to neutral had an average of 68 p.p.m. of copper.

A comparison of the copper soil values from New Jersy (*12*), Puerto Rico and Java (*18*) makes it evident that the soils studied in Puerto Rico are quite well supplied with copper.

TABLE 7.—*Minimum, maximum and average content of copper in the grass samples studied*

Grass	Minimum	Maximum	Average	Number of samples
	p.p.m.	*p.p.m.*	*p.p.m.*	
Malojilla	—	—	—	—
Mixture of the following grasses and legumes:	43	57	49	3
Pasto amargo				
Yerba Dulce				
Carpet grass				
Coquí				
Escobilla				
Zarzabacoa				
Moriviví				
Pasto Amargo	27	27	27	1
Cerrillo	33	33	33	1
Mixture of the following grasses and legumes:	31	74	50	3
San Agustín				
Carpet grass				
Pasto Amargo				
Grama de Costa				
Arrocillo				
Zarzabacoa				
Moriviví				
Botoncillo blanco				
Coquí				
Merker	27	42	34	8
Malojillo	35	43	39	8

The copper content of the grasses studied varied from a minimum value of 27 p.p.m. to a maximum value of 74 p.p.m.

The average copper content of the mixture of grasses and legumes was 46 p.p.m. while that of the grasses alone was 36 p.p.m. The mixtures of grasses and legumes had also the highest content of cobalt (table 6) and copper (table 7). Bould *et al.* (*1*) report copper leaf values in the range of 1.1 to 3.0 p.p.m. for deficient apple and pear trees while values of 5.1 to 8.0 p.p.m. are designated as normal. Pack *et al.* (*12*) report average copper values of 7, 11, and 12 p.p.m. for such crops as alfalfa, red clover, and field corn leaves. The values found for our grasses and the grass-legume mixture are much higher than these values, thus indicating that the soils where these grasses were growing are well supplied with copper. As in the case of cobalt no significant relationship was found between the copper content of the soil and that of the grasses.

The supplying power of the soils studied for both cobalt and copper can be termed as adequate. This means that the grasses growing in them are adequately supplied with these two minerals and, in turn, the cattle grazing on them would not be expected to suffer from a deficiency of any one of these two minerals.

SUMMARY

Several soil and grass samples were collected with the purpose of determining their copper and cobalt content. One of the soils studied, Cayaguá sandy loam, had the lowest cobalt content and the highest copper content. The Toa sandy loam had the highest cobalt content and the lowest copper content. In general, the soils had a much higher content of copper than of cobalt and a higher content of cobalt and copper than any of the grasses studied. The soils had about twice as much copper and cobalt as the grasses.

In all cases the mixture of grasses and legumes had a higher content of copper and cobalt than the grasses alone. The consumption of grasses by the cattle grazing in the areas where the samples were taken does not constitute a hazard for the cattle, because the grasses do not accumulate toxic amounts of the minerals.

RESUMEN

Se tomaron muestras de suelos y yerbas con el propósito de determinar su contenido de cobre y cobalto. De los suelos estudiados, el tipo de suelo Cayaguá franco-arenoso tuvo el contenido más bajo de cobalto y el más alto de cobre. El tipo de suelo Toa franco-arenoso tuvo el contenido más alto de cobalto y el más bajo de cobre. Los suelos estudiados tuvieron un contenido más alto de cobre que de cobalto. El contenido de cobre y cobalto en los suelos fue superior al de las yerbas.

La mezcla de yerbas y leguminosas fue superior en cuanto al contenido de cobre y cobalto que cualquiera de las yerbas. Las yerbas estudiadas no son un riesgo para el ganado, ya que ninguna acumula cantidades tóxicas de los minerales estudiados.

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