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CATION EXCHANGE CAPACITY OF SOME TROPICAL SOILS OF PUERTO RICO

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INTRODUCTION

Cation exchange capacity is the capacity that a soil has to hold cations in readily replaceable forms. Plant nutrients in this form are considered to be readily available to crops. The fact that these cations are fixed by the soil, though in a replaceable form, reduces their losses due to rainfall leaching. In general, it may be said that the higher the total exchange capacity a soil has, the higher its inherent fertility. But a soil with a high value may have unfavorable physical conditions that would limit crop production.

Fundamental knowledge about the nature of the soil exchange complex that is responsible for this exchange capacity is of importance. Three groups of clay minerals are known to constitute the soil complex: Kaolin, hydrous mica or illite, and montmorillonite. One of them may be dominant. The kaolin group has the lowest exchange capacity and possesses favorable physical properties such as good drainage, good aeration, and good structure. The montmorillonite group has the highest exchange capacity and possesses unfavorable physical properties. The characteristics of the illite or hydrous mica group fall between those of the other two. Jeffries, et al. (4)[2] have brought to light new data for the best understanding of the clay minerals of some soils of Puerto Rico.

No data have been published yet concerning the total cation exchange capacity of soils in Puerto Rico, except for exchangeable bases reported in the Soil Survey of Puerto Rico for only nine soil types. Very little has been published from other tropical regions. This paper presents data on the total cation exchange capacity and exchangeable bases of a number of important soil types and groups from Puerto Rico.

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[2] Numerals in parentheses refer to Literature Cited, p. 56.

SOIL SAMPLING AND METHODS

Eighty-one soil samples were collected from one or two depths of the A horizon for 51 soil types in Puerto Rico representing 47 soil series. The soils were classified into 13 great soil groups, according to Roberts (7): Rendzina, Wiesenboden, Reddish Brown, Reddish Chestnut, Reddish Prairie, Gray Brown Podzolic, Red and Yellow Podzolic, Reddish Brown Lateritic, Yellowish Brown Lateritic, Ground Water Laterite, Laterite, Lithosols, and Alluvial.

The total cation exchange capacity was determined by one of the following two methods:

(a) Ten to twenty grams of 20- or 100-mesh soil, depending on its total exchange capacity, were placed in a 100-ml. Truog soil tube and shaken 5 times with 50 ml. of normal calcium chloride solution. The extract was centrifuged and the supernatant liquid discarded. The excess of calcium chloride was washed off with water, followed with 80-percent alcohol, and the supernatant liquid was discarded after centrifuging. The total exchangeable calcium was extracted with normal ammonium acetate solution kept at pH 6.8, and after centrifuging, the extracting solution was evaporated to dryness. The residue was taken up with 10 ml. of hydrochloric acid, diluted with water to a volume of 300 ml., and the calcium precipitated as oxalate and determined volumetrically to calculate the total cation exchange capacity.

(b) Twenty grams of 20-mesh soil were placed over an absorbent c.p. cotton pad in a carbon-filter funnel and leached with 400 ml. of neutral normal ammonium acetate solution. The excess of ammonium was washed off with 400 ml. or more of c.p. ethyl alcohol. The exchangeable ammonium was displaced with a 10-percent solution of sodium chloride containing 0.005 normal hydrochloric acid, the extract was made up to a volume of 500 ml. from which a 200-ml. aliquot, corresponding to 8 gm. of soil, was distilled by adding magnesium oxide. The distillate was collected in standard acid, and the excess of acid titrated with standard alkali. The total exchange capacity, expressed as milliequivalents per 100 gm. of soil, is equal to the milliliters of standard acid used, times normality of the acid, times the factor 12.5.

Exchangeable bases were determined in some soils. Those free of calcium carbonate were leached with a normal ammonium acetate solution kept at pH 6.8; the alcoholic-salt solution recommended by Magistad and Burgess was used for calcareous soils (5). Standard volumetric methods were followed for determining the exchangeable calcium and magnesium; exchangeable sodium was determined by the uranyl acetate method and exchangeable potassium by the cobaltinitrite method.

PRESENTATION OF DATA

The soils were grouped according to the degree of profile development and further subdivided by great soil groups. The total exchange capacities for soil types in the zonal and intrazonal soil groups are reported in table 4 and for azonal soils in table 5, and the minimum and maximum values and their differences in tables 1 and 2, respectively. Exchangeable calcium, magnesium, potassium and sodium for some soil types and groups of Puerto Rico are reported in table 3.

TABLE 1.—*Minimum and maximum values for total exchange capacity in some zonal and intrazonal soil groups of Puerto Rico*

Soil group	Number of samples	Milliequivalents per 100 gm. of dry soil		
		Minimum value	Maximum value	Difference
Rendzina	1	63.5	63.5	—
Wiesenboden	2	36.0	43.2	7.2
Reddish Brown	1	22.6	22.6	—
Reddish Chestnut	4	21.0	41.6	20.6
Reddish Prairie	8	12.0	31.2	19.2
Gray Brown Podzolic	9	5.2	51.6	46.4
Red and Yellow Podzolic	11	8.7	34.1	25.4
Reddish Brown Lateritic	9	5.2	24.0	19.2
Yellowish Brown Lateritic	2	7.7	7.7	—
Ground Water Laterite	2	7.1	1.2	5.9
Laterite	2	2.1	3.2	.9

TABLE 2.—*Minimum and maximum values for total exchange capacity in some azonal soil groups of Puerto Rico*

Soil group	Number of samples	Milliequivalents per 100 gm. of dry soil		
		Minimum value	Maximum value	Difference
Lithosols	8	8.2	40.0	31.8
Alluvial	11	7.7	60.3	52.6

DISCUSSION

The highest value obtained for total exchange capacity was 63.5 m.e. per 100 gm. of soil for Soller clay, a Rendzina, and the lowest was 2.1 m.e. for Nipe clay, a Laterite (tables 1, 2, 4). In most of the soil groups there is a wide difference between the minimum and maximum values for total exchange capacity varying from 5.9 m.e. in the Ground Water Laterite, to 7.2 in the Wiesenboden, to 20.6 in the Reddish Chestnut, to 19.2 in the

TABLE 3.—*Exchangeable bases for some soil types of Puerto Rico*[1]

Soil type	Soil group	Depth (inches)	Milliequivalents per 100 gm. of dry soil				
			Ca	Mg	K	Na	Total exchangeable bases
Coloso clay	Alluvial	0–12	12.97	1.10	0.92	0.52	15.51
Do.	do.	12–24	11.18	.94	1.08	.36	13.56
Do.	do.	0–12	9.27	.66	.76	.38	11.07
Do.	do.	12–24	7.99	.57	.90	.27	9.73
Do.	do.	0–12	18.08	3.20	.26	.74	22.28
Do.	do.	12–30	14.79	2.89	.17	.82	18.67
Coloso silty clay	do.	0–12	9.03	.41	1.94	.35	11.73
Do.	do.	12–24	8.87	.73	2.73	.45	12.78
Do.	do.	0–12	6.45	.25	1.61	.26	8.57
Do.	do.	12–24	6.34	.44	2.18	.33	9.29
Piñones clay	Wiesenboden	0–12	10.81	.72	.94	.28	12.75
Do.	do.	12–24	10.52	1.05	.84	.37	12.78
San Antón clay loam	Alluvial	0–30	21.60	.15	.50	1.40	23.65
Aguirre clay	do.	0–12	35.10	.14	1.06	3.80	40.10
Do.	do.	0–12	27.40	.31	.62	9.00	37.33
Do.	do.	12–36	24.00	.15	.79	9.50	34.44
Do.	do.	0–12	48.10	.15	.16	11.00	60.41
Do.	do.	0–12	48.80	.27	.59	8.30	57.96
Catalina clay	Reddish Brown Lateritic	0–12	3.40	1.52	.19	—	5.11
Santa Clara clay	Chernozem	0–5	22.01	.90	.16	.74	23.81
Do.	do.	5–17	20.87	1.51	.19	.82	23.39
Ponceña clay	do.	12–16	33.73	1.63	.23	.44	36 03
Santa Isabel silty clay	Reddish Chestnut	6–12	24.01	1.93	.16	1.85	27.95
Santa Isabel clay	do.	0–12	30.00	.16	.43	2.50	33.09
Fe clay	do.	10–22	24.73	2.23	.28	.52	27.76
Paso Seco loam	Reddish Prairie	16–28	17.37	2.23	.17	.37	20.14
Mabí clay	do.	0–6	17.37	3.32	.24	.74	21.67
Do.	do.	6–16	14.01	6.33	.23	1.33	21.90
Coto clay	Yellowish Brown Lateritic	0–7	4.07	.90	.26	.62	5.85
Do.	do.	7–17	.57	.48	.12	.64	1.81

[1] The data given for the Santa Clara clay and other soils down to the Coto clay, except Santa Isable clay, were taken from Roberts (7). The data for Catalina clay were taken from Bonnet (1).

Reddish Prairie and Reddish Brown Lateritic, to 25.4 in the Red and Yellow Podzolic, and to 46.4 in the Gray Brown Podzolic (table 1). The difference for the Lithosols and Alluvial soils (table 2) were 31.8 and 52.6 m.e., respectively. Weathering had been active in the podzolic and more

TABLE 4.—*Total exchange capacity of some soil types*[1] *in some zonal and intrazonal soil groups of Puerto Rico*

Soil type	Soil group	Milliequivalents per 100 gm. of dry soil
Soller clay	Rendzina	63.5
Guánica clay	Wiesenboden	36.0
Do.	do.	43.2
Jácana clay	Reddish Brown	22.6
Fraternidad clay	Reddish Chestnut	21.0
Do.	do.	32.8
Santa Isabel clay	do.	22.0
Do.	do.	41.6
Mabí clay	Reddish Prairie	31.2
Do.	do.	13.3
Do.	do.	18.8
Paso seco silty clay	do.	20.1
Paso seco loam	do.	13.0
Amelia clay	do.	29.4
Llave loam	do.	12.0
Machete loam	do.	14.3
Plata clay	Gray Brown Podzolic	35.7
Ciales clay loam	do.	17.0
Do.	do.	11.8
Utuado loam	do.	10.6
Do.	do.	5.2
Juncos clay	do.	51.6
Las Piedras clay loam	do.	7.1
Humacao loam	do.	11.4
Teja loam	do.	8.2
Moca clay	Red and Yellow Podzolic	34.1
Lares clay	do.	16.5
Do.	do.	13.7
Cabo Rojo clay	do.	14.1
Do.	do.	26.9
Los Guineos clay	do.	8.7
Do.	do.	20.9
Fajardo clay	do.	14.5
Jayuya silty clay loam	do.	12.1
Vía silty clay	do.	13.0
Do.	do.	18.1
Catalina clay	Reddish Brown Lateritic	10.8
Do.	do.	8.4
Catalina stony clay	do.	11.2
Catalina clay, level phase	do.	10.9
Cialitos clay	do.	14.9
Alonso clay	do.	24.0

[1] Guánica, Jácana, Fraternidad, Santa Isabel, Amelia, and Llave are soils of the arid region; Paso Seco and Machete of the semiarid; all others of the humid regions.

TABLE 4.—*Continued*

Soil type	Soil group	Milliequivalents per 100 gm. of dry soil
Matanzas clay	do.	7.1
Bayamón sandy clay	do.	5.2
Río Piedras clay	do.	15.9
Sabana Seca sandy clay	Ground Water Laterite	7.1
Caguas clay	do.	12.0
Coto clay	Yellowish Brown Lateritic	7.7
Nipe clay	Laterite	2.1
Do.	do.	3.2

so in the lateritic groups, as indicated by the low total exchange capacity 5 to 8 m.e., that points to the presence of kaolinlike minerals as reported by Bonnet (1) for Catalina clay, a lateritic soil. Jeffries et al. (4) will later publish a paper on the identification of minerals in soils of Puerto Rico with low and high exchange capacities.

The highest value obtained for total exchangeable bases (table 3) was 60.4 m.e. per 100 gm. of soil for Aguirre clay, an alluvial soil, and the lowest was 1.81 m.e. for Coto clay, a lateritic soil at a depth of 7 to 17 inches. The content of exchangeable calcium (Ca) was about 80 percent for the former soil and about 32 percent for the latter, but rose as high as 94 percent in Ponceña clay, a Chernozem. The calcium-to-magnesium ratio varied from 1.2 in the Coto clay to 321 in the Aguirre clay reported above. The exchangeable potassium (K) varied from 0.12 to 2.73 m.e. per 100 gm. of soil, and the exchangeable sodium from 0.26 to 11.00, the latter in a saline Aguirre clay.

SUMMARY

Data are presented here for the total exchange capacity of 81 soil samples in Puerto Rico and for available cations: Calcium, magnesium, potassium, and sodium, in 30 soil samples. The soils analyzed were representative of the following 13 groups: Rendzina, Wiesenboden, Reddish Brown, Reddish Chestnut, Reddish Prairie, Gray Brown Podzolic, Red and Yellow Podzolic, Reddish Brown Lateritic, Yellowish Brown Lateritic, Ground Water Laterite, Laterite, Lithosols, and Alluvial. Exchangeable bases are also reported for some soils in the Chernozem group.

The highest value obtained for total exchange capacity was about 64 milliequivalents per 100 gm. of dry soil for a Rendzina and the lowest was about 2 m.e. for a Laterite. There is a wide difference between the minimum and maximum values of total exchange capacity for the various soil groups. Weathering had been active in the podzolic and more so in the lateritic group.

The highest value for total exchangeable bases was over 60 m.e. for an Alluvial soil and the lowest was less than 2 m.e. for a lateritic soil; these contained 80 and 32 percent, respectively, of exchangeable calcium.

TABLE 5.—*Total exchange capacity of some soil types*[1] *in some azonal soil groups of Puerto Rico*

Soil type	Soil group	Milliequivalents per 100 gm. of dry soil
Múcara silty clay loam	Lithosols	8.2
Do.		36.0
Do.		40.0
Múcara silt loam		20.7
Pandura sandy clay loam		19.3
Tanamá stony clay		8.5
Guayama loam		19.3
Descalabrado silty clay		17.0
Vega Baja silty clay	Alluvial	17.7
Coloso silty clay		32.1
Do.		38.6
Toa loam		14.7
Toa silty clay loam		23.6
Do.		35.0
Estación silt loam		13.1
Viví sandy loam		7.7
San Antón clay loam		31.4
San Antón loam		26.6
Do.		23.7
Vayas silt loam		46.0
Aguirre clay		28.0
Do.		42.1
Do.		43.8
Do.		45.0
Do.		45.8
Do.		48.2
Do.		50.4
Do.		52.2
Do.		54.4
Do.		60.2
Do.		60.3

[1] Guayama, Descalabrado, San Antón, Vayas, and Aguirre are soils of arid area; all others of the humid area.

RESUMEN

En este trabajo se informan las capacidades totales de intercambio para 81 muestras de suelos en Puerto Rico y los cationes intercambiables: calcio, magnesio, potasio, y sodio, para 30 muestras de suelos. Los suelos analizados representan los siguientes 13 grupos: Rendzina, Wiesenboden, Rojos Pardos, Rojos Castaños, Rojos de Pradera, Podsólicos Gris Pardos, Podsólicos Rojos y Amarillos, Lateríticos Rojizos Pardos, Lateríticos Amarillentos Pardos, Lateritas Hidropédicas, Laterita, Litosoles y Aluviones. Se informa también el contenido de bases intercambiables para algunos suelos en el grupo Chernozem.

El valor más alto que se obtuvo para la capacidad total de intercambio fué de 64 miliequivalentes por 100 gramos de tierra seca para un Rendzina y el más bajo fué de 2 m.e. para un suelo laterítico. Hay una variación grande entre los valores mínimos y máximos de la capacidad total de intercambio para varios de los grupos de suelos. El proceso de meteorización ha sido activo en los suelos Podsólicos y más aún en el grupo de los Lateríticos.

El valor más alto para el total de bases intercambiables fué de 60 m.e. para un suelo de aluvión y el más bajo fué de 2 m.e. para un suelo laterítico con 80 y 32 por-cientos, respectivos, de calcio intercambiable.

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